CONSERVATION ECOLOGY OF ENDANGERED DIURNAL PRIMATES AND GAUR IN TRISHNA WILDLIFE SANCTUARY, TRIPURA

THESIS

SUBMITTED TO THE

FOREST RESEARCH INSTITUTE

DEEMED UNIVERSITY

DEHRADUN, UTTARANCHAL

FOR

THE AWARD OF THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

FORESTRY

BY

SABYASACHI DASGUPTA

भारतीय वन्यजीव संस्थान

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March 2006

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(Dr. K. Sankar)
Co-Supervisor

(Sabyasachi Dasgupta)
Research Scholar

DECLARATION

I hereby declare that this dissertation is my own original work, and does not include anything which is the outcome of work done in collaboration, except where it is clearly stated to the contrary. No part of this thesis has been submitted to this or any other University for any degree, diploma or qualification.

Sabyasachi Dasgupta

Dr. Atul K. Gupta, IFS
Chief Conservator of Forests (Planning & Development)

CERTIFICATE

This is to certify that **Shri Sabyasachi Dasgupta** has carried out an original piece of research work entitled "**Conservation Ecology of Endangered Diurnal Primates and Gaur in Trishna Wildlife Sanctuary, Tripura**" in partial fulfillment of award of the degree of **Doctor of Philosophy in Forestry** and the thesis fulfils the requirement of the Ordinance governing award of Ph.D. degree of FRI, (Deemed University). These investigations were carried out under my supervision at the Wildlife Institute of India, Dehradun from September 2002 to March 2006. I also certify that this work has not been submitted for any other degree of any university.

Date: 17th March 2006
Place: Dehradun

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CERTIFICATE

This is to certify that the thesis entitled "**Conservation ecology of endangered diurnal primates and gaur in Trishna Wildlife Sanctuary, Tripura**" submitted to F.R.I., (Deemed University), Dehradun, Uttaranchal is a record of bonafide research work carried out by **Sh. Sabyasachi Dasgupta** under my guidance. No part of the thesis has been submitted for any other degree and it fulfills all requirements laid down in the ordinance of F.R.I. (Deemed University), for this purpose.

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To my Parents

Aparajita Dasgupta and Satyapriya Dasgupta

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When I lost my laptop with all my data and thesis work, there was no lack of helping hands from my friends in WII. Redoing all these would not have been possible without their help. In absence of Poonam I don't know how I would have continued with the patience to complete this work. Her help in compiling this thesis is deeply acknowledged. Any single word of appreciation in this regard is insufficient to thank her.

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(Sabyasachi Dasgupta)

SUMMARY

The aim of the study was to prepare land cover & vegetation maps, quantify vegetation structure and composition in different vegetation types, and assess the status, distribution and habitat use and feeding ecology of capped langur (*Trachypithecus pileatus*), hoolock gibbon (*Bunopithecus hoolock*), pig-tailed macaque (*Macaca nemestrina*) and gaur (*Bos gaurus gaurus*) in Trishna Wildlife Sanctuary (TWS) (23° 12′ - 23° 32′ N to 91° 15′ – 91° 30′ E), Tripura. Attempt was made to discuss single species vs. multi species approach in conservation and suggest conservation recommendations for the study species and the vegetation resources of the study area.

Fieldwork was carried out between January 2002 and June 2004. The land use land cover (LULC) map was prepared using unsupervised classification of IRS LISS III imageries followed by supervised classification. Systematic sampling was carried out in 64 out of 82 grids (1min. X 1min.) covering the study area for vegetation characterization and quantification of distribution, diversity, richness and association of different plants at both individual species level and community level. Analysis was carried out in the supervised LULC map using ERDAS Imagine 8.5 and Arc View 3.2.

After an initial reconnaissance survey, the southern part of the Sanctuary was selected as an intensive study area (ISA). To determine abundance of study species in the intensive study area, six (6) permanent transects which varied in length from 2 to 3.2 km, covering six habitat types were monitored between November 2002 and July 2004. A total of 35 sites of 400m X 400m were demarcated in the six habitat types for estimating site use and its covariates. Mean group size for the study species was obtained from the seasonal total counts of study (primate) species in ISA. Habitat use was determined by recording presence and absence of all the study species, group size and structure, geographical location and sampling co-variates *viz.* anthropogenic disturbance, weather information, presence-absence of other animals etc. in different sites. Initial three

months were utilized for habituating the selected study group of each study primate species. Scan animal sampling (dawn to dusk) for 8 days/season split into 2 blocks of 4 days each, for 2 years was carried out spent for collecting information on their food habits. Phenological monitoring of important food plants was carried out. In total, 38 plant species were monitored once in ten days for their phenological status.

Total area estimated for TWS in Geographical Information System (GIS) domain was estimated to be 213 Km². Total forest area of the Sanctuary estimated was 93.95 % of the total area. The ground flora of the area is represented by 96 plant families. The moist deciduous forest occupied 26.77% of the TWS, followed by mixed dipterocarpus forest: 16.56%, Highly degraded sal forest: 9.67%, mixed bamboo forest: 8.92%, bamboo bakes dominated by *Oxytenanthera nigrociliata*: 8.29%, clearfelled/Jhumed/open forest: 3.26%, water body associated vegetation: 0.68%, crop fields/agriculture land: 6.59%, habitation/homegarden: 1.99% and barren land: 0.01%.

Flora of the area is represented by 96 families of plants species. Dispersion of plant species of the area was found to be aggregated and their heterogeneity in dispersion was discordant. Grass showed independent heterogeneity and climber was found to be randomly distributed.

Observed species richness for trees in 114 plots spread over entire TWS was 106 and accounted for 765 individuals. Herb and shrub species richness was 187. Diversity and Evenness was estimated by SHE analysis. For trees, decrease in evenness was accompanied by increase in species richness. This suggested that added species tend to be relatively uncommon or rare, and each sample community was best fit by log normal species abundance distribution.

Out of fifteen species so far recorded from India, six species namely hoolock gibbon, capped langur, Phayres' langur, pigtailed macaque, rhesus macaque and slow loris were found in the ISA. Total population of pigtailed macaque within the ISA decreased from 107 to 80 individuals during the study period. Their mean group size decreased from 21.4 to 16 individuals but there was no change in the total number of group in the ISA. Mean group size of capped langur varied between 5.1 to 6.3 individuals and ranged between 2 to 13. Their total population decreased to 62 from 76 individuals during the study period.

Six distinct habitat categories were found in the ISA *viz:* semi-evergreen, degraded semi-evergreen, mixed deciduous, mixed bamboo, *Bambusa tulda* dominated and savanna woodland. The semi-evergreen habitat (Shannon index value of 0.898, reciprocal Simpson value of 24.045 and Berger–Perker measures of 7.437) was observed to be the most diverse as compared to other habitat types. Tree basal cover was highest in the mixed deciduous habitat and trees with larger girth class were more than trees with lower girth class. Compared to mixed deciduous habitat, the degraded semi-evergreen habitat had more individual tree density. The mixed bamboo habitat showed significant improvement in terms of herbs/shrub density in two years. Moist deciduous habitat did not show any considerable increase in the density of herbs/shrubs. Semi-evergreen and savannah woodland habitat showed overall decrease in the density of the lower strata of vegetation. Except for mixed deciduous habitat, overall percentage cover of fallen twigs/branches in the ground showed decrease in other habitats. Six types of habitat differed significantly by the relative abundance of different tree species and plant species diversity. Except gaur no other study species were found to use the savanna woodland. The gibbon occupied only semi-evergreen and degraded semi-evergreen patch. Gaur had the highest rate of individual as well as group encounter rate in the mixed bamboo habitat followed by degraded semi-evergreen habitat and was significantly different between habitats. They did not show any seasonal change in encounter rate.

Discontinuity between forest patches of ISA restricted the movement of studied primate species. Though there was emigration and immigration of individuals between groups but no new group formation was observed. For gibbon, ecological density estimated was 0.11 groups/km^2 and 0.44 individuals/km^2. Biomass estimate of gibbon was 2.89 kg/km^2 in the beginning of study and reduced to 0.48 kg/km^2 at the end of May 2004. Ecological density of pigtailed macaque was 0.13

groups/km^2 and 1.69 individuals/km^2. This estimate decreased to 1.19 individuals /km^2 at the end of study. Their estimated biomass in the beginning was 7.95 kg to 26.06 kg/km^2 which reduced by 16.6% after 2 years. Capped langur had the density of 1.52 individuals/km^2. There was a 21.5% decrease observed in their biomass during the study period.

Density of gaur in the ISA was found to be 1.50 group/km^2 and 5.96 individual/km^2. In the beginning of the study this was estimated as 2.23 groups/km^2 and 6.82 individuals/km^2 respectively. There was no significant variation in the seasonal changes of group density or individual density of gaur in the area but across six different habitats there was significant difference in group and individual density.

Though hoolock gibbon, capped langur and pigtailed macaque co-existed in semi-evergreen type of forest they are not competitively structured in any of the habitat types in ISA. This shows niche limitations are not likely to constrain co-existence of studied primate species.

Gibbon and pigtailed macaque used habitats with similar characteristics, whereas capped langur used different niches of the same habitat. Gaur being ground living animal obviously uses entirely different niche. Capped langur exploited maximum number of food items during summer, whereas both pigtailed and gibbons were found to explore more food items during winter.

A total of 38 food items were eaten by capped langur during summer, out of which, 23 plant species were eaten for vegetative parts, while 15 species were eaten for reproductive parts. During winter a total of 33 plant species were used by capped langur, of which 26 plant species were used for vegetative parts. Total 35 and 30 plant species contributed in the diet of pigtailed during winter and summer respectively. Gibbons diet included 14 tree species for fruits. *Bombax ceiba* flower contributed a large amount of morning diet of gibbons. Only 23 plant species were recorded in the list of food plants during summer. During winter, pigtailed spend 69.9% of their activity time on foraging followed by 65.12% for

capped langur and 53.12% for gibbon. During summer this reduced for capped langur (42.3%) and pigtailed (57.8%) and increased for gibbon (61.3%).

Capped langur food contained 70% leaf , 12% flower and flowed bud, 7% seeds, 6% ripe and unripe fruit, 4% insect and others. Pigtailed macaque consumed 32% ripe fruit, 23% unripe 13% young leaf 15% matured leaf, and 7% flower. Gibbons food contains 43% ripe fruit, 23% unripe fruit, 10.5% flower and 8% young and mature leaf.

Gibbon preferred more sloppy terrain compared to pigtailed and capped langur and there was no significant seasonal variation for preferred terrain type by any of the study species. Preferred height of roosting by hoolock gibbon ranged between 6m to 8m. Pigtailed preferred 8m to 10m whereas capped langurs preferred 9 to 11m for roosting. Gibbon preferred denser canopy as compared to other study primate species.

Total 56 food plants were recorded as gaur food plants, which include 12 tree species, 22 shrub and herb species, 9 climber species, 13 grass species including 4 species of bamboo. Gaur prefers relatively flat terrain on the hillocks or flat land of valley with shaded cover in undisturbed areas for resting during day.

Availability of flower and fruit was highest during summer. Rainy season showed higher availability in matured and young leaves. Winter remained the most scarce in terms of leaves availability.

There is an immediate need of providing protection to semi-evergreen and degraded semi-evergreen patch. In order to avoid inbreeding depression of gibbon, it is suggested that individuals isolated in certain parts of the state can be transported to study area. Tree species of Moraceae family needs to be planted in the gaps as habitat improvement measures. There is also a need to improve vegetation around water bodies. Protection of gaur would require ensuring adequate grassy glades, dense cover, perennial streams and 'salt-licks'. An attempt should be made to maintain the available grasslands for the use of gaur and no cattle grazing should be allowed.

It was clearly evident that the species specific conservation methods are not sufficient enough for TWS, where the study species habitat is fragmented. In absence of continuity of different habitats, the complex mosaic of different habitat characters are unable to maintain the ideal interaction at different trophic level. Thus use of any one species as a key species and linking it with others may not be possible while prioritizing conservation goals in areas like TWS. The better way could be through understanding the synergies and incompatibilities if any among the needs of key species at different level of resource use, also at different strata of the canopy and optimize the chance of survival of isolated endangered species. Research outcome of this study will help in re-evaluating the existing forest resources for the conservation of biodiversity and thus redefining the ecological boundaries. This study shall provide a basic framework for future conservation initiatives in and around the study area and help in fine tuning the management options by the park authorities.

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LIST OF ABBREVIATIONS AND ACRONYMS

CITES	-Convention on International Trade in Endangered Species of Wild Fauna and Flora
CL	-Capped langur
FMD	-Foot-and-mouth Disease
GIS	-Geographic Information System
GPS	-Global Positioning Syatem
HG	-Hoolock gibbon
IRS	-Indian Remote Sensing Satellite
ISA	-Intensive Study Area
IUCN	-International Union for Conservation of Nature and Natural Resources
LULC	-Land Use Land Cover
MFP	-Minor forest products
NHP	-Non Human Primate
NTFP	-Non Timber Forest Products
ONGC	-Oil and Natural Gas Corporation
PTM	-Pigtailed macaque
RS	-Remote Sensing
SOI	-Survey of India
TWS	-Trishna Wildlife Sanctuary

Chapter 1

Background and Concepts

1.1 INTRODUCTION

Tropical forests are of considerable interest to conservation biologists due to their high species diversity and for providing sustainable habitat to many endangered animals (Ashton and Gunatillake 1987, Gunatillake and Gunatillake 1990, 1991; Myres 1990). Understanding the ecological and social interdependence of forestry resources, wild fauna and local people is vital for proposing management strategies for a protected area. Biodiversity conservation concerns have focused not only on the availability of habitat but also on the structural integrity of that habitat. One index of structural integrity is habitat contiguity, which can be measured in terms of the relative isolation of forest patches, i.e., an island biogeography concept, or the amount of interior forest cover that is functionally distinct from edge forest, i.e., a landscape ecology concept. Effective conservation calls for targeting actions not only towards areas in which habitat conditions are currently limiting but also towards those in which conditions are expected to become limiting in the future. Providing proper management strategy for the conservation of existing resources (plants and animals) is possible after proper survey and assessment of existing resources, collection of adequate data on species diversity, populations, location and extent of habitat use, major threats to different species, etc. This will help in determining whether or not the park or reserve in question is likely to be adequate for the long-term survival of the species or if it merely harbors a disappearing population remnant (Russell 1986). Conservation biologists face the ultimate problem in conservation: the rate of extinction far surpasses those of the most apocalyptic mass extinctions our planet has ever experienced (Ward 2004). Species that are chosen for this study fall under endangered category due to their decreased global population and threats in terms of habitat destruction.

Before any conservation can begin it is essential to know about distribution and population status of the species of concern. This usually involves survey works of the most basic kind. The fact, however remains that we still know little about wild populations of even some of the best-known endangered mammals. In spite of primates being a well studied group, there are still several species yet to be studied in detail to know their ecological needs. Gaur (*Bos gaurus gaurus*) is no exception in this regard, considering several other well studied ungulates.

Two major characteristics of primates, home range size and the degree of specialization in the diet of a given species influence the ability of different species to live in forest fragments (Tutin and White 1999, Onderdonk and Chapman 2000, Estrada and Coates-Estrada 1996, Lovejoy *et al.* 1986). The interaction between fragment size, home range size, and diet type is complex. Limited area resulting from fragmentation reduces the diversity of plant species and the number of food plants available to consumers (Tutin and White 1999). Diet and feeding behavior is one of the key aspects of ecological study to know the floral resource utilization leading to the conservation of the target animal species. The abundance of food, its distribution and availability, especially at times of scarcity, are most critical factors, which influence the behavior of animals (Clutton-Brock and Harvey 1977, Marsh 1981). With the rise of new powerful statistical techniques and GIS tools, the development of predictive habitat distribution models has rapidly increased in ecology. Such models are static and probabilistic in nature, since they statistically relate the geographical distribution of species or communities to their present environment (Guisan and Zimmermann 2000).

1.2 Ecology versus Conservation ecology

Ecology is the branch of science that studies habitats and the interactions between living and non living components and the environment. The term was coined in 1866 by the Darwinist and German biologist Ernst Haeckel from the Greek *oikos* meaning "house" and *logos* meaning "science". Much of ecological research is concerned with the distribution and abundance of organisms and how these are influenced by characteristics and properties of the environment.

Conservation ecology provides insights into many benefits and services that nature offers and explores strategies for management options to sustain ecological balance. It is an interdisciplinary approach for harmonizing the interactions between nature and people at ecosystem scales. Emphasis is given to the synthesis and integration of knowledge, skills and abilities that are needed to address conservation issues of bio-resources facing threat of extinction at local scale and need immediate management intervention. Classical metapopulation (CM) theory considers that species persistence in the landscape depends on a turnover of extinction-(re)colonisation of suitable habitat patches at each generation. Therefore, metapopulation dynamics are approximated by binary changes in the state of individual patches (Baguette 2004). In competitive systems, niche construction leads to alternative competitive consequences, which implies that trade-offs between the abilities of competition, colonization, and niche construction are important to competitive coexistence.

Proposals for experimental management regimes have exposed and highlighted some really fundamental conflicts in ecological values, particularly in cases in which endangered species have prospered under historical management and would be threatened by ecosystem restoration efforts. There is much potential for adaptive management in the future, if we can find ways around the barriers (Walters 1997). Two streams that can be recognized within conservation ecology:

- **Conserving endangered species**—Demographic and genetic consequences of small population size, population viability analysis, biology of small populations, manipulative techniques that enhance survival probability and design of nature reserves for particular species.
- **Conserving functional and structural aspects of important ecosystems**—Diversity and stability of ecological communities, habitat fragmentation, landscape ecology, island biogeography, and restoration ecology

1.3 Conservation ecology- Global and local approaches

Whenever biologists discuss forest, mention is invariably made of a particular species (of key ecological functions) of interest often, because of its rarity or endemic status. In other words, it is not just the number of species, which makes an area important for biodiversity conservation, but there are biological qualities, which are used when assessing biological value (Pearce 1991).

Tropical environments are being destroyed, and those that are not totally destroyed, are broken into fragments, unable to support large animal/bird species with large home ranges, and long-term viable populations of such species (Bierregaard *et al.* 1992). The edges of these habitats may also be the point of entry of humans, introduced species, and exotic diseases that may further reduce and even eliminate many species on a local scale (Gentry 1986, Janzen 1986).

With the fragmentation of primary forests, mammals and birds with large aerial requirements and specialized food demands will be particularly vulnerable to extinction. A number of animals appear to be particularly susceptible to the effects of the habitat disturbances, and in many cases this can be tentatively correlated with particular facts of the species ecology (Johns 1985). Species that have generalist-feeding strategy are likely to be resilient to extinction and better able to colonize secondary habitat (Terborgh and Weske 1969). Species that are more specialized in their pattern will be more prone to extinction (MacArthur 1972).
The replacement of primary with secondary forest brings about the following three changes which are of relevance to Phayres' langur: reduction in plant species diversity, dominance of a few colonizing species at the cost of evergreen species, and loss of forest contiguity (Gupta and Kumar 1994).

Notwithstanding the many causes of species extinctions, whether through chance events or direct causes (e.g. hunting), a central issue for forest conservation in any country is the loss or degradation of forest habitats. Given the large number of animals and plant species in forests, and the lack of information on distribution or abundance for many of them, comparison of different areas has relied on using sub-section of the biological community about which most information on population is available. The use of such 'indicator' species has become standard practice with preliminary analysis (Bibby *et al.* 1992, Collar and Stuart 1988).

The history of conservation of forests and wildlife in Tripura is not very old. Very little attention was given to conservation and protection of forest and wildlife resources. Though the Indian Wildlife (protection) Act, 1972, was adopted by the State Government way back in 1973, no serious attempt aiming at conservation of wildlife was initiated until 1986 when the first Sanctuary was notified, followed by another three by 1988 (Gupta 1993).

1.4 Floral diversity of Trishna Wildlife Sanctuary (TWS)

Flora of Tripura (Deb 1981) lists 330 tree species out of which TWS has more then 270 species of tree. There are about 69 families of plants in the study area besides some belonging to monocotyledons. Trees do have epiphytes and semi parasitic plants on them. Profuse crustaceous lichens grow on the trees all over the study area which also registers a non-polluted atmosphere. The richness of shrubs (about 120 species recorded in Tripura state) was evident from the recording of about 80 species (only 30 dicotyledons) in the study area. Herbaceous layer of the sanctuary includes regeneration of trees, shrubs, climbers and about 200 species of herbs representing 52 families. There is no luxuriance of epiphytes or terrestrial ferns in the study area. However they cannot be ignored as they are conspicuous at some localized sites and create some micro wildlife niches. The epiphytes grow on tree trunk, branches and crowns, of which some are succulents, xerophilous, shade tolerant and hygrophilous and have both epiphytic and terrestrial forms. Tripura has 21 species of bamboo, of which 11 have distribution in the TWS. Large woody climbers, a type of 'life form' and a biotic association in this forest, are a remarkable feature due to their abundance and forms. Earlier study indicated presence of about 80 species of climbers and 80 species of climbing shrubs (Anon. 1996). These grotesque life forms offer a unique landscape in TWS. Presence of six (6) species of primates in this climber infested area is in perfect match with the arboreal structure for acrobatics and easy movement in search of food and shelter. A new biotype is created at various levels where nitrogen and other nutrients collect; arboreal ants colonize, build their nests, lay eggs, drag seeds and some species of plants grow in such niche. Faunal association also grows up in these biotypes. The insectivorous birds are attracted by the ants and eggs, also arboreal squirrels, and insects of various orders come in and form a good chain of profound interest. Micro-faunal population is sometimes conspicuous in forest floor or on dead wood, but their interactions with ground animals are not known.

1.5 Nonhuman primates (NHP) of TWS

Tripura is known for its floral and faunal diversity. This diversity is best represented by the NHP populations found in the state. Of the 6 genera and 16 species of NHPs known throughout the India (table 1.1), as many as four (4) genera having 7 species are known from Tripura alone (Gupta 2001a). Of these six (6) species are found exclusively in TWS (Table 1.1). The only ape species inhabiting India is the gibbons, of which a single species, the hoolock, is also found in a small patch of the sanctuary. These are- hoolock gibbons *(Bunopithecus hoolock),* capped langur (*Trachypithecus pileatus)*, pigtailed macaque (*Macaca nemestrina*), Phayre's langur (*Trachypithecus phayrei*), rhesus macaque (*Macaca mulatta*) and slow loris (*Nycticebus coucang*). Though stump tailed macaque (*Macaca arctoides)* was reported earlier from TWS, the species were not seen during the study period and require intensive search to make any conclusive remarks on their local extinction. Based on the habitat specialization three species, one each from langur, macaque and ape were selected for this study.

1.6 Gaur in TWS

In Tripura, gaur is found only in the southern part of TWS. Earlier there was reporting of gaur from Gumti Wildlife Sanctuary situated in the northeast part of the State (Pers. com. A. K. Gupta). As per the records of the forest department, TWS was notified basically to provide a protective cover to the only surviving population of gaur in Tripura, which is also considered a pride of the state. Gaur population found in and outside the TWS is an isolated population and has conservation importance in terms of managing small population essential for prevention of local extinction. This study is the first scientific detailed study on this species in northeast India. Rich biodiversity of the TWS puts it in the priority list of biodiversity conservation areas of the Tripura state.

Table 1.1 Status of nonhuman primates in India (taken from Gupta 2001a).

Species	General status	WL (P) A	CITES	IUCN category
Semnopithecus entellus	Common, but declining	Sch II (1)	I	LR1c/N
Trachypithecus johnii	Limited to South India	Sch I(1)	II	VU A 1 (d)
Trachypithecus geei	Rare, endangered	Sch I (1)	I	CR/N A 1 acd C2a
†Trachypithecus phayrei	Rare, limited distribution	Sch I (1)	II	EN C 2a
†Trachypithecus pileatus	Rare, limited distribution	Sch I (1)	II	EN A 1 cd, C 2a
†Macaca mulatta	Common in North India	Sch II (1)	II	LR 2 (n/t)
Macaca radiata	Common in South India	Sch II (1)	II	LR 3 (lc)
Macaca arctoides	Rare, endangered	Sch II (1)	II	LR nt/N
Macaca assamensis	Unknown	Sch II (1)	II	LR nt/N
†Macaca nemestrina	Rare, endangered	Sch II (1)	II	VU A 1 (c) (d)
Macaca fascicularis	Rare, endangered	Sch I (1)	I	CR/N
Macaca silenus	Rare, endangered	Sch I (1)	I	B 12c C 2 (a)
†Bunopithecus hoolock	Rare, endangered	Sch I (1)	I	EN A 1 cd
Loris tardigradus	Rare, endangered	Sch I (1)	II	Lrnt/N
†Nycticebus coucang	Rare, endangered	Sch I (1)	II	DD

Note: *Macaca munzella* (Sinha *et al.* 2004) is recently added as a new species of macaque in the list. Species was recorded from Arunachal Pradesh.
†- **NHP** found in TWS, **Sch**- Schedule, **WL (P) A**- Wildlife Life (Protection) Act, **CITES**- Convention on International Trade in Endangered Species of Wild Fauna and Flora, **IUCN**- International Union for Conservation of Nature and Natural Resources.

1.7 Background of the study

Individual primate societies have been comprehensively studied and relevant information published for many decades. However studies comprising different primate communities are very few. Recommendations based on individual species generally fall short in fulfilling the holistic approach towards conservation. The ability of primates to deal with the challenges of living in fragmented habitats varies and clear patterns that can characterize this response have yet to be found (Onderdonk and Chapman 2000). Present study was undertaken with an objective to study the resource utilization by the three primate species; hoolock gibbon

(Bunopithecus hoolock hoolock,), capped langur (*Trachypithecus pileatus)* and pigtailed macaque (*Macacca nemestrina*) and one large ungulate, gaur (*Bos gaurus gaurus)* to assist in formulating area based conservation strategy. This thesis is a part of research project (November, 2001 – July, 2005) entitled "Conservation ecology of endangered mammals in Trishna Wildlife Sanctuary, Tripura" funded by Wildlife Institute of India, Dehradun. This study aimed towards holistic approach in biodiversity management. Faunal species of immediate conservation importance with different habitat requirements yet occupying the same management unit were selected as study species.

1.8 Aim and Objectives

The aim of this study was to assess the availability of important forest resources with reference to four endangered mammals gaur (*Bos gaurus gaurus*), capped langur (*Trachypithecus pileatus durga*), hoolock gibbon (*Bunopithecus hoolock*), and pig-tailed macaque (*Macaca nemestrina*)) and suggest recommendations for the conservation of the area and study species. The study attempted at outlining a framework for integrating habitat and population status objectives at different spatial and temporal scales using resource analysis that joins the conservation concepts used by community ecologists and population biologists.

The major objectives are:

- To prepare land cover and vegetation maps, quantify vegetation structure and composition in different vegetation types of the Sanctuary using Remote Sensing and Geographical Information System (GIS) tools.

- To study distribution, population structure, habitat use and food habits of gaur, capped langur, hoolock gibbon and pig-tailed macaque in the Sanctuary.

- Suggest recommendations for the conservation of endangered mammals (study species) in Trishna Wildlife Sanctuary.

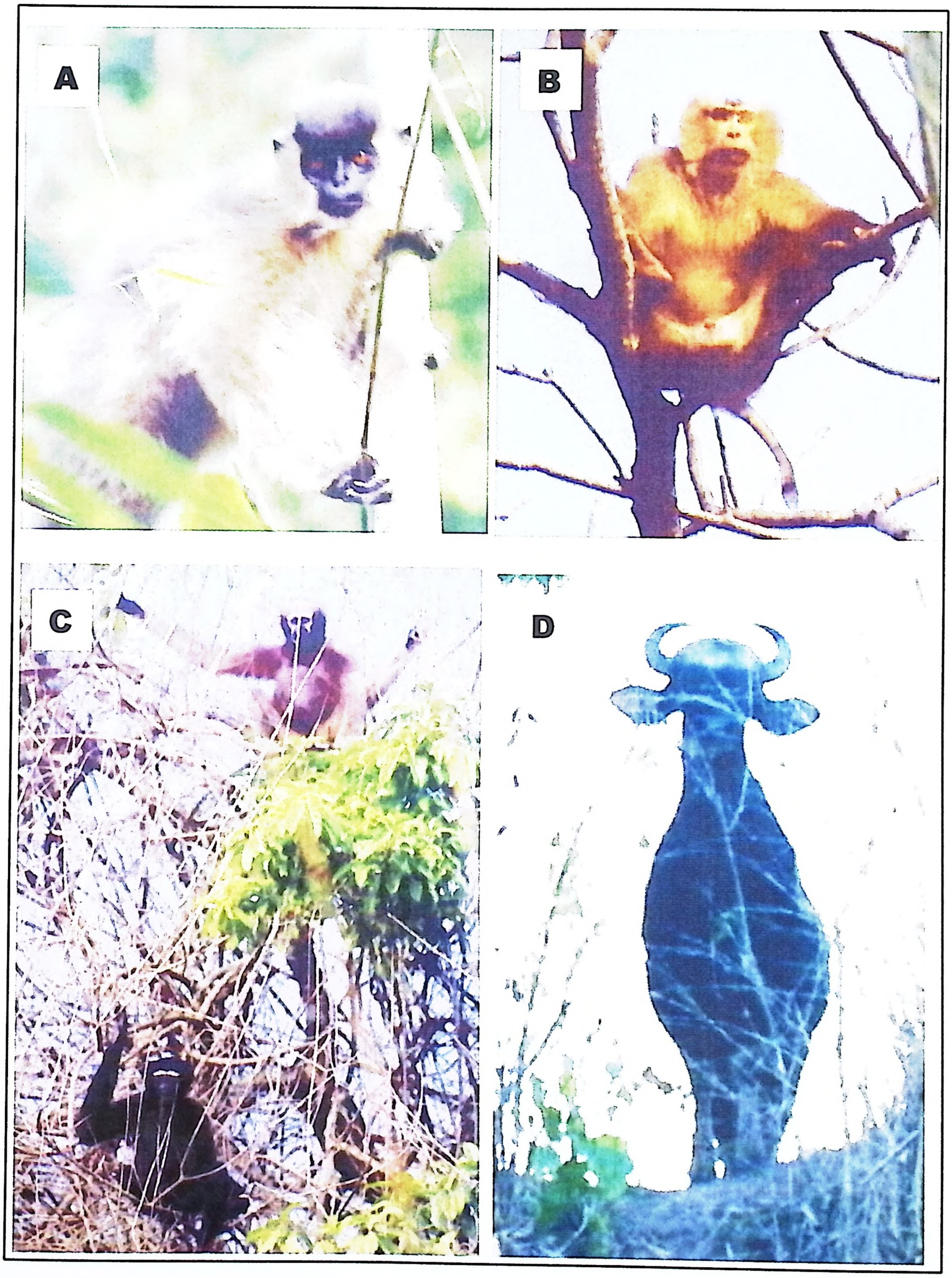


Plate 1. Study species (A- Capped langur, B- Pigtailed maaque, C- Hoolock ibbon, D-Gaur) in the Trishna Wildlife Sanctuary, Tripura.

Chapter 2

Study area and current knowledge on study species

2.1 INTRODUCTION

Till November 1949, Tripura was ruled by the Maharaja and then the state merged with the Union of India. Tripura received the recognition as a state on 21.01.1972, before this the state was administered as a union territory. Study was carried out in the forested area of southern part of Tripura state (fig. 2.1). The state stretches in between 22° 56′ and 24° 32′ North Latitude and 91° 09′ and 92° 20′ East Longitude covering an area of 10492 km^2. Protected area coverage of the state is 603.65 km^2 and has four wildlife sanctuaries, Sipahijala (18.4 km^2), Gumti (389.54 km^2), Trishna (194.71 km^2) and Rowa (0.86 km^2). Tripura owes rich biodiversity and copious wealth of biological resources to its unique Bio-geographical (8B Assam Hills) and Zoogeographical (Indian sub-region of Oriental Zoogeographical Region) location and position. These areas served as a great faunal gateway. Out of 15 free ranging primate species in India, 7 species are found in Tripura, which is the highest for any one Indian state (Gupta 2001b). Among these seven species, TWS itself is inhabited by six primate species ranging from the only ape of India to loris. This protected area is also the last home for gaur (*Bos gaurus*) in the state and has significant conservation importance as far as maintaining regional species richness and biodiversity is concerned. TWS, with less than $1/50^{th}$ area of the state, harbours more than 60% of the plant species recorded in the state (Choudhury 1996).

2.2 History

The TWS was notified in the year 1988 vide notification no F8 (58) For-WL/88/Vol.II/39253 dt.18.11.1988 of Govt. of Tripura. Prior to that, a smaller Sanctuary was constituted in the year 1987 vide. Government of Tripura Gazette notification no.F.8(50)/For-WL/86/55165 dated 02.02.1987. As per the guidelines of Wildlife (protection) Act 1972, this notification was made in terms of the cadastral survey (CS) plots already included in Government records showing administrative jurisdiction of Forest Department of Tripura. Then with the 1991 amendment to the Wildlife (Protection) Act, 1972, Government clarified its intension of creating this Sanctuary giving its general boundaries followed by the extinguishment of rights and concessions (Anon. 1996).

2.3 Physical attributes

2.3.1 Location

Trishna Wildlife Sanctuary [194.708 km², (23° 12′ - 23° 32′ N) to (91° 15′ – 91° 30′ E)] is situated in the south Western end of Tripura (Figure 2.1). The Sanctuary boundary protrudes deep into Bangladesh and bordered its area from three sides – the west, the east and the south. Joychandpur, headquarter of the Sanctuary is about 110 km from Agartala, the Capital of Tripura. Nearest towns in the periphery of the Sanctuary are Sonamura, Udaipur and Belonia. TWS falls in biogeographic zone 8 B- Assam Hills Province of North East India.

2.3.2 Area

The Sanctuary was notified in 1988 with an area of 194.71 sq. km. as per the provisions of the wildlife (protection) Act, 1972.

2.3.3 Topography

The area is hilly to undulating, marked by low hillocks barely 8 meter to 35 meters above mean sea level cut by constricted valleys. The Sanctuary and nearby areas are quite undulating with small hillocks, locally called *tilla*, interspersed with narrow and long valleys called *lunga*. These uplands are small in the southern parts but in the central portion, near a place called Manaipathar, these are relatively higher and rise about 200m above mean sea level. The central land running North to South is hilly and slowly flattens out towards the East, West and South finally merging into the low lying paddy fields of Bangladesh.

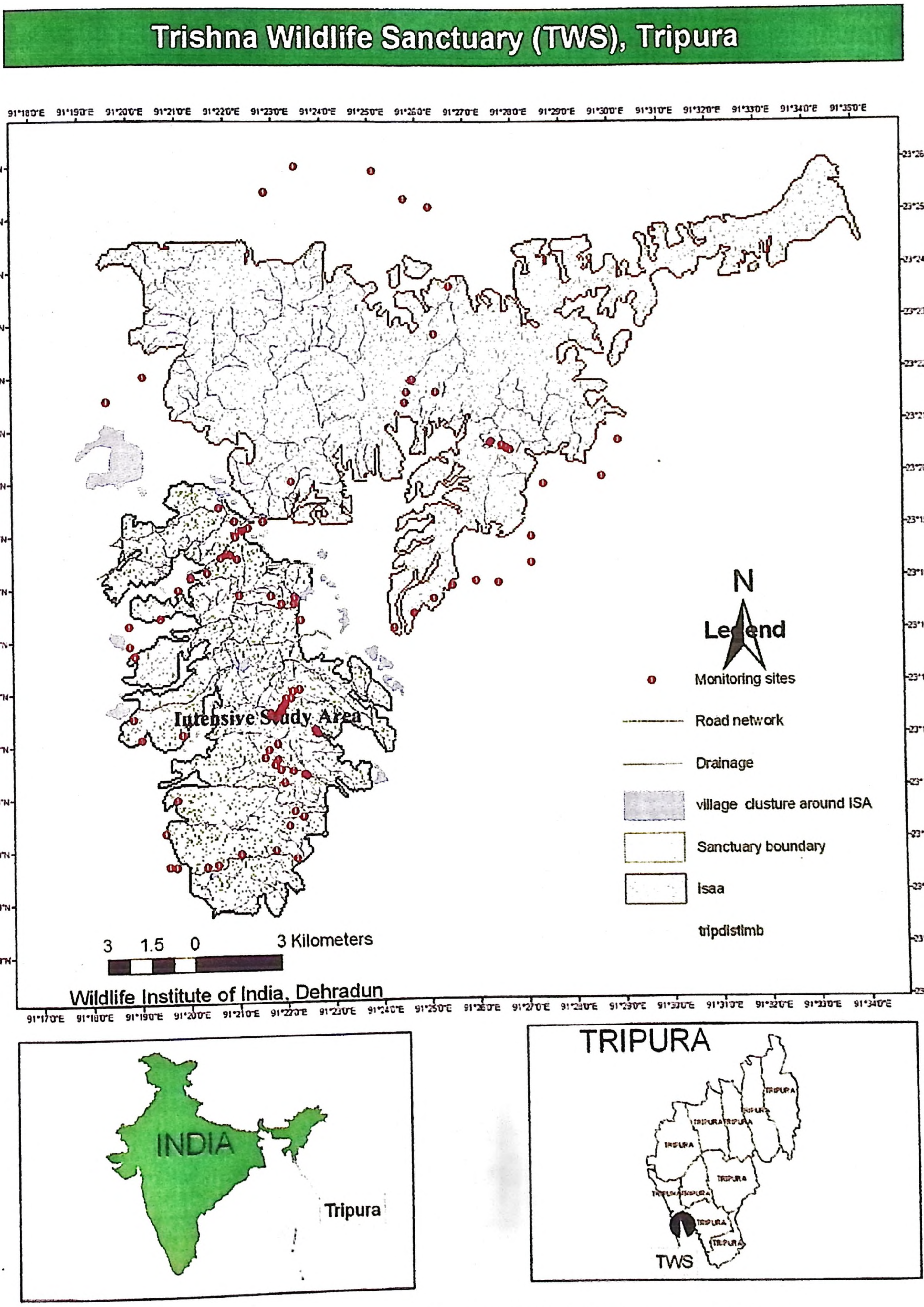


Figure 2.1 Location map of Trishna Wildlife Sanctuary, Tripura.

2.3.4 Drainage

The drainage in the Northern parts of the Sanctuary is towards West and South and in the Southern part of the region, it is towards East and West both. There are many rivulets in the area, which flow through it and out into Bangladesh. Most of these flow Westwards and only a few flow down towards the East. The smaller ones dry up during the summer but the larger rivulets contain water throughout the year. These form an important source of water for the animals of the area and also contain small fish and crabs etc. which many animals feed on. There are a number of man made ponds and lakes. Biggest of these is a lake near Rajnagar which is called lake no: 3 and attracts local tourists for winter birds. This and other ponds/lakes, retain water throughout the year and cater to the needs of the wild animals of the area. They also support various aquatic life forms. It may however be noticed that in the northern part of the Sanctuary, availability of water to the animals is mostly restricted to the streams which flow through the area and the animals have to go long distances for drinking water.

2.3.5 Geology

Geological structure of the Sanctuary is described under Gumati and Alluvium group (Anon. 1996). The general character of the rocks in the lower portion of the upper gumati group clearly indicates that they were deposited under rather shallow water conditions and probably of fluviatile origin. The lower Gumati rocks are of marine origin (Anon. 1996). Alluvial deposits are of recent origin. The soil is deep and usually fertile. The texture varies from sandy loam to loamy sand. Clay is found occasionally in scattered low-lying areas in small pockets. The soil in the undulating hillocks and hill ranges are mostly porous well drained sandy loam while the soil of the undulating small hillocks in the western part adjoining Bangladesh are more lateritic, characterized by red soil (Anon. 1996).

2.4 Ecological attributes

Ecological attributes are discussed in terms of climate, flora, vegetation types, fauna and anthropological parameters.

2.4.1 Climate

To collect climatic data of area during study period, temporary weather station was setup in the base camp. Details of rainfall, temperature and humidity are given in the figure 2.2.

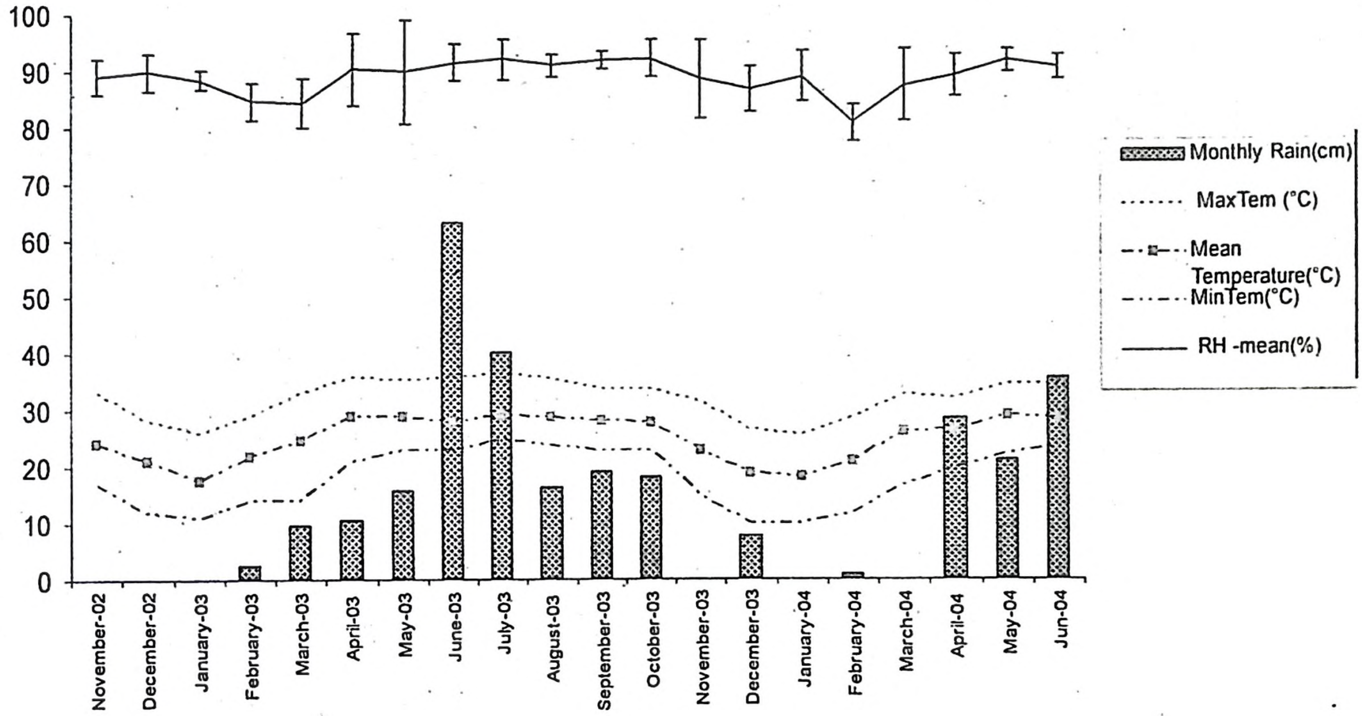


Figure 2.2 Monthly rain falls and mean monthly temperature and relative humidity of Trishna Wildlife Sanctuary between year 2002 and 2004.

2.4.1.1 Rainfall

The area receives heavy rains (2400 mm annual) but these are well distributed throughout the year. Approximately 63% of the total annual precipitation is received between June and September. Month of June is generally the hottest month (Max. 40°C) and January happens to be the coldest (Min. 5°C). Due to heavy rainfall and warm climate, relative humidity in this area is quite high and on an average varies from 68% to 75%. During the monsoon it is usually above 85% (Anon. 1996).

It rains nine months a year. November to February usually is the dry period and rain starts in the month of March with sometimes exceptional rain during February and November (fig. 2.2). Monthly rainfall was as high as 63.7 cm in June 2003 where as minimum of 0.78 cm was recorded in the month of February 2004 (table 2.1).

Table 2.1 Climatic data of Trishna Wildlife Sanctuary from November 2002 to June 2004.

Parameter	Maximum Temp (°C)	Mean Temp(°C)	Minimum Temp (°C)	Mean RH (%)	Monthly Rain(cm)
November-02	33	24.05	17	89.07	0
December-02	28	20.87	12	89.96	0
January-03	26	17.57	11	88.54	0
February-03	29	21.91	14	84.92	2.61
March-03	33	24.80	14	84.64	9.75
April-03	36	28.99	21	90.86	10.54
May-03	35.5	29.19	23	90.51	15.87
June-03	36	28.11	23	92.26	63.72
July-03	37	29.37	25	93.00	40.56
August-03	36	29.18	24	92.03	16.58
September-03	34	28.55	23	93.20	19.22
October-03	34	27.98	23	93.51	18.28
November-03	32	23.07	15	89.93	0
December-03	27	19.18	10	88.03	7.67
January-04	26	18.33	10	90.41	0
February-04	29	21.11	12	82.06	0.78
March-04	33	26.65	17	88.80	0
April-04	32.5	26.92	20	90.56	28.95
May-04	35	29.48	22.5	93.41	21.53
June-04	35	28.78	24	92.21	36.37

2.4.1.2 Temperature

Mean monthly temperature for the study period varied between 17 °C and 30 °C. Hottest month was July with 29.4°C of mean and 37°C of maximum temperature. Coldest months have been December and January with 10-11°C of minimum and 18 °C to 19 °C of mean monthly temperature. Summer months range between March and June for the present study where as November to February is taken as winter period (fig. 2.2).

2.4.2 Landscape scale vegetation composition

TWS supports about 60% of the plant species recorded in the state (Anon. 1996). Secondary grasslands and plantations on such lands, natural forests of

Dipterocarpus turbinatus and *Shorea robusta*, bamboo, etc. together make the forest, a mixture of Tropical and Moist deciduous forests with a variety of life forms. List of identified plants in the present study is given in the Appendix-8.

2.4.3 Vegetation types

As per revised classification of Champion and Seth (1986), the forests of TWS can be grouped into the following types-

2.4.3.1 Northern Tropical Semi- Evergreen forests (2B)

This forest type consists of few deciduous species of trees mixed with evergreen species forming top canopy, while the lower canopy is formed mainly of evergreen species. This type occurs in the central part of the Sanctuary between Barpathari – Rajnagar road in the east and earlier (Choudhury 1996) it was even found around Tindephaepa - Radha nagar road in the west particularly in valleys. Few deciduous species like *Bombax ceiba* are also found atop the hillocks.

From documentary evidences and local people's information it was confirmed that some years ago cane-brakes in the valleys in this forest was a typical characteristic of the region (Choudhury 1996). At present only small clumps of cane are available at a few places. Wet bamboo brakes are also present on wet ground along perennial streams. Dominant tree species found in this forest are *Schima wallichii, Artocarpus chaplasha, Bombax ceiba, Toona ciliata, Vitex peduncularis, Albizzia procera, Lagerstroemia parviflora, Terminalia bellirica* etc.

Pure forest patches of *Garjan* (*Dipterocarpus turbinatus*) occurred along the Bangladesh border in the east from Rajnagar to Garjania about 10-15 years ago but are now severely degraded following illicit felling and encroachment.

2.4.3.2 Eastern Bhabar Sal Forests (3C/C1b)

This type of forest is found in the northern parts of the Sanctuary i.e. at Tuisama, Dhuptali, West Patichhari, Garjee RF and Pipariakhola. Sal (*Shorea robusta*), which forms gregarious patches has profuse regeneration. Sal associates in this forest type are *Schima wallichii, Lagerstroemia parviflora, Vitex peduncularis, Terminalia bellirica* etc. The density of undergrowth is medium to high.

2.4.3.3 East Himalayan Moist Mixed Deciduous Forest (3C/C3b)

This forest type is found to the south and east of Abhoya beat outside the TWS. The forests are patchy especially in the Southern parts of Rajnagar Range. Both deciduous and evergreen tree species are found in this forests. The undergrowth is medium to heavy in density. The top storey consists of *Albizzia procera, Artocarpus Chama, Schima wallichii, Terminalia bellirica, Terminalia chebula, Lagerstroemia parviflora, Bombax ceiba, Chukrassia tabularis* etc.

The dominant species forming middle storey are *Dillenia pentagyna, Holarhena antidysentrica, Lannea grandis, Cedrella toona* etc. Bamboo, other grasses and bushes have invaded the groups created by felled trees.

2.4.3.4 Savannah woodland

Savannah type of forest is found in the northern part of the Sanctuary i.e. north of Manaipathar, excluding the area under sal forests of Tuisama, Dhuptali, West Patichhari and Pipariakhola. Besides, savannah woodland is present at places in the southern parts of Rajnagar range. The savannah woodland represents a forest where trees are very few in number and sparsely vegetated with bamboos, thatch grass and bushes. The area was heavily jhumed in the past leading to this forest type. The tree species found in this type of forests are *Bombax ceiba, Dillenia pentagyna, Albizzia procera, Sterculia villosa, Careya arborea* etc. *Eupatorium odoratum* dominates the bush land. *Melastoma malabathricum* is also found frequently as undergrowths.

2.4.3.5 Man made forests (plantations)

Plantations of *Shorea robusta, Dipterocarpus turbinatus, Tectona grandis, Acacia auriculiformes, Anacardium occidentale* etc. have been raised in the area. These plantations are interspersed with all above referred forest types in a small patch. Very recently cashew plantations have appeared in large scale mainly covering the buffer areas of the administrative boundary of the TWS.

2.4.4 Fauna

Amongst the wild mammals found in the TWS, hoolock gibbon *(Bunopithecus hoolock),* capped langur (*Trachypithecus pileatus),* pigtailed monkey (*Macaca nemestrina*), Phayre's leaf monkey (*Trachypithecus pheyrei*), gaur (*Bos gaurus gaurus*), wild pig (*Sus scrofa*), barking deer (*Muntiacus muntjac*), and leopard (*Panthera pardus*) are the few important species. Of the six primate species found in TWS, four are listed in schedule I of the wildlife (protection) Act 1972. The gaur population in the Sanctuary is one of the two that the State has. Check list of fauna is given in Appendix- 7.

2.5 Anthropological attributes

2.5.1 People and economy

The zone of influence of the Sanctuary is substantial as it supports and influences the local people over a large area in number of ways. Though there is no human habitation (villages) inside the Sanctuary, there are encroachments of forestland by local people at places. There are about 41 villages located at the periphery of the TWS. The estimated human population around the park is approximately 1,00,000 (Anon. 1996). The main occupation of local people is agriculture and animal husbandry. Large number (550000 cows) of brahmani cattle (*Bos indicus*) and goats are being kept by local people (Anon. 1996).

2.5.2 Resource use

Bamboo, firewood and thatch grass are removed from the forests by the local people residing adjoining to the boundary of TWS. Firewood is the main fuel for cooking food and cooking gas or kerosene stove is rarely used in the villages. Fuel from plant origin is taken for free and is therefore used by the villagers. Stall feeding is more or less unknown here and almost 99.78% of 550000 cows graze in the forest.

2.5.3 People and wildlife

Fuel wood collection, woodcutting, minor forest produce (MFP) collection (especially bamboo), cattle grazing, intentional forest fire and illegal fishing are the major management problems faced by the park authorities.

Poaching for meat mostly by local tribals in the northern parts and *Mundas* in the southern part of the TWS is a big management problem. This is particularly true of *Mundas* who hunt with bows and arrows. In all the cases, hunting is for meat and the meat is sold either locally or across the border (mostly meat of gaur). Gaurs are generally killed by people from Manaipathar and Siddinagar (outside Sanctuary) who themselves eat the flesh and sell a larger part of it to people on the other side of the border (as found while interviewing villagers during the present study). Poaching is not so frequent amongst Bengali communities although they also kill wild pigs at times when these raid crops.

2.6 Administrative structure

Wildlife warden has jurisdiction over almost half of TWS and over some more area outside the southern part of it. The area under the jurisdiction of the Wildlife Warden is divided into three Ranges, namely Rangamura Range, Rajnagar Range and Abhoya Range. Some of the Sanctuary is managed by the Divisional Forest Officers, Udaipur and a small portion by Divisional Forest Office, Bagafa. Protection responsibility is shared by staff of the territorial Ranges and the wildlife protection party stationed at Joychandpur. The administrative boundaries are shown in map (Fig 2.1). Compartment boundaries are not marked in the field although these were mentioned in earlier working plan documents of the respective territorial Forest Divisions.

2.7 Intensive study area (ISA)

After the preliminary survey of TWS, the southern part of TWS having majority of the gaur and primate population was selected as intensive study area. The total area of ISA estimated through GIS domain is 76.6 km^2 (Fig. 2.1). Zone of influence (5km buffer outside ISA) in terms of villages surrounding the ISA are Rajnagar, Paikhola, Sukanta Nagar, Chittamara, Laxmipur, Jashmura, Niharnagar, Radhanagar, Ekinpur, Dimatali, Indiranagar, North Srirampur, South Srirampur, South Radhanagar, West pipariakhola, S.B.C. Nagar, Barapathari, Kasari R.F., Trishna, Rangamura, South Rajnagar, I.C. Nagar, N.B.C. Nagar, East Pipariakhola, West Pipariakhola, West Kalabaria, East Kalabaria. The ISA is traversed by two major roads, one, connecting Rajnagar and Radhanagar, and second connecting Kasari and Teendepha. Both the roads meet at Teendepha before leading to Kakrabon. Apart from these two major motorable roads, vast road network exists in the northern part of the ISA. Several foot trails/paths connect villages in the surrounds of the TWS and thus criss-cross the entire ISA. At present ISA has five major artificially created lakes spread over the area. Three of these lakes fall in the ecotourism zones and are accessible to tourists. The area has well developed network of seasonal and perennial water.

2.8. CURRENT KNOWLEDGE ON THE STUDY SPECIES

2.8.1 Hoolock gibbon *(Bunopithecus hoolock)*

Traditionally, the hoolock gibbon (herein after called gibbon) has been considered being a member of the genus *Hylobates* and the monotypic representative of the sub-genus *Bunopithecus* (Geissmann 1995, Rowe 1996, Marshall and Sugardjito 1986). Recent molecular evidence documented that the distance among gibbon sub-genera was as large or larger than the distance between chimpanzees (*Pan*) and humans (*Homo*) (Roos and Geissmann 2001). As a consequence of this finding, all four subgenera are now recognized as full genera, and the scientific name of the hoolock has been changed from "*Hylobates hoolock*" to *Bunopithecus hoolock.*

2.8.1.1 <u>Status and Distribution</u>

The hoolock gibbon occurs (20° and 28° N, and 99° to 98° E) in Bangladesh (Khan and Ahsan 1986), Mayanmar, India (Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland,Tripura)(Roonwal and Monhot 1977, Tilson 1979, Mukherjee 1986, Mukherjee *et al.* 1988, Alfred and Sati 1986, 1990, 1994; Choudhury 1987, 1988, 1991, Wolfheim 1983, Srivastava 1999, Gupta 2005) and

South Western China (Geissmann 1995, Groves 1967, MacKinon and MacKinon 1978). The gibbon is found in tropical evergreen forests, wet tropical semi-evergreen forests, sub-tropical monsoon evergreen broadleaf forests, and sub-tropical evergreen broadleaf hills or mountain forests. The gibbon appears to be less common in deciduous forests and scrub forests, and totally absent from mangroves (Choudhury 1996a, Gittins and Tilson 1984, Link and Karanth 1994). It occurs at an altitude between 80m to1500 m (Choudhury 1996a,b, Mukherjee 1986).

Survey conducted by Indo-US primate project between 1994 and 1999 indicated their presence in isolated forest patches throughout northeast India. Habitat loss and indiscriminate hunting is responsible for bringing the gibbon population at brink of extinction almost in the entire distribution range in India (Srivastava 1999).

2.8.1.2 Ecology

Estimated head and body length of gibbon is about 60 to 90 cm, and their body weight ranges between 6.0 to 8.5 kg (Geissmann 1993). Gibbons live in small, monogamous family groups (Nowak 1999). Average group size ranges from 2.7 to 4 (Alfred 1992, Choudhury 1990, 1991, 1996a, Feeroz and Islam 1992, Gittins and Tilson 1984, Mukherjee 1992, Siddiqi 1986, Tilson 1979).

Gibbons are arboreal, live in a family unit of 3 to 4 individuals and maintain a definite territory of about 0.15 km^2 to 0.35 km^2, which is defended by loud territorial songs (Marler 1968, Tilson 1979, Alfred and Sati 1990, Gittins 1980, Gittins and Akonda 1982, Gittins and Tilson 1984, Islam and Feeroz 1992). Overlapping zones between the two adjacent groups varies from 0.05 to 0.075 km^2 (Tilson 1979), 0.05 to 0.10 km^2 (Alfred and Sati 1986, 1990), and 0.02 km^2 (Islam and Feroz 1992).

When their habitat is fragmented and food trees are isolated, gibbons are forced to descend from trees to cross clearings (McCann 1933). Each family group occupies a home range of about 14 to 55 hectares (Alfred and Sati 1990, Feeroz 1996, Feeroz and Islam 1992, Gittins and Tilson 1984, Tilson 1979, Kakati 1999). Mukherjee (1982) reported home range of 300 to 400 ha from Tripura. On an average, a group covers a day range of about 600 to 1200 m (Feeroz and Islam 1992, Mukherjee 1986). Gibbon is frugivorous and a diurnal species and prefers the upper canopy of the forest, and roosts on emergent trees (Leighton 1987, Alfred and Sati 1986, 1990). In addition gibbons also consume smaller quantities of flowers and insects (Alfred 1992, Feeroz and Islam 1992, Gittins and Tilson 1984, Islam and Feeroz 1992, Tilson 1979). Gibbons bask in the morning sun, especially during the cold winter season (Choudhury 1996a, Tilson 1979). Gibbon exhibits brachiatry, i.e., moving through the canopy using long fore-arms. Gibbon appears to have favorite arboreal pathways across the canopy of their territory, which they use more frequently than others (Feeroz and Islam 1992, Islam and Feeroz 1992). In the winter season, hoolock gibbon spends more time feeding, less time traveling, their songs start later, they produce fewer song bouts, and they retire to their sleeping trees earlier than in summer (Feeroz and Islam 1992, Islam and Feeroz 1992, Mukherjee 1986). The family group spends the night in one of several preferred "sleeping" trees of the territory (Feeroz and Islam 1992). Mating appears to occur more often in March-May (Feeroz and Islam 1992). Habitat utilization by the gibbons in the northeastern states of India have been recorded by Mukherjee 1982, Alfred and Sati 1986, 1990, Choudhury 1987, 1990, 1991, Gupta 2005.

2.8.1.3 Threats to gibbon population

The species is threatened by habitat loss and by hunting for food (Ahsan 1995, Choudhury 1990, 1991, 1996a, Mukherjee *et al*. 1992, Srivastava 1999, Sati and Alfred 2001). Slash-and-burn cultivation (Jhum) is the main factor leading to the destruction and fragmentation of gibbon habitat. Conversion of tropical forest to teak plantations, betel-leaf (*Piper betel*) plantation, and encroachment of forestland for settlements (Choudhury 1996a, Mukherjee *et al*. 1992) are the few other cause of habitat destruction adversely affecting gibbons. In Bangladesh, North East India and South West China, much of their habitat is extremely fragmented (Alfred and Sati 1990, Choudhury 1996b, Lan 1994), making them doubly vulnerable to hunting and predation. Recent study done in the Gibbon Sanctuary, Assam also reported the problem of gibbon habitat fragmentation (Gupta 2005). Most populations are very small and declining (Choudhury 1996b, Mukherjee *et al.* 1992), and many local populations will probably go extinct in the near future (Alfred and Sati 1990, Srivastava 1999).

2.8.2 Capped langur (*Trachypithecus pileatus*)

2.8.2.1 Status and Distribution

The capped langur is found in Bangladesh, China, India (Assam, Manipur, Meghalaya, Nagaland, Tripura), Myanmar and Bhutan. This species lives in evergreen, tropical wet deciduous, montane, and primary forests (McCann 1933, Pocock 1939, Oboussier and Maydell 1959). There are five recognized sub-species of capped langur (Ellerman and Morrisonscott 1951, Napier and Napier 1967), found in South Asia (Roonwal and Mohnot 1977). The *Trachypithecus pileatus durga* is found in Chittagong (Bangladesh), Nagahills and Tripura (Wroughton 1916).

2.8.2.2 Ecology

This langur has a black face and head, with cheeks paler and sharply contrasting, sometimes suffused with red. There is a cap of long, erect, coarse hairs directed backwards which gives the species a typical name. The dorsal colour is grey to blackish grey (McCann 1933). The pelage of the newborn is apricot in color. Males can have a body mass of up to 11 kg, and the female body mass is between 10 to 11 kg. Group sizes range from 2 to 15 individuals. Head and body length of males and females are 68.4 cm to 70 cm and 59 cm to 67 cm respectively. Tail length varies from 94 to 104 cm for males and 78 to 90 cm for females (Oboussier and Maydell 1959). The capped langur gives birth to a single offspring about every two years (Stanford 1991), and the young ones are born from April to May at the start of the monsoon season (Stanford 1987). Capped langurs are almost entirely arboreal and forest-dwelling animals. The capped langur moves through the forest quadrupedally (Fleagle 1988).They come to the ground only in the dry season for drinking and in rainy season they do not leave the trees at all. They move about on trees and make tremendous noise, with the branches bending and breaking under their weight as they jump from tree to tree (McCann 1933). Stanford (1991) found that group home ranges will overlap, with an average of 84% overlap in groups found in Madhupur National Park, Bangladesh. The capped langur is a folivorous species, but fruit forms a major component of the diet (Choudhury 1989). This species eats a large amount of mature leaves as well as immature leaves when they are available. During the monsoons fruits are a major part of the diet. Stanford (1987) found that in Madhupur National Park, Bangladesh, the fruits and leaves of two species, *Albizzia procera* and *Spondias mangifera*, accounted for 64% of the feeding time. Islam and Husain (1982) found that in Madhupur National Park mature and young leaves were consumed 61% of the time and flowers, fruit, and seeds were consumed 30% of the time. Gupta (1998, 1996b) while studying capped langurs at Sepahijala Wildlife Sanctuary, Tripura, found that young leaves (59.1% of the time) were consumed the most and *Albizzia stipulata* was the most preferred plant. In Madhupur National Park, Stanford (1987) found that the mean group size of the capped langur was 7.0 individuals with a range of 4 to 13. Gupta (1996a) reported the species at Sepahijala Wildlife Sanctuary spent 32.6% time in feeding, 27.2% resting, 22.8% traveling, and 17.4% in other activities. At Sepahijala Wildlife Sanctuary, the capped langur is found sympatric with Phayre's langur, *Trachypithecus phayrei*, and golden langurs, *Trachypithecus geei* (Gupta 1998). Gupta (1998) also found that this species shared 35 food plant species with Phayre's langur and 26 food plant species with golden langurs.

2.8.2.3 <u>Threats to capped langur population</u>

Habitat loss primarily induced by human activities is the main reason for its endangered status (Hilton-Taylor 2000, Gupta 1996b).

2.8.3 Pigtailed macaque (*Macaca nemestrina*)

2.8.3.1 <u>Status and Distribution</u>

This species is distributed in South and Southeast Asia (India, Malaya, Indonesia, Sumatra, Borneo, and a few small adjacent island) (Fooden 1969a, Medway 1970), Bangladesh, Thailand, Cambodia and Laos. Within northeast India the pigtailed macaque inhabits areas in Assam, Arunachal Pradesh, Mizoram, Nagaland, Meghalaya, Manipur, and Tripura (Srivastava 1999). The habitat of pig-tailed macaque is quite variable from lowland primary and secondary forest to coastal, swamp, dry land, and montane forest up to 1700 m (Caldecott 1986)..

2.8.3.2 Ecology

Their diet is composed of fruits, seeds (Rowe 1996) and animal prey (Caldecott 1986). They have been reported to raid crop fields and kitchen gardens in Assam and Meghalaya (Srivastava 1999) respectively. They spend most of their time in upper canopy (Srivastava 1999). Opportunistic feeding occurs throughout the day and food sources seem to be located and exploited by small, widely separated parties; this is considered to enhance the efficiency with which small food sources are harvested. This is not always true and need more study to conclusively prove so. The average day range length is 1000 m to 3000 m (Caldecott 1986). Other then above studies, Oi (1990) also described ecology of pigtailed macaque in Sumatra.

2.8.3.3 Threats to pigtailed macaque population

Habitat destruction is the main threat to the existing population. Hunting for food is also a threat to the pig-tailed macaque in northeast India.

2.8.4 Gaur (*Bos gaurus gaurus*)

2.8.4.1 Status and Distribution

Commonly referred to as the Indian bison, the gaur belongs to the subfamily Bovinae of the order Artiodactyla. It is the largest living bovine, confined to the oriental biogeographic region of the world. The gaur population in India occurs in more or less isolated pockets largely corresponding to the major mountain systems of the western Ghats, the Central Indian highlands and north-eastern Himalayas. As diverse as their distribution, their habitats range from bamboo forests in the Northeast to dry deciduous forests in Central India and moist deciduous forest in the

Western Ghats. In Western Ghats gaur is reported at elevations of 2000 m in relatively undisturbed habitats. In Tripura, gaur is found in the southern part (TWS) and got locally extinct from northeast part (Gumti Wildlife Sanctuary) of the State.

2.8.4.2 Ecology

The gaur is the tallest living oxen (Brander 1923), and the second heaviest land mammal (Krishnan 1972). The bull gaur weighs 600 to 1000 kg and stand 1.6 to 1.9 m at shoulder, whereas the cows are about 10 cm shorter and weigh about three fourth of the males. Both sexes have horns which in the males especially are larger at base with more outward swath and less curving at the tips. The average spread / length of horn is 80cm to 100cm.

Gaur is gregarious animal. Group size may range from 2 to 16 animals or sometimes more then 20 animals (Schaller 1967, Sankar *et al.* 2001). Gaur is a generalist feeder but prefers to browse in dry seasons and predominantly graze in monsoon. Their diet chiefly includes shoots and foliage of trees, shrubs, buds, fruits, herbs, tender shoots of bamboo, grasses and barks of trees. Free-ranging gaur showed seasonal and local movements between foraging sites (Sankar *et al.* 2001). During the hot hour of the day gaur retires to the shelter under thick tree cover and ruminate. Feeding is more prominent during early morning and evening hours (Schaller 1967).

They snore and give *phoo* calls when alert. During the rut, the males produce rutting calls with very high pitch and can be heard at long distances. The bulls exhibit `flehmen', an up curled lip movement, when approaching a cow in heat. The time of mating season or rut varies across its distribution ranges but has definite peaks. But some individuals do breed throughout the year. Cows give birth to a single calf after a gestation period of eight to nine months. Twins may be very rare (Schaller 1967, Sankar *et al* 2001).

2.8.4.3 Threats to gaur population

Gaur has little immunity to some cattle diseases. Population of gaur has succumbed to epidemics of foot and mouth disease (FMD), rinderpest and anthrax (Krishnan

1972). Study on ecology of gaur in Pench tiger reserve (PTR), Madhya pradesh by Sankar *et al.* (2001) noticed FMD in the gaur population. In fact no wild animal in India is so profoundly influenced by transmitted infections from domestic livestock as gaur. Further, poaching of animals and sport hunting in the past and habitat degradation are mainly responsible for the decline or extinction of small local populations. For these reasons the distribution of gaur has been altered in the last 30 years, and accounts of their distribution as obtained in the forties are no longer valid now. If the declining trend in gaur population is not reversed, it could effectively reduce the genetic diversity of gaur populations (Krishnan 1972).

Except a few long term studies on gaur (Schaller 1967, Chandi Ramani 1984, Vairavel 1998, Sankar *et al.* 2001) no detailed study of gaur anywhere in India has been done. Several casual observations of gaur, however, are available (Baker 1980, Ali 1953, Spillit 1967, Khader 1969, Sahai 1972, Sahai 1977, Johnsingh 1979, Krishnan 1972, Guin and Pal 1982, Nair and Jayson 1988).

Chapter 3
Study design and methods

3.1 INTRODUCTION

Fieldwork was done in Trishna Wildlife Sanctuary (TWS), beginning from year 2002 at Rajnagar range in the southern most part of the Sanctuary. Field work began in the month of January 2002. In the beginning attempts were made to approach as many areas as possible inside TWS. A small part of north east portion of TWS was inaccessible due to insurgency problem; however information on those areas was collected from sources like interviewing villagers and talking to forest department officials.

Information was acquired to formulate "area based conservation strategy". Study enumerated resource utilization pattern by the non-human primates and one ungulate in intensive study area. Information was also collected on vegetation structure and composition (site/habitat quality) parameters from the entire study area. Data collection methods were grouped separately for habitat assessment, primates and gaur and the detailed methods are described in the relevant chapters.

3.2 STUDY DESIGN

3.2.1 Time frame

Field study was carried out between January 2002 and June 2004. Reconnaissance survey took initial 5 months and included fieldwork and preliminary analysis to decide study design and sample size. Following suitable study design, systematic data collection was started from November 2002 and two subsequent seasons (winter and summer) were covered. The data on study species was not collected during rainy seasons as the study area became inaccessible.

Framework of the study is shown in the figure 3.1.

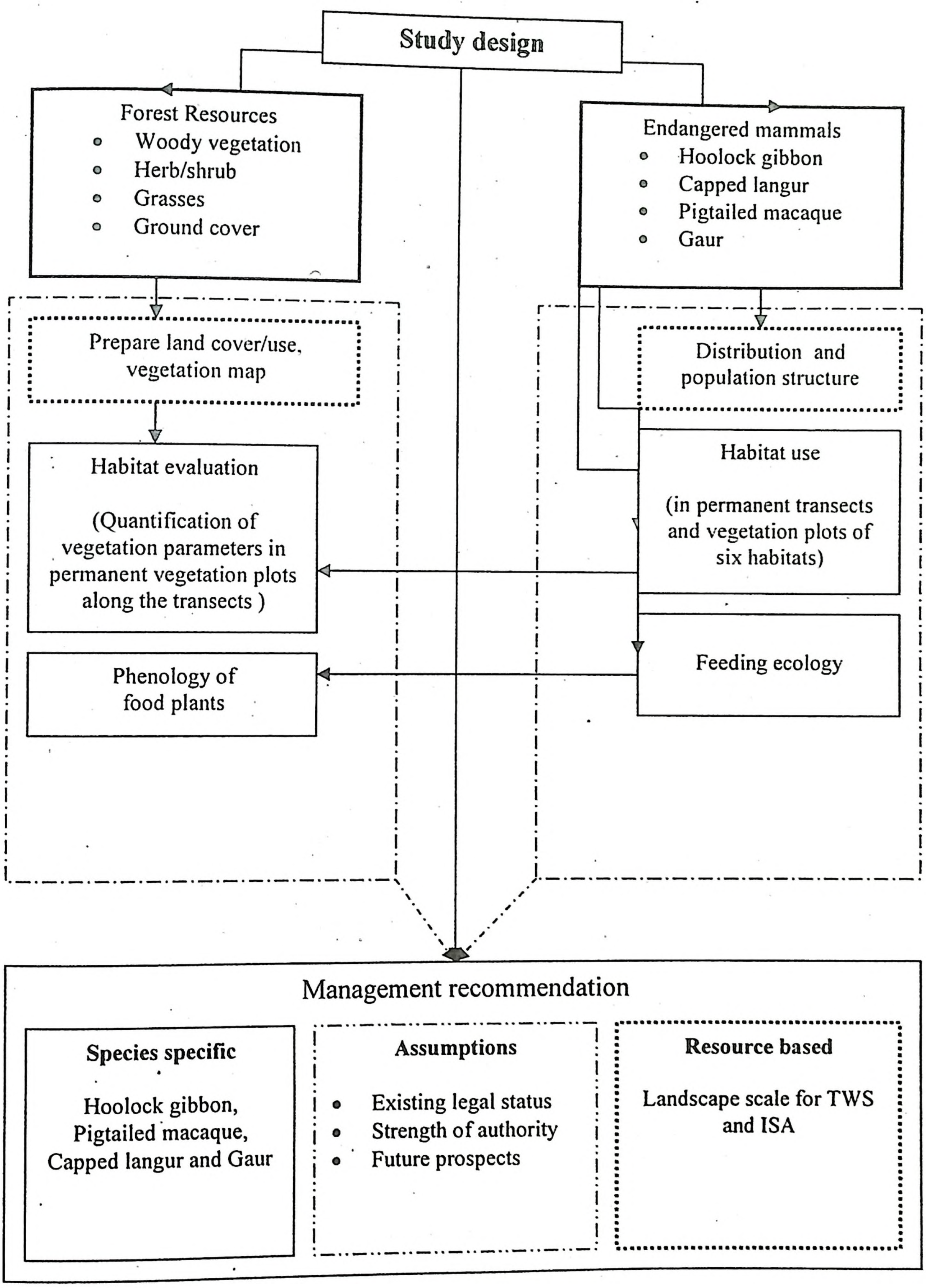


Figure 3.1 Conceptual framework of the study conducted in Trishna Wildlife Sanctuary, Tripura (2002-2004).

3.2.2 Reconnaissance survey

Before the intensive study area was selected and systematic data collection started, the entire Sanctuary was surveyed based on grid based stratification on IRS LISS III data procured from National Remote Sensing Agency, Hydrabad (NRSA) for the purpose of land cover and vegetation classification of TWS. Each grid was marked at 1 min x 1 min interval. Out of 82 marked grids, 65 grids were covered during reconnaissance survey. Adequate numbers of sampling points were surveyed within each grid depending on the terrain and accessibility. Interviews with local people were conducted during initial stages of the survey to locate study species groups and their approximate size. Land cover categories, broad vegetation types, presence-absence of animals and information on signs of anthropogenic pressures were recorded for each sampling point.

3.2.3 Primate and gaur survey

During reconnaissance survey of study species, four to five days a week were spent by researcher with two field assistants. During systematic data collection, primate and gaur surveys were carried out once in 15days for 3 months. The survey was conducted during morning (0500 to 1030 h) and evening (1430 to 1800 h) hours. After preliminary survey, the ISA was covered once in a season for total count of study species of primate and presence-absence for gaur. Stratification of the area was done based on alignment of the permanent transects and thus eight survey blocks (Rajnagar, Durgapur, Joychandpur, Kasari, Teendepha, Bhavanipur, Rangamura and Radhanagar) were delineated along the natural features like streams and tillas. Each block was covered once in a month by distributing regular transect walk uniformly in the temporal scale.

3.3 MAPPING METHODS

The methods used for developing the land cover classification of TWS followed the standards described in the Chapter 4. The mapping strategy included three stages: 1) unsupervised classification of LISS III imageries 2) reconnaissance and 3) supervised classification following repeated ground truthing. First, an unsupervised classification of TWS was conducted using ERDAS IMAGINE 8.5 to characterize the probable land use classes across the landscape. This was done based on the earlier classification followed for the region and secondary literature available on the study area. The gradients recognized were mainly agricultural landscape, forested land, disturbed forested landscape and habitations. During the reconnaissance, fourteen preliminary landcover and vegetation types, based on land management practices, plant species dominance and composition, were recognized. The initial list of types includes four types of land cover (agricultural landscape, forest land, water body and habitation) and 11 forest classes. The second stage consisted of sampling different forest types for recording dominant vegetation along with presence absence of animals including signs of anthropogenic disturbance, so as to get homogeneous representative samples of all major vegetation types. Preliminary vegetation types were coarsely delineated by plotting sampling points over unsupervised classification of imagery and grouping similar classes together. A total of 114 vegetation plots spread over 64 grids (1min grid) led to making of the final land cover map. The final stage of the mapping strategy to validate the classification was by putting random points within the ISA and visiting the encompassed area. Misclassified points were taken as errors in the map. However, the changes noted after the date of imagery were not taken as misclassified points and were manually rectified. All descriptions on the vegetative cover at TWS were collected from circular plots.

3.4 ECOLOGICAL METHODS

The objective was to collect data on wildlife habitats from sample based inventories so that wildlife habitat management strategies can be planned. The analytical approach involves identifying different habitats present on field plots, estimating area present for each habitat condition, and linking the habitat classifications with study animal habitats. Data sheet used for different ecological studies are given in the Appendix-1 to 6.

Equipment

Following equipment were used –

(i) Global positioning system (GPS, GARMIN 12 XL) for recording all geographical coordinates (ii) Clinometer (SUUNTO PM-5) for measuring tree height (iii) See through compass (SUUNTO) for taking animal bearing in transects, (iv) Map reading compass for reading topographic map, (v) Densiometer for estimating canopy cover of vegetation, (vi) Pedometer for measuring distance while walking, (vii) Spring balance for taking weight of food plants, (viii) Binocular for sightings of study species, identifying age and sex composition and recording behavioural observations and (ix) Canon EOS 66 camera with 300 mm lens was used for keeping photographic evidences of animals, food plants, land cover types, people and activities.

3.4.1 Population status of study animals.

Line transect method (Buckland *et al.* 1993; Burnham *et al.* 1980) was used to determine abundance and density of study species in the ISA area. Total count for study primate species was also carried out in ISA. Six (6) transects varying in length between 2 km to 3.2 km were laid following stratified random sampling. Each transect was walked at least five times in a season. For each study species sighting on the transect, the following parameters were recorded – a) GPS location b) sighting angle, sighting distance, c) group size and d) sex and age classes of the individuals. Field and analytical methods used for assessing population status of study species are described in details in chapter- 5.

3.4.2 Habitat assessment

The ISA was inventoried by delineating permanent plots along six (6) permanent transects laid in different habitats of study species. Primary sampling sites were decided based on the different habitat types available in the area, and stratification was done based on topography and feasibility of sampling. A total of 67 permanent plots (spread in six habitats) were sampled once in a year for two consecutive years. Tree, herb, shrubs, anthropogenic disturbances and presence-absence of study animals were recorded and analysed for habitat use and availability. This information was used in habitat suitability analysis. Details on the procedures and protocols of habitat assessment are described in the chapter-6.

3.4.3 Non-human primates group

For this study, protocol used by Gupta (1996b) for studying phayre's langur, capped langur and golden langur in Sepahijala Wildlife Sanctuary, Tripura, India was adopted. Whenever required the protocol for field study were modified depending on the feasibility and objectives of study. Methods followed for population estimation in different areas using line transect surveys (e.g. Cant 1978, Green 1978, Peres 1990, Gonzalez-Kirchner 1998, Wallace *et al.* 1998) were taken into consideration while modifying the protocol. Details of methods are discussed in the chapter-4.

3.4.3.1. Selection of troop

Within the ISA, one troop of hoolock gibbon, capped langur and pigtailed macaque each was selected for studying feeding ecology and other resource use patterns. All study troops were selected within the limit of same contiguous patch of vegetation. Troops were selected keeping in mind the accessibility within the home range of selected troops of study species; home range overlapping of each selected troop and typical troop size.

3.4.3.2. Habituation

Habituation of selected troop was carried out from March 2002 to May 2002 and then from November 2002 to January 2003. Habituation process was started with gibbon followed by capped langur and pigtailed macaque. The hoolock gibbon habituation took least time and initially for about one month they were followed dawn to dusk without studying them systematically, and later on systematic recording was started.

The largest group of capped langur in the ISA was selected for habituation and detailed ecological study. Same procedure of habituating was followed for hoolock gibbon and capped langur.

Habituating the pigtailed macaque group was observed to be the most difficult process as they were very shy and moved into low visibility ground cover whenever alerted. The selected pigtailed group was using the same part of ISA same as the other two habituated groups of gibbon and capped langur. The group was found to be very alert in presence of any other animal and human.

3.4.3.3. Observation schedule and data collection

Ecological data on all the three study species was collected from dawn to dusk for a block of 8 days in a season spread over 2 sessions (4 days a session), referred as '4Day follow'. Details of design related to recording observations are discussed in respective chapters. For each study group, ecological data were collected through a total of 32 days and 'follow' covering 4 seasons in two years and field study. The data was analysed for studying feeding ecology, ranging pattern and use of forest cover by each study group.

3.4.4 Gaur

The instantaneous sampling technique (Lehner 1979) or "point sampling" (Dunbar 1976) was adopted for the collection of activity data on target species. Every time they were sighted a quick scan of the activity being performed was noted down along with the age and sex of the individual. Observations were distributed in space and time to reduce the statistical error due to non independence of data.

As crop depredation by gaur was one of the main human-animal conflict issues in TWS, this was quantified mainly based on the indirect evidences. Crop fields adjoining gaur populations were visited at regular intervals, and also whenever reports on crop raiding were received. To quantify the extent of damage, parameters like area damaged by both eating and trampling, developmental stage of crop species and estimated minimum number of gaur responsible for such damage were recorded. The locations of crop damaged areas were recorded using a GPS.

3.4.5 Feeding ecology

Present study focused on species of plants eaten by all the four study species in TWS. Data on food habits of target species were collected by opportunistic sightings in case of gaur and by scan sampling (Altmann 1974) for primates.

3.4.5.1 Phenology of food plants

Phenological studies of important food plants (trees, shrubs, herbs and grasses) used by study species (gaur, hoolock gibbon, capped langur and pig-tailed macaque) were carried out throughout the study period. Selected plants were marked and monitored once in fifteen days for their phenological status. At least 10 plant species for each study animal species were selected for this study. Five (5) individuals of each plant species were marked for year round monitoring of phenophases. Detailed procedure for marking, recording and analysis are discussed in the chapters describing feeding ecology of gaur and primates (chapter- 6).

Chapter 4

Land use / land cover and vegetation composition

4.1 INTRODUCTION

There are many situations where vegetation merits are studied. The commonest examples of the use of vegetation description are in the recognition and definition of different vegetation types and plant communities known as the science of phytosociology; the mapping of vegetation communities and types; the study of relationships between plant species distributions and environmental controls; and the study of vegetation as a habitat for animals, birds and insects. Information on vegetation may be required to help to solve an ecological problem: for biological conservation and management purposes, an input to environmental impact statement, to monitor management practices or to provide the basis for prediction of future changes (Kent and Coker 1992).

This chapter deals with the vegetation classification for TWS, a field key to the land use / land cover (LULC) types for TWS, and descriptions of each vegetation type with its composition and distribution of different plant life forms. Remote sensing with multi-spectral and multi-temporal data collection systems allows one to perform the work of data collection and integration more quickly and effectively. It also brings a great deal of knowledge about surface features. This has opened up new frontiers for conservation and sustainable use of forest resources (Blamont and Méring 1987). Forest cover classification, based on satellite remote sensing provides an efficient and cost-effective method for acquiring up-to-date and accurate information that is useful to resource planners, researchers and conservationists (Millette *et al.* 1995).

Here an attempt has been made to discuss landscape characteristics of the study area, characteristics of vegetation at landscape level, vertical and horizontal distribution of plant resources, spatial changes in the distribution, richness, evenness and diversity of this area, and specific association among different plant life forms.

4.2 METHODS

The methods used for developing the land use / land cover classification for TWS followed the standard methods for vegetation mapping (Singh *et al.* 2002). The small size of the protected area permitted sampling in 64 out of 82 grids of size 1 min X 1min covering the TWS. The sampling strategy included three stages: 1) field reconnaissance survey, 2) unsupervised classification of IRS LISS III imageries followed by supervised classification, and 3) seasonal vegetation sampling on permanent vegetation plots along the permanent transects laid for regular monitoring of study animals.

First, a reconnaissance survey of TWS was undertaken to characterize the land use and vegetation across grid map of the study area to identify its relationship with vegetation classifications as described by Champion and Seth (1968). The gradients recognized for stratification were, major land use types, topography, and site disturbance in terms of distance from the Sanctuary boundary. During the reconnaissance, sixteen LULC types were recognized based on plant species dominance and composition.

For vegetation characterization and quantification of distribution, diversity, richness and association of different plants at both individual species level and community level, systematic sampling (Magurran 1988) was done in the TWS.

4.2.1 Land use / land cover mapping

IRS-IC LISS-III digital data were used for classification of the land-cover/use. The data provided information in four spectral bands in the visible and infrared regions with spatial resolution of 23.5 meter. Standard methodology (Singh *et al.* 2002) has been followed and preprocessing of image had been done which comprises of geometric and radiometric correction. Geo-referencing of master scene has been carried out on 1 : 50,000 scale using ancillary data and GPS locations. The multiple images obtained through unsupervised and supervised and site-specified classifications, and area of knowledge, were overlaid and a final classified image was generated. Field knowledge was subsequently incorporated to improve the accuracy. This approach takes the advantages of both the procedures and therefore it is called as hybrid (Singh *et al.* 2002). It is an integrated approach comprising unsupervised classification, supervised classification and human knowledge. Vegetation classes were delineated on the basis of their spectral value of FCC. The spectral channel 3, 2, 1 (RGB) of LISS-III proved significant in the process of class separation, though the major contributor was near infrared (NIR), which showed relevant differences in spectral (DN) value of different vegetation classes.

Survey of India (SOI) topographical map on the 1: 50,000 scale (surveyed in 1970) covering study area and its surrounding, and IRS-IC (LISS III) data of 11th November 2001 were used in the present study. Data procured was in two scenes.

LISS III data was processed by using ERDAS-Imagine 8.5 and ArcInfo 8.2 software. Images were geo-rectified with the help of SOI toposheets. The georectified data has root mean square (RMS) error of 2.42%. Desired area was extracted after mosaicing and featuring two images.

Drainage, road, contour, village clusters and other important locations were extracted from the SOI toposheets on 1:50000 scale. RMS error for the digitized data was 3.6%. Later these layers were digitized independently to create coverage and shape files and registered in GIS domain.

4.2.1.1 Field method (Classification Scheme)

Study area foster very different types of flora. For the sake of uniformity, Level II vegetation classification is attempted. Land-cover/use classification system followed in this thesis includes only second level classification. The system satisfies the three major attributes of classification: (1) it gives names to categories by simply using accepted terminology; (2) it enables information to be transmitted; and (3) it allows inductive generalization. Here in this classification term 'forest' and 'non-forest' are used purely based on the LULC and not as per the government notification. Forest lands are those which have tree-crown aerial density of 10 percent or more and capable of producing timber or bamboo. Auxiliary concepts associated with Forest land, such as wilderness reservation, water conservation, or ownership classification, are not detectable using remote sensing data. At level II, forest land is divided into six major categories: moist mixed deciduous, teak and bamboo mixed, mixed dipterocarpus, mixed bamboo forest, water body associated vegetation, bamboo brakes. Settlements in the area are usually surrounded by dense vegetation (homegardens) or plantation and in almost every case the crown cover is more than 10 percent, but this has not been considered under the forest category to help analyzing more effectively from management point of view.

Fourteen different LULC types were identified inside the study area during the reconnaissance survey and following classification scheme was followed. This classification was developed for this study to suit further analysis while associating different classes with the habitats of study animals. Following classification scheme has been attempted for stratification using satellite remote sensing digital data.

I. Forests

1. Dominant phenological types
    1.1 Moist mixed deciduous
2. Gregarious types (single species dominated forest)
    2.1 Teak and bamboo mixed
    2.2 Mixed Dipterocarpus
    2.3 Mixed Bamboo forest
3. Local-specific classes
    3.1 Water body associated vegetation
    3.2 Bamboo brakes (Kalai)
4. Degradational types
    4.1 Highly degraded sal forest
    4.2 Clear-felled/ Jhumed/Open forest
    4.3 Degraded scrubland
    4.4 Highly degraded bamboo forest

II. Non-Forest

5. Crop-fields / Agriculture
6. Fallow / Barren land
7. Water body
8. Habitation / Home garden

Ground truthing

Ground truthing was done in three phases *viz.* before unsupervised classification during reconnaissance, after unsupervised classification and before finalizing supervised map.

Digitization of Sanctuary Boundary

The Sanctuary boundary as obtained from the office of the wildlife warden, TWS was properly registered on the geometrically corrected image and geo-referenced topographic map. Area of interest, described as ISA was designated by southern segment of the Sanctuary.

4.2.1.2 Analytical method

GIS analysis was carried out in the supervised land use / land cover and vegetation map using ERDAS Imagine 8.5 to calculate area under different land use / land cover categories. To obtain information on sampling plots, and generate maps, information associated with each sampling plot wes overlaid on the unsupervised classes, using ArcView GIS software (Version 3.1, Environmental Systems Research Institute Inc. 1993).

4.2.2 Vegetation characteristics

4.2.2.1 Field method

Circular plots in different quadrats of TWS for quantification of vegetation and following parameters had been recorded once in the study period. At least one plot was laid in each of the 64 grids out of 82. This is because the area under 16 grids was inaccessible. Ten to fourteen plots each in nine forest types of land use / land cover category was sampled for vegetation quantification.

- Trees: Circular plots of 10 m radius were laid for total enumeration of tree species, their number, GBH, canopy cover in percentage (using densiometer) and tree height.
- Shrubs: Circular plots of 5 m radius nested within 10 m radius were laid to record number of individual shrub species including the seedlings and their individual height.
- Herbs and grasses: Circular plots of one (1) meter radius nested within 5 meter plots (laid for enumeration of shrubs), were laid to estimate the percentage of herbs, grasses, litter, bare soil etc. using `Point Intercept' method.

4.2.2.2 Analytical method

BioDiversity Professional (A biodiversity parameter computation software developed by The Natural History Museum and the Scottish Association for Marine Science) was used for analyzing vegetation structure and composition, species diversity, richness, abundance etc.

Species richness estimation was carried out using observed and estimated species richness, to show the number of species in the population of flora of TWS, and justify sample size in representing species from the region. Species richness analysis randomly pooled the samples and examined how specific indicators accumulate as the samples are pooled. This generates a graph of the selected indicators against the number of pooled samples [Chao (1984, 1987), an estimated collector's curve and Jacknife (Burnham and Overton 1978, 1979) is an estimation method to predict how many species would have been discovered had the sampling been more intensive]. Species distribution was analyzed by using chi-squared tests to understand whether the organisms are distributed randomly through the samples or aggregated or uniformly distributed. The whole community analysis was also used to assess whether individual species are randomly distributed with respect to each other, or aggregated together or aggregated in different samples. SHE analysis (Buzas and Hayek 1996, Hayek and Buzas 1997) was carried out to examine the relationship between S (species richness), H (diversity as measured by estimated Shannon-wiener index) and E (eveness) in the samples.

In SHE analysis, the relative contributors of richness and evenness to H′ diversity are partitioned using the decomposition formula: $H=\ln(S) + \ln(E)$. Assumptions for this are (1) maximum H′ diversity occurs when all species are equally distributed [$H'_{Max} = \ln(S)$], and (2) E is related to H’ by equation $E= e^{H'}/S$. SHE analysis partitions H′ diversity into richness and evenness components and allows independent evaluation of their contribution to H′.

This is to test whether the data resembles a log-normal, a log-series or MacArthur's broken stick model (Mac Arthur 1957). SHE analysis is being considered one of the most effective method for testing for 'goodness-of-fit' to these stochastic models (Tokeshi 1990). Results showed the expected pattern of S, H and E for all samples of trees, regeneration, herbs/shrubs, climbers and grasses.

4.3 RESULTS

4.3.1 Land use / land cover mapping

Total area estimated for TWS in the GIS domain was 213 Km^2 (Table 4.1). Total forest area of the Sanctuary estimated was 92.9 % of the total area. Non forest cover areas include fallow land, water bodies and crop fields (7.1% *i.e.* 15.3 Km^2). ISA (76.6 Km^2) is no different (Table 4.2) in terms of proportion of forest (70.9 Km^2) and non forest area (7.5%, 5.8 Km^2). However the patchiness and spatial distribution of land use / land cover matrix in the classified map generated after supervised classification differed significantly. Ground flora of the area is represented by the trees, herbs, shrubs, climbers and grass species from 96 families (Table 4.3).

I. Forests

Following are the characteristics of different land use / land cover classes categorized under forest.

1. Moist-mixed deciduous (Mmd)

This forest types was present in the slopes of *nullah* (small streams), and in the core zone of the Sanctuary. Mmd was represented over 26.8% (20.5 Km^2) and 28.8% (61.4 Km^2) of the total areas under ISA and TWS respectively (Table 4.2 and 4.1).

This type of forest is dominated by *Terminalia bellirica*, ,*Aglaia spectabilis, Dillenia pentagyna, Canarium strictum, Syzygium cumini, Ficus sp. Eupatorium odoratum* etc. Though both ISA and TWS comprises of almost equivalent area in land use/ land cover yet they differed in patchiness. Moist mixed deciduous being less fragmented within ISA and patchiness was found to be restricted only in the central part of the northern section of TWS. Some part of the Mmd were dominated by *Callicarpa arborea, C. longifolia, Lagerstroemia speciosa, L. parviflora, Sterculia villosa, Mangifera indica, M. sylvitica, Ficus semicordata, F. hispida* and other *Ficus* species. Other than these, species like- *Holarrhena antidysenterica, Vitex peduncularis, Hymenodictyon orixense, Saraca asoka, Bombax ceiba, Mallotus sp., Castanopsis indica* etc. were also found in abundance.

Table 4.1 Land use / land cover classes in proportion of the total area of Trishna Wildlife Sanctuary. (2002 – 2004)

Land use / land cover types	Area (Km²)	Percentage area
Fallow Land	0.03	(0.01)
Water body	0.95	(0.44)
Vegetation associated to waterbody	1.46	(0.68)
Teak and bamboo mixed	2.18	(1.02)
Habitation / Homegarden	4.26	(1.99)
Clearfelled/ Jhumed/Open forest	6.95	(3.26)
Highly degraded bamboo forest	8.91	(4.19)
Cropfields/ Agriculture	14.03	(6.59)
Bamboo brakes (Kalai)	17.66	(8.29)
Mixed Bamboo forest	19.00	(8.92)
Degraded scrubland	20.30	(9.53)
Highly degraded sal forest	20.60	(9.67)
Mixed Dipterocarpus	35.27	(16.56)
Moist mixed deciduous	61.42	(28.83)
Total	**213.02**	**(100)**

Table 4.2 Land use / land cover classes in proportion to the total area of Intensive Study Area (ISA). (2002 – 2004)

Land use / land cover class	Area (Km²)	% area
Fallow Land	0.02	0.03
Water-body	0.10	0.13
Vegetation associated to water body	0.11	0.14
Teak and bamboo mixed	0.23	0.30
Clearfelled/ Jhumed/Open forest	0.48	0.62
Habitation / Home garden	2.76	3.59
Highly degraded bamboo forest	3.67	4.80
Mixed Dipterocarpus	3.79	4.95
Degraded scrubland	4.82	6.29
Crop-fields / Agriculture	5.63	7.35
Mixed Bamboo forest	7.05	9.20
Bamboo brakes (Kalai)	11.55	15.08
Highly degraded sal forest	15.90	20.75
Moist mixed deciduous	20.50	26.77
Total	**76.59**	**100**

2. Mixed Dipterocarpus (Md)

Mixed dipterocarpus forest classified in this section was mostly dominated by the *Shorea robusta* and *Dipterocarpus turbinatus* near Joychandpur at the southern boundary. This land use/ land cover type contributes to 16.56% (35.27 Km^2) of total area, whereas in ISA, Md covers only 4.95% (4.95 Km^2) of the area (Table 4.1 and 4.2). Other than earlier mentioned two Dipterocarpus species, characteristic tree species of this type are, *Ficus sp., Sterculia villosa, Emblica officinalis, Macaranga denticulate, Terminalia bellirica, Schima wallichi* etc. Lower canopy of the area includes species like- *Eupatorium odoratum, Zizyphus sp., Urena lobata, Flemingia sp., Randia racemosa, R. facicularis, Curcuma sp., Ixora nigricans, Ervatamia coronaria, Emblica officinalis, Vernonia cinera, Vitex negundo, Imperata cylindrica* and *Oxytenanthera* clump. Few sites of this forest type also recorded species like- *Castanopsis indica, Artocarpus chama, Litsea panamonja, Callicarpa arborea* in the upper canopy and *Ervatamia coronaria, Cissus sp., Dalbergia sp., Urticaceous sp., Smilax zeylanica, Osbeckia rostrata, Hemidesmus sp., Lycopodium cernuum, Diplazium sp., Curculigo sp., Hypoxis sp., Jasminum pubescens, Mucuna sp.* in the lower canopy. *Bambusa tulda* was also recorded in places. Other dominant bamboo, grasses, sedges recorded were *Alloteropsis cimicina, Erianthus ravennae, Panicum sp., Cyeprus sp., Saccharum procerum, Malocanna bambusioides, Cyrtococcum oxyphyllum* etc. In the northern part between Barapathari and Tulamura, there are pure sal forest found and the associated species recorded were *Dipterocarpus turbinatus, Schima wallichii, Garuga pinnata, Macaranga denticulata, Flacourtia indica, Holarrhena antidysentrica, Dellenia scabrella, Syzigium cumini* etc.

3. Highly degraded sal forest (HdSf)

This forest type makes up for 9.67% (20.602 Km^2) of TWS and 20.75% (15.897 Km^2) of ISA area indicating a very high anthropogenic pressure in ISA (Table 4.2 and 4.1). This type of forest cover is spread in the buffer or in the edge of Sanctuary boundary. There is hardly any pure natural sal forest in the southern part of the Sanctuary. This pressure can be attributed to high demand for sal poles and sleepers for construction purpose (Annon. 1996). This forest type is characterized by regeneration of *Shorea robusta, Syzygium caarasoides, Litsea* *sp. Stereospermum personatum, Garuga pinnata* etc. Herb, shrub, climbers comprises of *Streblus asper, Smilax zeylanica, Ixora accuminata, Zizyphus sp. Eupotarium odoratum, Ipomea sp.* Bamboo and grasses in the northern part of TWS are *Oplismenus compositus, Saccharum ravennae* etc. and in southern part clumps of *Oxytenanthera nigrociliata.*

4. Degraded scrubland (Ds)

A total of 20.30 Km² (9.53%) of TWS area falls under this category found mostly in the South-west part of the ISA (Table 4.1 and 4.2). This is relatively less within ISA and contributes 6.29% (4.82 Km²) of the area.

This type of forest is rarely represented by any big trees. Species association in this forest type varies from place to place and no uniformity was found in the composition. Felled stumps and regeneration of miscellaneous tree species were also recorded in some parts of TWS. This forst type is dominated by *Clerodendrum viscosum, Leea sp., Bridelia sp., Vitex altissima, Ixora sp., Grewia viminea, Macaranga denticulata, Crotolaria sp., Emblica officinalis, Syzigium cumini, Hypoxis aurea* etc. Ground vegetation of the area is represented by *Hemidesmus heterophylla, Desmos sp., Aristolochia tagala, Acacia pinnata, Dalbergia volubilis, Cissus sp., Cryptolepis sinensis,* Cucurbitaceae species, etc.

5. Mixed Bamboo forest (Mbf)

Distribution of this forest type is almost uniform in the entire TWS and contributes 8.92% (19.00 Km²) of TWS and 9.20% (7.05 Km²) of ISA (Table 4.1 and 4.2). This type of forest is a very important habitat for most of the wildlife species supporting their food and cover need. Characteristic plants of the area were Ficus sp., *Stereospermum personatum, Artocarpus lakoocha, A. chana, Terminalia chebula, Schima wallichii, Ficus glomerata, Micromelum integerrimum, Holarrhena antidysentrica, Actinodaphne obvata, Bombax ceiba, Careya arborea, Albizia procera, Lagerstroemia parviflora, Lannea coromandelica, Grewia viminea, Pterospermum acerifolium, Bridelia retusa, Randia sp., Trevelia palmate.* Lower and middle canopy of the forest is represented by- *Dalbergia volubilis, Eupotarium odoratum, Thunbergia grandiflora, Mucuna sp., Alpinia galangal, Alpinia allughus* etc.

6. Bamboo brakes (Bb)

This type of forest cover is dominated by single bamboo species (*Oxytenanthera nigrociliata*). This showed a very distinguishable reflectance value in the FCC and covers almost entire southernmost part of the Sanctuary. There is a significant difference in its contribution to total land use/ land cover of TWS and ISA. Only 8.29% (17.66 Km^2) of the total area of TWS falls in this category whereas 15.08% (11.55 Km^2) of ISA is covered by this type of forest (Table 4.1 and 4.2). Dependency of local people on this bamboo is a potential threat towards its conservation. As this bamboo species is endemic to this region, this need attention from the park management. Typical ground flora of the area is composed of *Eupotarium odoratum, Mallotus philippinensis, Alstonia scholaris, Grewia viminea, Mimosa pudica, Vitex negundo, Ageratum conyzoides, Macaranga denticulata* etc. Asclepiadaceous climbers like *Hemidesmus sp., Cryptolepis sp.* and Convolvulaceous climbers like *Ipomea sp., Argyrea sp.* and *Erycibe sp.* are very common in this type of land-cover/use. Grasses of the area are dominated by *Imperata arundinacea, Alloteropsis cimicina* etc.

7. Highly degraded bamboo forest (HdBf)

In both TWS and ISA this forest type contributes almost equally for TWS (4.19%, 8.914 Km^2) and ISA (4.80%, 3.673 Km^2) (Table 4.1 and 4.2). This originated mainly due to harvesting of bamboo at the periphery of Sanctuary boundary.

This forest type is dominated by *Oxytenanthera nigrociliiata*. Associated ground flora are *Mallotus philippiensis, Eupotarium odoratum, Alstonia scholaris, Mimosa pudica, Grewia viminea, Alloteropsis cimicina, Ageratum conyzoides, Osbeckia chinensis, Macaranga denticulata, Vitex negundo, Croton oblongifolius, Syzygium cumini, Imperata arundinacea*, etc.

8. Clearfelled/ Jhumed/Open forest (CJO)

There is a significant difference in this type of land use/land cover within TWS and ISA. Total 3.26% (6.951 Km^2) in the TWS is covered by this type of land and only 0.62% (0.475 Km^2) of ISA (Table 4.1 and 4.2). Cultivation in northern part of the TWS is mostly *jhoom* agriculture by tribal population.The ISA is relatively free from this kind of practice and in most of the cases clear felled areas can be attributed to felling of tree species, forest fire.

Plant species recorded in this cover type were *Garuga pinnata, Ficus semicordata, Callicarpa arborea, Macaranga dnticulata, Saccharum narenga, Eupatorium odoratum, Mallotus sp., Albizia procera, Shorea robusta, Duabanga grandiflora, Blechnum orientale, Butea parviflora, Thysanolaena maxima, Millettia pachycarpa, Clerodendrum viscosum, Malacanna bambusoides Entada phaseoloides, Cucurbitaceous climber, Musa elongata, Arundo donax, Themeda caudata, Apluda mutica, Saccharum fallax*, etc.

9. Teak and bamboo mixed (Tbm)

This forest type is found only in the northern part of TWS. The estimated cover of Tbm is 1.02%(2.18 Km²) (Table 4.1). This forest type is negligible in the ISA (0.30%, 0.23 Km²)(Table 4.2). The area in ISA under this category is mostly *Tectona grandis* plantation and are of recent origin. Dominant tree species of the area in between Kasari and Teendepha recorded tree species like- *Macaranga denticulata, Terminalia bellirica, Micromelum integerrinum, Randia sp., Grewia viminia, Ficus cunia* etc. Herb/shrub/climbers of the area comprised of *Musa acuminata, Eupotarium odoratum, Leea crispa, Ixora acuminata, Thunbergia grandiflora, Mikania cordata, Hemidesmus sp., Combretum sp., Osbeckia rostrata, Dioscorea sp. etc. Grass and bamboo of the area are Melocanna bambusoides, Saccharum ravennae, Thysanolaena maxima, Imperata cylindrica, Themeda caudate* etc.

10. Water body associated vegetation (Wav)

This is a much localized type of land use category and showed very distinguishable reflectance value in the satellite imagery. ISA has more proportion of this area under the category (0.14%, 0.17 Km²) than in TWS (0.68%, 1.46 Km²) (Table 4.2 and 4.1). Though this area looks very small but from wildlife habitat point of view this is very important in providing crucial microhabitats for avifauna, reptiles, primates and herbivore.

Apart from a few bamboo species the area around lakes within ISA was found to be dominated by trees like- *Elaeocarpus rogosus, Callicarpa arborea, Lagerstromia speciosa, L. parviflora, Eurya japonica, Turponia ponifera,* *Sterculia villosa, Psychotria sp., Styrax serrulatum, Mangifera sylvatica,* and several *Ficus sp.* Plants in the edges of water bodies were found to be *Floscopa scandens, Polygonum hydropiper, Hydrolea zeylanica, Smithia sensitiva, Rotala indica, Alpinia sp., Imperata cylindrica, Erianthus arundinaceus, Saccharum spontaneum, Marisus compactus* etc.

II. Non-Forest Areas

Non-forest areas include agricultural fields (cultivated), barren and fallow lands, water bodies and home gardens around habitations. As per TWS notification category, all these types do fall in the forest category but from land use / land cover and habitat characteristics, these were categorized under non forest areas based on woody vegetation cover and its origin.

11. Crop-fields / Agriculture (CA)

Contribution of crop fields or agricultural lands under cultivation in the land use/ land cover of TWS was estimated to be 6.59% (14.03 Km^2)(Table 4.1). This is relatively high in the ISA as compared to TWS and covers 7.35% (5.63 Km^2) of the area (Table 4.2). Most of the area is though brought inside TWS by accruing them from the villagers but they are still under cultivation practice.

Plant species recorded in this forest type are *Imperata cylindrica, Dentella repens, Centella asiatica, Fimbristylis sp., Dysophylla sp., Limnophilla heterophylla, Digitaria adscendens, Brachiaria distachya, Marsilea minima, Oxalis corniculata, Eragrostis tenella, Paspalum scrobiculatum, Cynodon dactylon, Evolvulus alsinoides, Monochoria sp., Borreria articulata, Torenia edendula* etc.

12. Fallow / Barren land (FB)

Overall contribution of barren land is negligible in both TWS and ISA and contributes 0.01% (0.03 Km^2) and 0.03% (0.02 Km^2) respectively (Table 4.1 and 4.2). This land use types shown in the map are recently burnt area or abandoned agricultural land which are not being cultivated and regeneration has not yet established. Some of the areas under this cover class are also under heavy pressure for soil mining purpose and no vegetation grows in those areas. Except a few grass species, no other plant was recorded under this land cover.

13. Water body (Wb)

Water bodies include perennial streams and lakes. As the satellite imageries used represents winter condition of the Sanctuary this does not include seasonal streams and other water sources. Though the area under this category is less but they are well distributed in the area and sufficient for survival of wildlife. Small and seasonal stream network in the area could not be identified in the satellite imagery. TWS and ISA is covered with 0.95 Km^2 (0.44%) and 0.10 Km^2 (0.13%) of water bodies respectively (Table 4.1 and 4.2). Floating aquatic ferns recorded are *Salvinia natans, S. cucullata, Azolla pinnata* and *Marsilea minuta.*

14. Habitation / Home garden (HhG)

In the absence of a detailed map demarcating private land, few private lands are also included in the map and thus the area calculated for this land use/ land cover category may be misleading if considered as a part of the Sanctuary. However, 1.99% (4.25 Km^2) of TWS and 3.59% (2.76 Km^2) of ISA are estimated to be covered by habitation and homegardens (Table 4.1 and 4.2). Homegardens are dominated by fruit plants and trees. Plants recorded in this land use type are *Areca catechu, Cocos nucifera, Artocarpus chaplasa, Citrus melo, Syzigium cumini, Artocarpus integrifolia, Psidium guajava, Mangifera indica, Musa paradisiaca, Anacardium occidentale, Phoenix syluestris, Carica papaya, Gmelina arborea, Zizyphus mauritiana, Cinnamomum tamala, Bambusa clump, Aegle marmelos, Acacia auriculiformis, Delonix regia, Ananas comosus, Vitex negundo, Litchi chinesis, Tectona grandis, Ficus hispida* etc.

4.3.2 Pattern of Vegetation composition

Flora of the area is represented by the trees, herbs, shrubs, climbers and grass species from 96 families of plants. Representative families of trees, herb and shrubs recorded from TWS and number of species in each family is given in table 4.3.

As compared with earlier checklist given by Choudhury (1996), 38 new records of trees have been recorded during the present study. Detailed checklist of all the species recorded is given in the Appendix-8. The flora of Tripura records about 330 species of trees, out of which 308 were recorded from the study area.

Table 4.3 Representative families (no of species) of flora in Trishna Wildlife Sanctuary. (2002-2004)

Family (species recorded)	Family (species recorded)	Family (species recorded)	Family (species recorded)
Acanthaceae (14)	Agnifohaceae (1)	Alangiaceae (1)	Amaranthaceae (7)
Anacaediaceae (1)	Anacardiaceae (4)	Anonaceae (11)	Apocynaceae (10)
Araliaceae (4)	Asclepiadaceae (1)	Asteraceae (25)	Averrhoaceae (1)
Balsaminaceae (6)	Bignoniaceae (5)	Bombacaceae (2)	Boragianaceae (2)
Burseraceae (3)	Calastraceae (1)	Cannabaceae (1)	Capparidaceae (2)
Caryophyllaceae (2)	Casealpiniaceae (3)	Casuarinaceae (1)	Combretaceae (4)
Convolvulaceae (5)	Datiscaceae (1)	Dilleniaceae (3)	Dipterocarpaceae (2)
Ebenaceae (1)	Ehretiaceae (4)	Elaeocarpaceae (6)	Elagnaceae 1)
Erythropalaceae (1)	Euphorbiaceae (41)	Fabaceae (55)	Fagaceae (4)
Flacourtiaceae (6)	Gentiananceae (1)	Geraniaceae (2)	Guttiferae (4)
Holragaceae (1)	Hypocastanaceae (1)	Hypoxidaceae (7)	Juglandaceae (1)
Lamiaceae (12)	Lauraceae (19)	Lecythidaceae (2)	Lythraceae (5)
Magnoliaceae (5)	Malvaceae (11)	Melastomaceae (7)	Meliaceae (14)
Menyanthaceae (2)	Mimosaceae (10)	Molluginaceae (4)	Moraceae (23)
Moringaceae (1)	Musaceae (1)	Myristicaceae (3)	Myrsinaceae (5)
Myrtaceae (11)	Nyctaginaceae (2)	Nymphaeaceae (5)	Onagraceae (5)
Oxalidaceae (2)	Papavaraceae (1)	Plumbaginanceae (3)	Polygonaceae (3)
Portulaccaceae (2)	Rhamnaceae (12)	Rhizophoraceae (1)	Rosaceae (7)
Rubiaceae (39)	Rutaceae (10)	Rutceae (10)	Sabiaceae (1)
Sapindaceae (3)	Sapotaceae (4)	Saurauriaceae (1)	Scrophulariaceae (10)
Simarubaceae (2)	Solanaceae (7)	Staphyleaceae (1)	Sterculiaceae (8)
Symplocaceae (1)	Teliaceae (4)	Theaceae (4)	Thymeliaceae (1)
Tiliaceae (13)	Ulmaceae (3)	Urticaceae (20)	Verbenaceae (12)
Violaceae (1)			

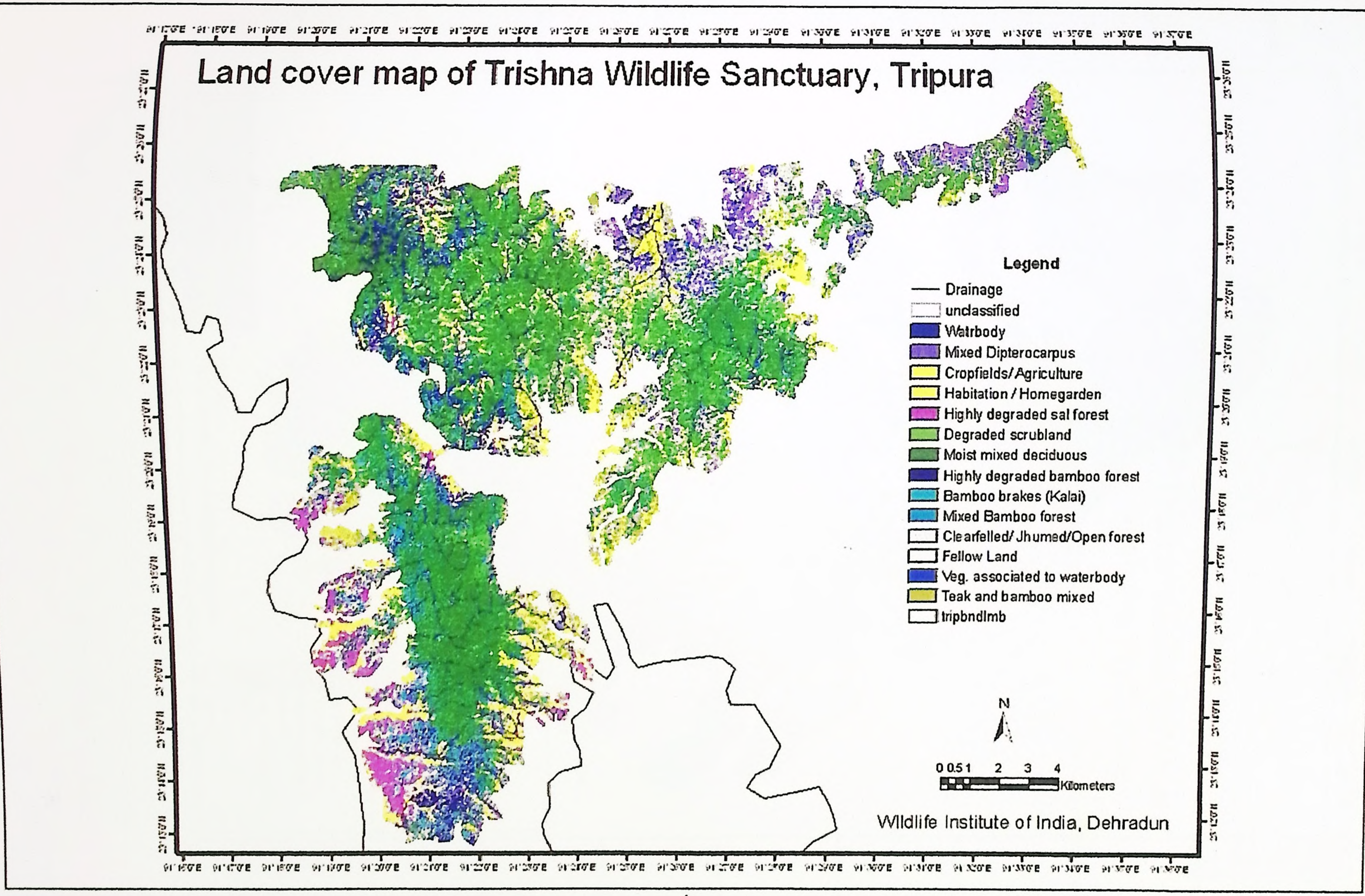


Figure 4.1 Land use land cover map of Trishna Wildlife Sanctuary (TWLS) , Tripura

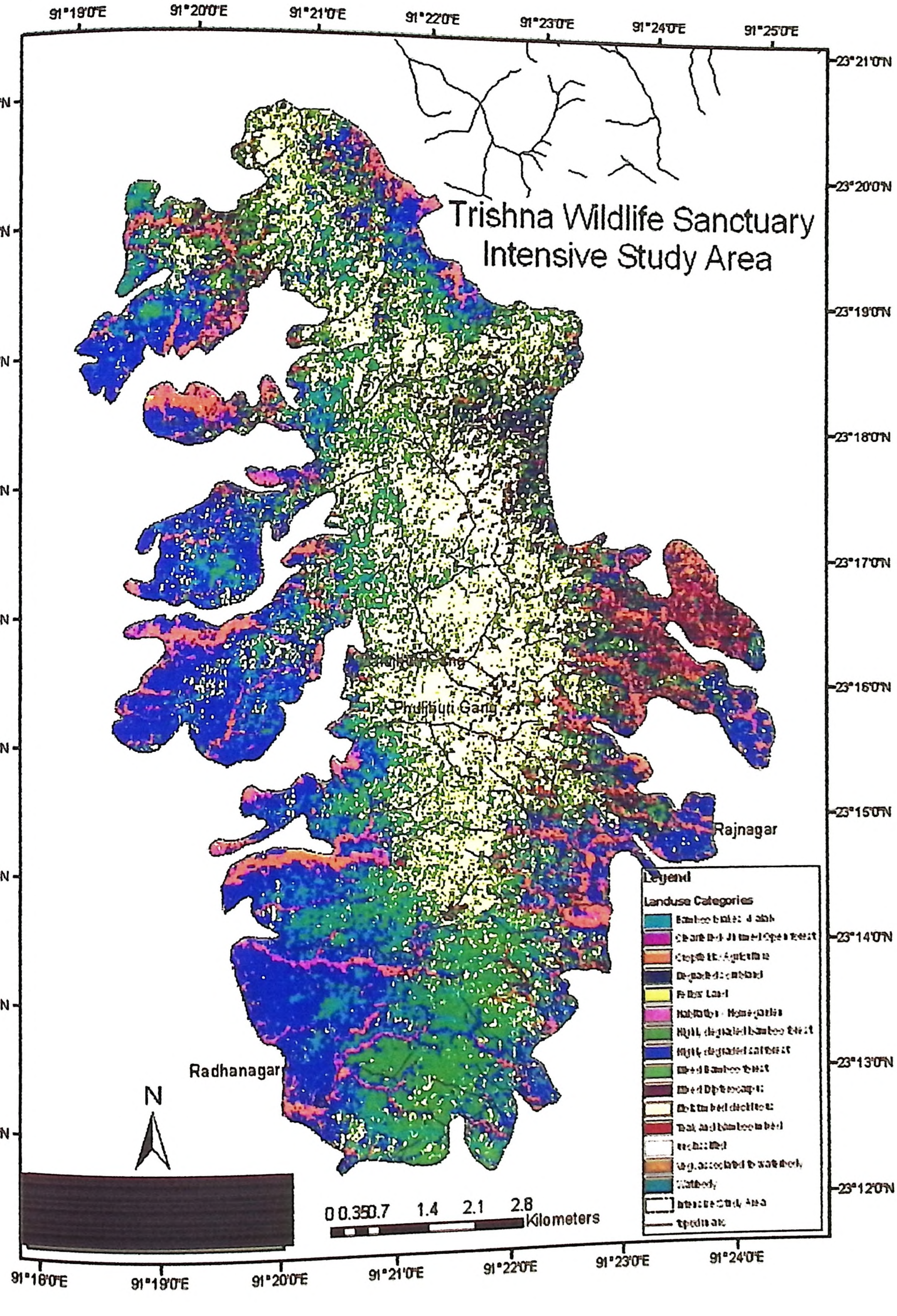


Figure 4.2 Land use land cover map of Intensive Study Area (ISA), Trishna Wildlife Sanctuary, Tripura.

4.3.2.1 Distribution

Distribution of different plant species was evaluated at both community and species level.

For trees, regeneration and herbs/shrubs at community level, their total and pooled samples showed aggregated dispersion (table 4.4). This showed that both in whole sample and with respect to each other they are aggregated. Heterogeneity in their dispersion was concluded to be discordant following Chi-square analysis (table 4.4). Although grass also showed aggregated dispersion for both total and pooled samples, their heterogeneity was independent with probability one (table 4.4). Climbers were unique as compared with other plant forms as the total sample showed random dispersion, with respect to each other they are aggregated and grass species heterogeneity found to be independent in dispersion (table 4.4).

Table 4.4 Distribution of different life forms of vegetation at community level in Trishna Wildlife Sanctuary.

	Chi - Square Value	D.F.	Probability	Dispersion
Trees				
Total	20425	12084	0	Aggregated
Pooled	591	113	0	Aggregated
Heterogeneity	19834	11971	0	Discordant
Regeneration				
Total	43927	8850	0	Aggregated
Pooled	1834	74	0	Aggregated
Heterogeneity	42093	8776	0	Discordant
Herbs/shrubs				
Total	246371	14773	0	Aggregated
Pooled	9426	78	0	Aggregated
Heterogeneity	236944	14695	0	Discordant
Grasses				
Total	20505	4240	0	Aggregated
Pooled	17886	79	0	Aggregated
Heterogeneity	2618	4161	1	Independant
Climbers				
Total	10279	10260	0.44	Random
Pooled	719	94	0	Aggregated
Heterogeneity	9559	10166	0.99	Independant

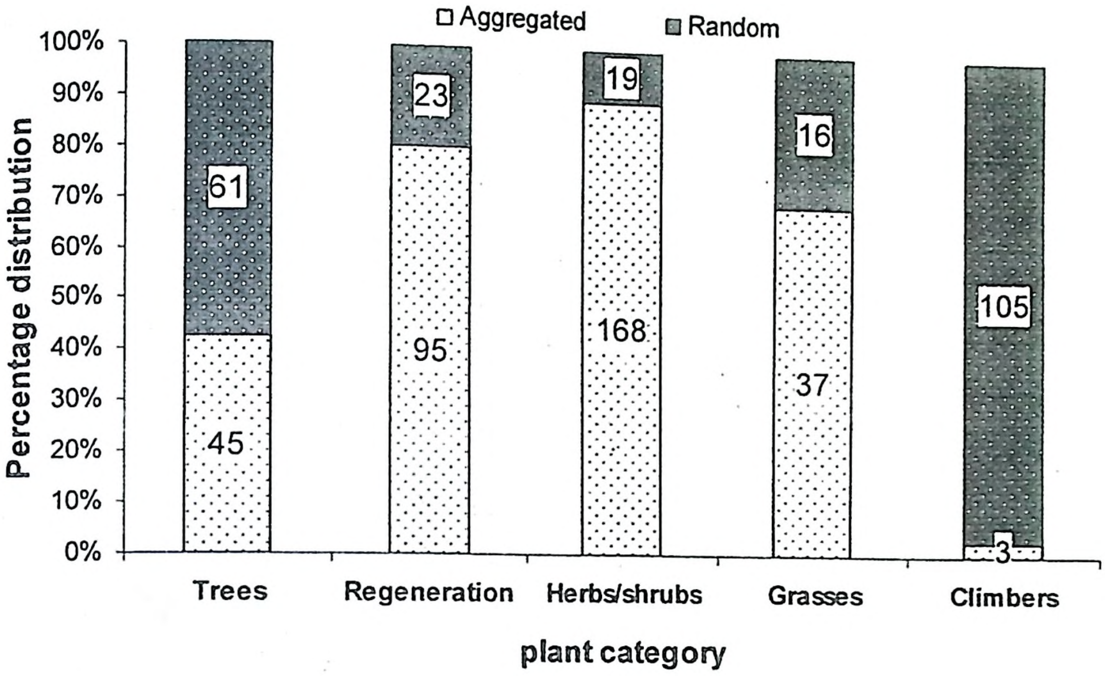


Figure 4.3 Percentage distribution of plant species aggregation in sample plots of Trishna Wildlife Sanctuary.

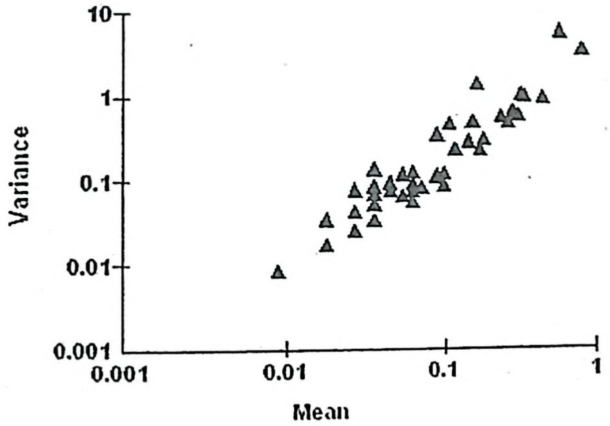


Figure 4.4 Tree species distribution in Trishna Wildlife Sanctuary.

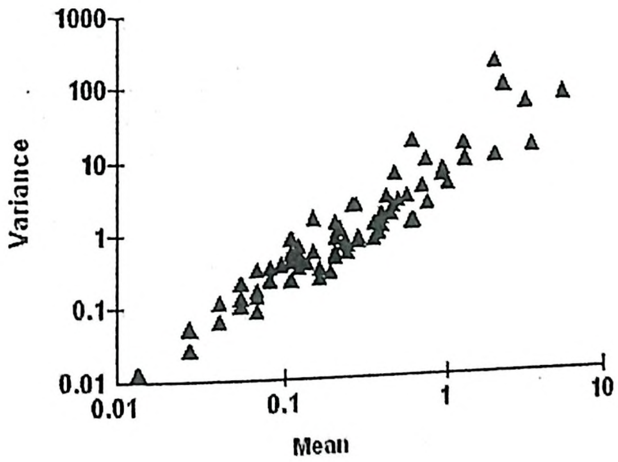


Figure 4.5 Regeneration characteristics in Trishna Wildlife Sanctuary.

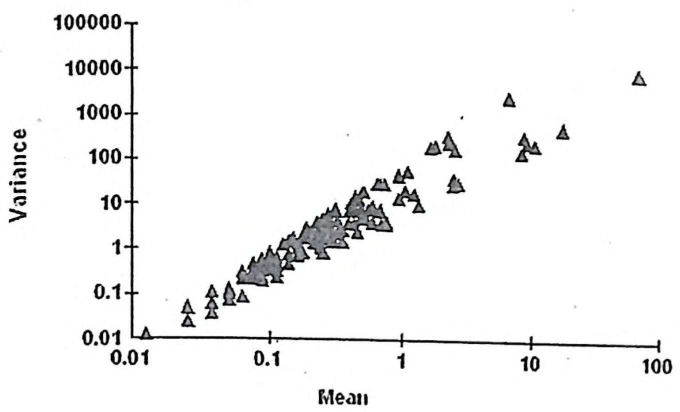


Figure 4.6 Herb-shrub characteristics distribution in Trishna Wildlife Sanctuary.

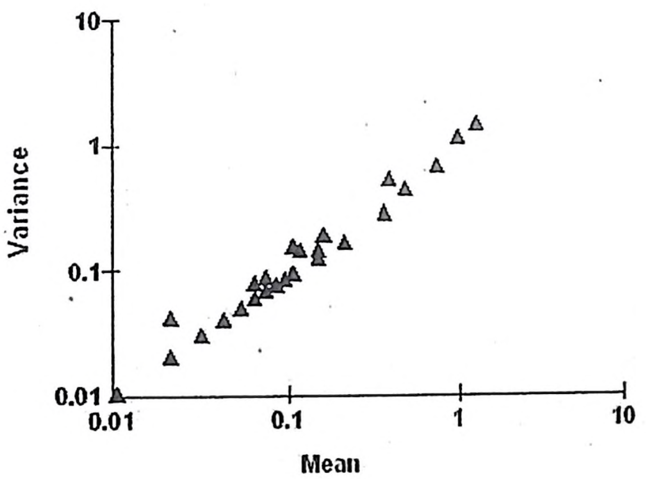


Figure 4.7 Grass species distribution in Trishna Wildlife Sanctuary.

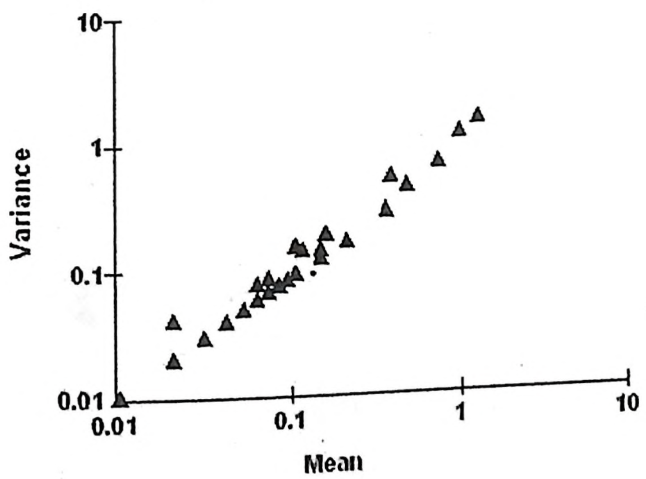


Figure 4.8 Climber species distribution in Trishna Wildlife Sanctuary.

Within the sample plots at species level, 45 trees (42.5%), 95 species (tree) of regeneration (80.5%), 168 herbs/shrubs (89.3%), 37 grasses (69.8%) and 3 climbers (2.78%) were found to be aggregated in their distribution (Fig. 4.3).. Distribution pattern of trees (Fig. 4.4), regeneration (Fig. 4.5) and herbs/shrubs (Fig. 4.6), did not show significant variation, however grasses (Fig. 4.7) and climbers (Fig. 4.8) showed independent heterogeneity.

4.3.2.2 Richness

Observed species richness for trees in 114 plots was 106 and accounted for 765 individuals. Jacknife 1, 2 and Chao 2 estimated 159, 199 and 223 species in the area (Table 4.5, Fig. 4.9). Chao 1 estimate for tree species richness was very high and not reliable, as flora of Tripura described only 350 species for the entire state. As Chao 1 estimate is very sensitive to random and patchy distribution, the estimate should not be used for predicting tree species richness in disturbed areas (Magurran 2002). Regeneration was accounted only for tree species that are not yet established and recorded 118 species of trees (Table 4.5). Large number (n=3016) of individuals show that the area has a very high regeneration potential, and almost all the tree species are regenerating. Except Chao 1 all other estimates are quite close to observed (Table 4.5). Though observed regenerating species recorded were more than established tree species, the estimated regenerating species were less than the corresponding estimate of established trees (Fig. 4.10). In case of herbs and shrubs, total observed species richness was 187 and the estimate using jackknife was close to observed richness. As expected from mixed deciduous and semievergreen areas, herb and shrub density was very high and counted 14817 individuals in 79 plots and was estimated to have 261, 250 and 263 species respectively from jackknife 1, chao 1 and chao 2. Jacknife 2 (Table 4.5, Fig. 4.11) did not perform well to predict the actual number and thus not to be referred. Jacknife 1 Estimation for grass species richness exactly matched with observed species richness (Fig. 4.12). Total 53 species were recorded from the area. Chao 1 again failed to give reliable estimate due to its limitation and sensitivity to singletons. Overestimates of Chao 1 in case of trees, regeneration and grasses and climbers clearly showed that the singletons (the number of species which occur only once in a single sample) were much more then doubletons (the number of species which occur only twice in a single sample). Ratio of singletons in case of climbers was likely to be maximum and showed scattered distribution. Observed number of climbers was 108 from 95 sample plots. Density of climbers is quite low as compared with the other similar areas of the region. Estimated number of climber from jackknife 1, jackknife 2 and chao 2 was 150, 174 and 157 respectively (Fig. 4.13).

Table 4.5 Estimated and observed species richness for different life form of vegetation in Trishna Wildlife Sanctuary.

Category	Tree	Regeneration	Herb/ shrub	Grass	Climber
Sample size	114	75	79	80	95
Observed species richness	106	118	187	53	108
Observed individual richness	765	3016	14817	924	738
Estimator: Jacknife 1,	159	162	261	53	150
Estimator: Jacknife 2	199	190	299*	37	174
Estimator: Chao 1	578*	222*	250	611*	4687*
Estimator: Chao 2	223	178	263	53	157

Note: * Over estimated value.

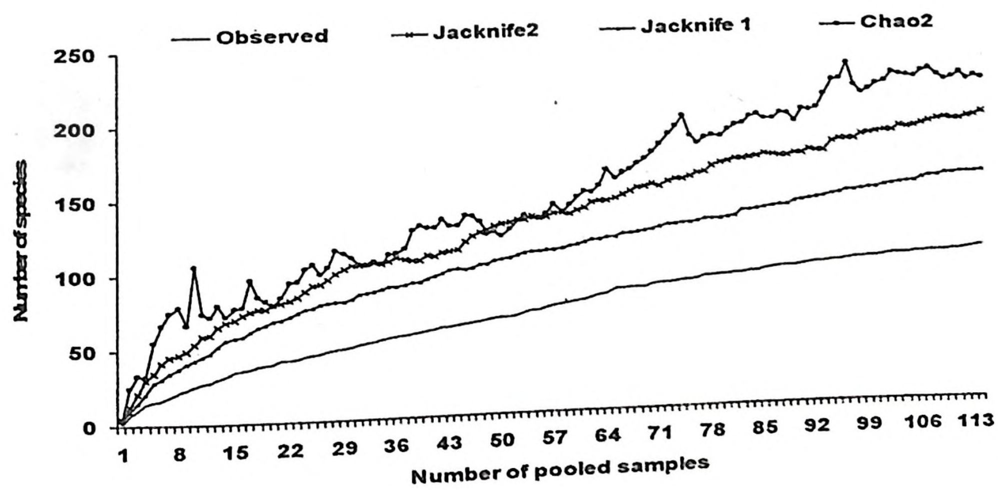


Figure 4.9 Observed and estimated richness of trees in Trishna Wildlife Sanctuary.

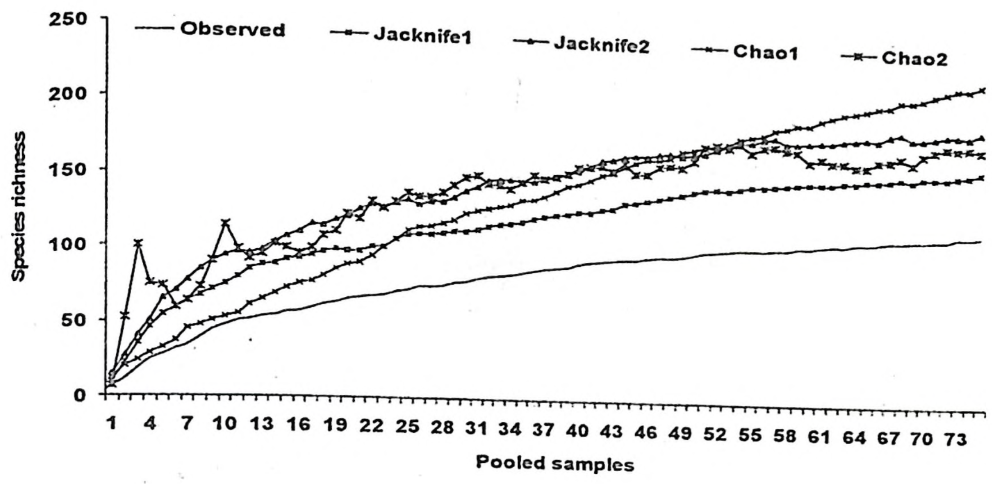


Figure 4.10 Observed and estimated richness of regeneration in Trishna Wildlife Sanctuary.

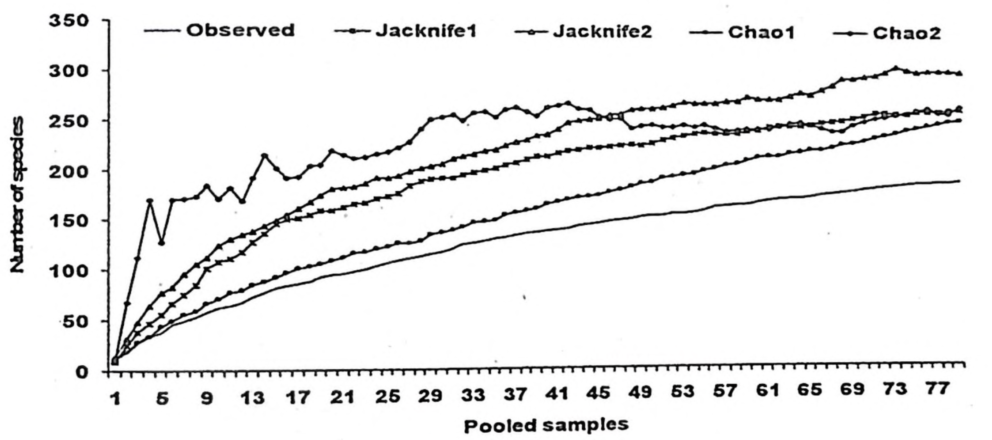


Figure 4.11 Observed and estimated richness of herbs and shrubs in Trishna Wildlife Sanctuary.

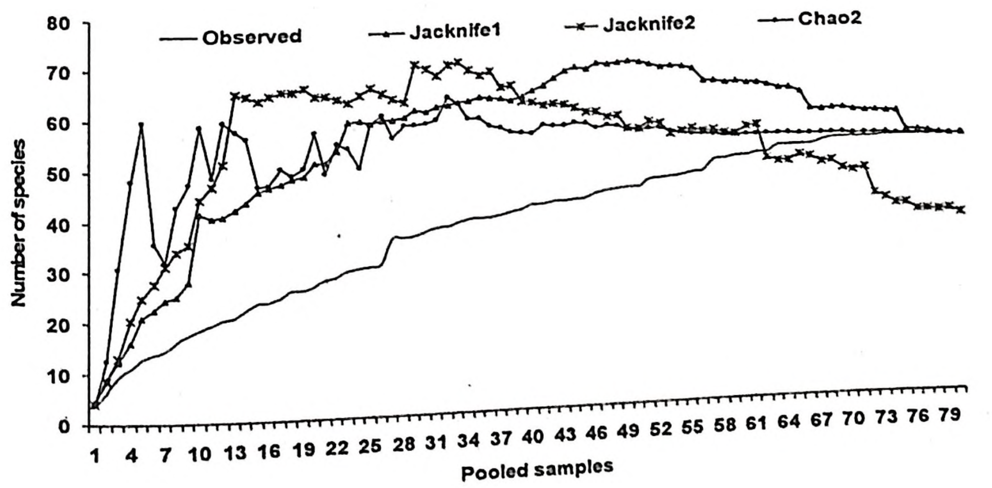


Figure 4.12 Observed and estimated richness of grass in Trishna Wildlife Sanctuary.

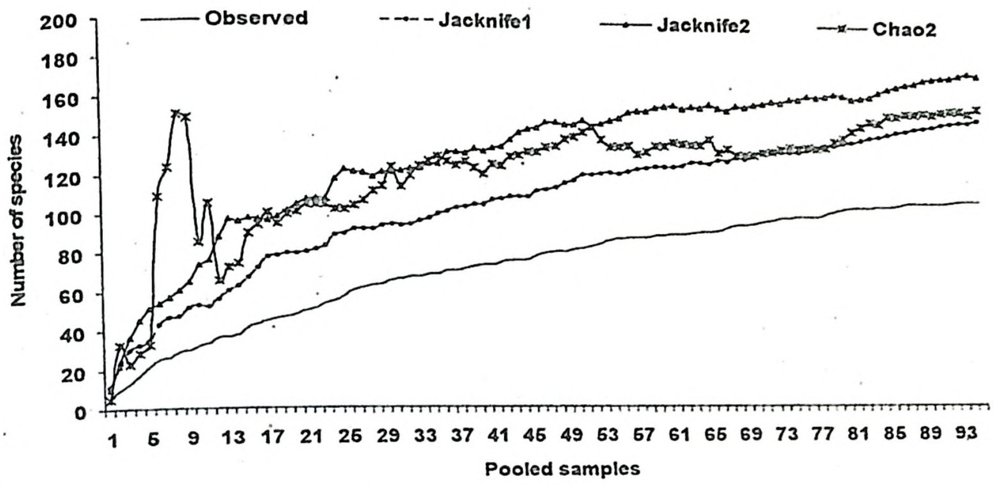


Figure 4.13 Observed and estimated richness of climbers in Trishna Wildlife Sanctuary.

4.3.2.3 Diversity and Evenness

SHE analysis allows independent yet simultaneous evaluation of relative contribution of richness and evenness to community diversity. In SHE analysis, the relative contribution of richness and evenness to H′ diversity was partitioned using the decomposition formula: H′=ln(S) +ln(E). SHE analysis here was also used to infer species abundance distribution best representing each sampled community, based on Hayek and Buzas (1997). Species abundance distributions are statistical distributions that models the relative abundance of species in a community. These distributions are often used to describe patterns of community organization or resource partitioning. Final estimates of diversity and evenness for each plant form are given in the table 4.6.

Tree

The SHE analysis graph depicted that the decrease in evenness was accompanied by increase in species richness. The decrease in the evenness was coherent with the parallel increase in species richness, resulting in little to no change in H′ diversity with increasing sample size. This decreasing evenness suggests that added species tend to be relatively uncommon or rare, while cumulative Ln(E)/Ln(S) remained relatively constant in each sample, indicating that each sample community will be best fit by log normal species abundance distribution (Fig. 4.14).

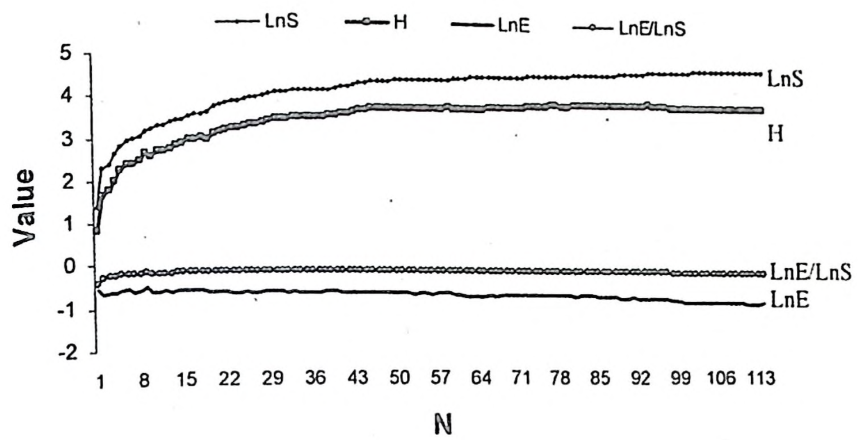


Figure 4.14 Estimated diversity and evenness of trees in Trishna Wildlife Sanctuary.

Regeneration

In comparison to tree species SHE analysis curve, regeneration SHE curve clearly marked the increase in richness outweighed the decrease in evenness for each added sample, resulting in higher H′ Diversity with increasing sample size. The more or less constant evenness with comparison to increased H′ Value predicts more heterogeneity in distribution expected with added species incorporation. Moreover, Ln(E)/Ln(S) significantly changes with increasing sampling plots clearly suggesting that regeneration distribution is sensitive to prediction (Fig. 4.15).

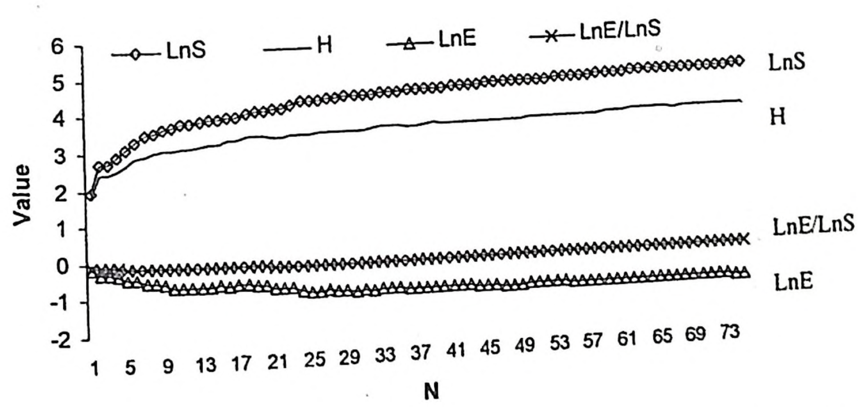


Figure 4.15 Estimated diversity and evenness of regeneration in Trishna Wildlife Sanctuary.

Herbs/shrubs

Ln(E)/Ln(S) ratio is relatively showing obvious change with increased sample plots accounted in comparison to tree community observed. This empirical observation clearly depicts the assemblage tending to depart from log normal distribution, which is an indicative of disturbance at community level as the number of sample size increases (Fig. 4.16).

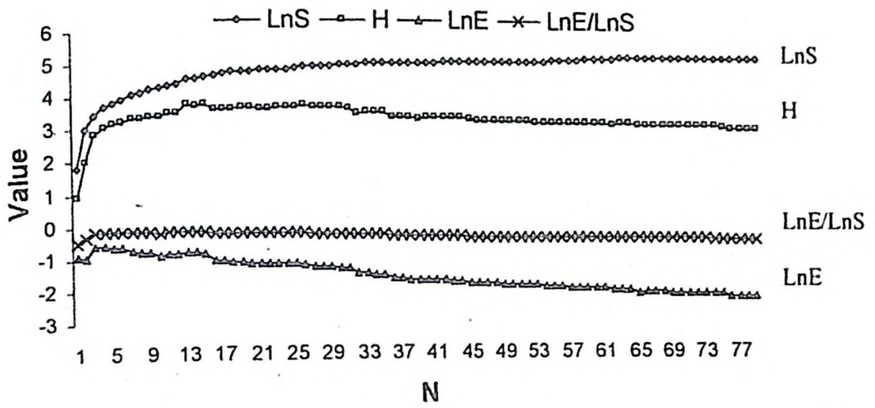


Figure 4.16 Estimated diversity and evenness of herb/shrub in Trishna Wildlife Sanctuary.

<u>**Grasses**</u>

For grass, initially changes of Lns with respect to LnE showed increase. However, with increase in species addition, rate of change in Lns and LnE showed decreasing trend. This suggests that the probability of getting common species was high. Ln(E)/Ln(S) remained more or less constant throughout with minimum deviation from Y axis fitting to lognormal distribution (Fig. 4.17).

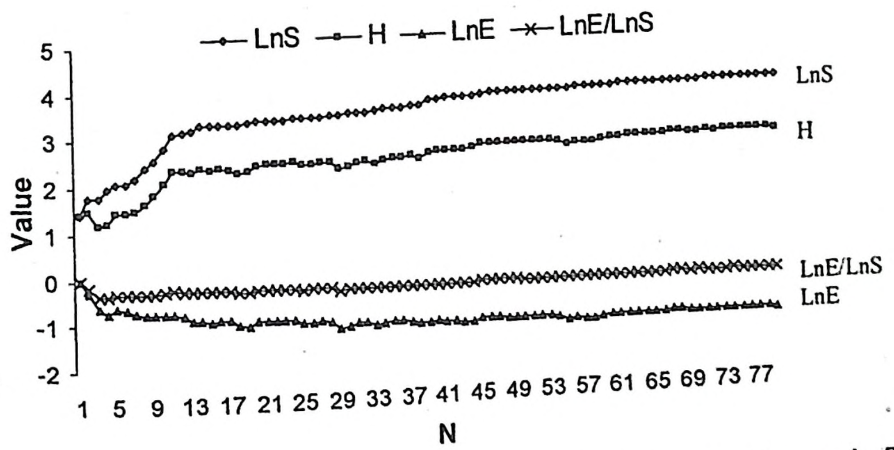


Figure 4.17 Estimated diversity and evenness of grass in Trishna Wildlife Sanctuary

<u>**Climbers**</u>

Climber plot data showed both cumulative Ln(N)/n(S) and H′ to be relatively constant with increasing number of samples. While constant ln(E)/ln(S) suggests the data to be best fit by lognormal distribution, constant H′ indicate a log series distribution (Fig. 4.18). This corroborates that climber community may exhibit characteristics intermediate between lognormal and log series distributions, as might be expected of a community with a small number of abundance species and a relatively a large proportion of rare species (Magurran, 1988).

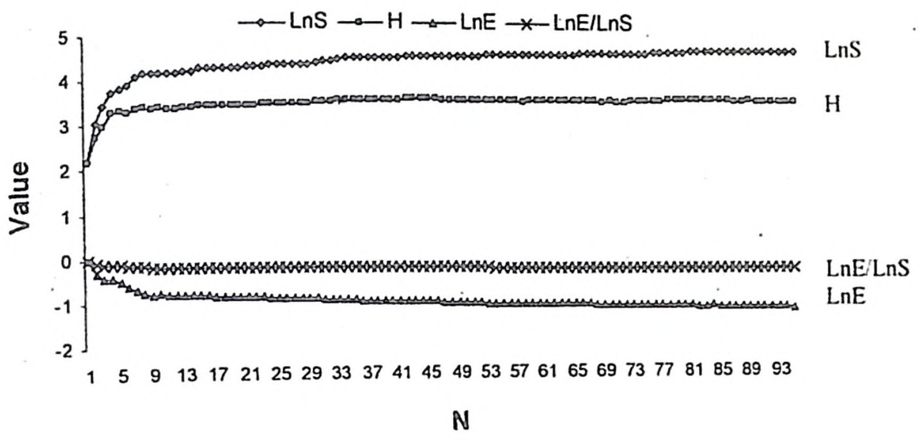


Figure 4.18 Estimated diversity and evenness of climbers in Trishna Wildlife Sanctuary.

4.4 DISCUSSION

4.4.1 Landscape Characterization using RS and GIS

Over the years landscape characteristics have changed in several primary forests and fragmented land-cover types have been created. Fourteen land use / land cover categories identified and mapped in this study showed significant variation in their floristic composition. As the information generated in this study is the first ever attempt to classify the study area, it is not possible to compare it with any earlier studies. However, the results can be compared with other similar areas. As for the analysis of spectral values, the spectral and spatial resolution of IRS LISS III images allowed a detailed discrimination of land use / land cover classes, even considering the large thematic complexity of the area under study. Overall, the hierarchical classification technique was found to be a useful technique even in studies by Singh *et al.* (2002) for classifying vegetation of Arunachal pradesh. The benefits allowed focusing attention on spectrally similar land use / land cover types (*i.*e. water, wetland and vegetation).

4.4.2 Land use / land cover and their vegetation composition

Estimated area (213 Km^2) of TWS in the GIS domain is 7.05% overestimate then the total area notified. This is because the error inbuilt in cartographic work in the boundary map. Moreover this boundary map does not exclude many human settlements in the northern part of the Sanctuary near Manaipathar and Killa areas. As the classification was done primarily to understand wildlife habitat, classification key used here was developed based on woody vegetation cover. Land-cover/use classes like fallow or barren lands are generally considered under forest classes but not considered here as a part of forest.

Moist mixed deciduous forest present in the TWS (28.83%) and ISA (26.77%) is not significantly different in its total percent contribution but they do differ in terms of patchiness. Dominant trees like *Terminalia bellirica, Amora speclatrus, Dillenia pentagyna, Syzigium cumini, Ficus sp* provides important habitat to the primates and good cover for herbivores. *Eupatorium odoratum* is an invasive species and indicates anthropogenic disturbances. Timber extraction was evident from recorded stumps in the sampling plots. *Shorea robusta* dominates most of the mixed dipterocarpus forest except a few patches of *Dipterocarpus turbinatus* in the northern part. Because the area under this forest cover is present in the periphery of the Sanctuary, in spite of its potential to sustain good number of primates, the area is presently used only by capped langur and rhesus macaque. Considerably good protection in the *Dipterocarpus turbinatus* patch near Joychandpur has improved the habitat with several other miscellaneous species including *Ficus*. However presence of very few primates and gaur had been recorded in this type of forest cover. The highly degraded sal forest was used only by gaur. In terms of its cover when, compared with other landuse types, over all contribution of this type in ISA is double than that of TWS. Sal being an economically valuable species and of being high calorific value, was found to be one of the favourite species for construction purpose and fuel wood among villagers around the Sanctuary. Degraded scrubland within the study area has been created by repeated felling of woody vegetation. Compared to southern part, northern part of the Sanctuary is having more of such area. Some of the areas under this class in the northern part of the TWS are the abandoned shifting cultivation areas and could not be distinguished from barren or fallow land in the map. There is hardly any woody vegetation in such type of forest. Good grass cover and regeneration of tree species provided good grazing ground for gaur in the ISA. *Bambusa balcooa, Bambusa polymorpha, Bambusa tulda, Melocanna baccifera, Neohuzeaua dullooa, Oxytenanthera nigrociliata,* *Bambusa affinis* and *Dendrocalamus strictus* represent the bamboo species of the area and are important for all kind of wildlife and human beings who are directly or indirectly dependent on the forest (Choudhury 1996). Bamboo-forest in the study area includes mixed bamboo forest, bamboo brakes of *Oxytenanthera nigrociliata* including highly degraded bamboo forest in the periphery of the ISA. However, bamboo of different species in mixture and its uniform distribution in the entire TWS has made the study area a good habitat for wildlife by supplying year round food. Bamboo brake here was categorized by single dominated bamboo species *Oxytenanthera nigrociliata* (endemic to the region). Local people sometime use this species as a substitute for iron rod in the reinforced buildings. This indicates the strength of the culms of this species. Estimated 6.951 Km^2 of land under clearfelled/*jhumed*/open forest spread within TWS is largely distributed in the northern part and rarely found in the ISA. Removal of vegetation cover at the time of *Jhooming* severely depletes the food resources for primates and they totally avoid such areas (Gupta 1996a), which was also evident even from the present study. According to Gupta and Kumar (1994) a minimum of 9 to 10 years of regeneration growth may be necessary on these plots to support a healthy langur population. Tribal population in the northern part of the study area still practices *Jhum* cultivation which in turn changes land use pattern. ISA is relatively free from this kind of practice and in most cases clear felled areas can be attributed to felling of tree species, accidental fire and intentional fire to enhance grass cover for cattle grazing. Though water body associated vegetation is very small compared to larger landscapes but this is very important to wildlife of the study area for cover as well as for large number of evergreen woody vegetation.

Land use / land cover estimates for non-forest category has more error as compared to forest cover as they were scattered within the study area and were confusing most of the time while isolating types like homegardens, fallow land and seasonally cultivated agricultural fields. In spite of having maximum ground truthing points for these types it was difficult to isolate the reflectance value in the imagery. According to the Sanctuary notification, all these types are now likely to be free from human activity but in some places they are still in use by the villagers. Crop fields though are not desired type of land cover within the protected areas from wildlife management point of view but here they support herbivores. During dry seasons gaur uses crop fields to fulfill their food. Almost 50% of the 5.630 Km² crop fields within the ISA were used either by gaur or macaques. Few private lands which are already being acquired by the TWS management as a part of habitat improvement measures are still under cultivation. This mapping can greatly help to identify such lands and take necessary steps so that the wildlife can use these areas as a natural cover. Overall estimate of barren land was negligible; it is because of high regeneration potential of the area, no area virtually remains without vegetation cover for more then a year. No big natural water body was found within the study area. Two big lakes were reflected in the estimates of water body category in the map. As most of the other water bodies were small and covered by vegetation from its sides, it was not possible to distinguish them in the imagery (23.5 m resolution) that was used for the classification. There were several private lands existing in the periphery of the Sanctuary. As most of them were very small, they could not be shown in the study area map. Under the Sanctuary notification, this type of land is unlikely to be a part of the Sanctuary, but they represent 1.99% coverage of TWS and 3.59% coverage of ISA. Most likely these were the areas which were outside the area of TWS but could not be demarcated in the map.

4.4.3 Spatial Diversity Pattern of Flora in TWS

New record of 38 tree species from the study area was an important outcome of this study. Some of these species were found to be very important for the primates of ISA. Out of 96 families that represented the flora of TWS, Fabaceae, Asteraceae, Moraceae, Rubiaceae, Urticaceae were the most species rich families. As found by Gupta (1996) in his study at Sepahijala Wildlife Sanctuary, abundance of families like –Leguminosae, Moraceae and Myrtaceae has a special relevance to primate population. Analysis of these estimated species richness for the plant diversity corroborates the fact that there would be some unrecorded plant species that may be found in the study area. Thereby it is required to carry out more intensive sampling both at temporal and spatial scale.

Distribution

Distribution of all different plant species category was evaluated in both community level and species level. As a whole community analysis assesses whether individual species are randomly distributed with respect to each other, or aggregated together. Different samples showed aggregated dispersion for trees, regeneration and herbs/shrubs categories. At individual level trees, regeneration and herbs/shrubs their total and pooled samples showed good fit to lognormal distribution. Analysis performed at both whole sample and with respect to each other showed that plants were found to be aggregated. Majority of large assemblages studied by ecologists exhibited log normal pattern of species abundance (May 1975, Sugihara 1980, Gaston and Blackburn 2000, Longino *et al.* 2002) and many of these log normal distributions can be described as canonical. Log normal is a consequence of the central limit theorem, which states that when a large number of factors act to determine the amount of a variable, random variation in those factors will result in the variable being normally distributed (May 1975). In case of lognormal distributions of species abundance data, the variable is the number of individuals per species (standardized by log transformation) and the determining factors are all the processes that govern community ecology. Heterogeneity in their dispersion was concluded to be discordant following Chi-square analysis (Sokal and Rolf 1981) (table 4.4). Chi-square tests are used to measure patchiness in species populations or in whole communities (i.e. whether the organisms are distributed randomly through the samples or aggregated or uniformly distributed). Although grass also showed aggregated dispersion for both total and pooled samples, their heterogeneity was independent with probability one. Climber were unique as compared to other plant forms as the total sample showed random dispersion, while with respect to each other they were aggregated. Grass species heterogeneity was found to be independent in dispersion (table 4.4). Maximum aggregation was observed for herbs/shrubs (89.3%) followed by tree species regeneration (80.5%), grasses (69.8%), trees (42.5%) and climbers (2.78%) in the TWS.

Richness

Tree ($\geq$ 20 cm gbh) richness recorded in 3.58 ha of the study area was 106 species and accounted for 213.7 individuals/ha. Observed number of tree species is comparable with similar habitat in adjoining areas in SWS by Gupta (1996, 96 species in 12.5 ha) and Bangladesh (Ahsan 1994, 114 species in Lawachera).

Tree density at 213.7 trees/ha is relatively less as compared to the tree density estimated by Gupta (1996, 250 trees/ha) in Sepahijala Wildlife Sanctuary (SWS), which is only about 80 km away from TWS. Jacknife 1, 2 and chao 2 estimated 159, 199 and 223 species in the area. Estimate is comparable with denser evergreen forests of Peninsular Malaysia (Raemaekers 1980: 229 species in 3.75 ha; Bennett 1983: 190 species). Patchy distribution of most of the species affects chao 1 estimate and thus it is better not to use it in artificially manipulated landscapes. Tree regeneration study observed 118 species of trees and a count of 3016 counted individuals indicates good regeneration potential of the area. It was observed that almost all the tree species found in the samples were regenerating. However, in some part of TWS their establishment was disrupted by repeated uncontrolled grazing by cattle and cutting of regenerating trees for fuel wood. Estimated regenerating species were less then the corresponding estimate of established trees, and may require more intensive sampling in each grid. Observed herb and shrub recorded 187 species and 14817 individuals respectively in 79 plots of 5m radius. Expected estimates of herb and shrub density varied between 250 and 263 species. This showed that the sampling was adequate to represent the herb and shrub density of the area.

Observed 53 species of grass exactly matched with the Jacknife estimate and are likely to represent actual grass diversity of the area. Findings show that singletons were much more then doubletons for trees, regeneration and grasses and indicated samples were true replicates. Noticeable kink in the graph suggested that some sort of ecotone line had been crossed for trees and regeneration (Magurran 2004).

Diversity and Evenness

Beta diversity is a property of the samples, and not an inherent property of the community (Greigh-Smith 1983). Beta diversity used here is used to compare responsiveness of different groups of flora to landscape and environmental changes in a sample (e.g., MaCune and Antos 1981).

This study showed that overall species composition differed between plots. This difference may be because of variations in the site conditions associated with topographic aspects. Studies from temperate regions showed importance of aspect on vegetation abundance and diversity. SHE analysis for trees showed that evenness was negatively correlated with species richness and added species tend to be relatively uncommon or rare if samples are increased and best fit corresponds to a log normal species abundance distribution. Richness of regenerating tree species in the area clearly showed increase as compared with the decrease in evenness. Estimated value of diversity increased with increasing sample size. Heterogeneity in the distribution of regeneration is likely to add more species as sampling intensity increases. As herb/shrub assemblage departs from log normal distribution at community level, it indicates presence of disturbance at ground level. Location and time of sampling and the size of the sampling area are critical considerations in the assessment of richness, evenness, and diversity patterns in spatially and temporally variable communities such as herbaceous forest understories (Small and McCarthy 2002). Low abundance of climber community and large proportion of rare species were found to be the characteristic feature of the area. Therefore, climbers require relatively larger sample areas and sizes. Probability of recording common species was found to be high for grasses and thus there was no need to increase sample size to study grass species at community level. Small and McCarthy (2002) also concluded that forest under story communities may be frequently undersampled in ecological studies, potentially biasing the understanding of forest diversity pattern. There should be different sampling protocol designed in time and space to capture natural patterns of variation in the forest vegetation.

4.5 LIMITATION

As a result of complex and irregular features, land use/ land cover categories obtained here may sometime mislead while identifying areas with similar topographic pattern. Moreover due to similar reflectance values of homegardens and natural vegetation, bare land and uncultivated land, mixed pixel problems occurred during the classification process. It is unlikely that the dataset generated by the land use/ land cover map can provide all the information that might be needed for current and future critical review of the change in landscape and its cover.

Comparison of areas based on estimated beta diversity for the TWS would not be biologically meaningful if different studies used different methods. Thus comparing the results from adjacent area with study area did not help in concluding anything with strong remarks while comparing beta diversity of the area. The same concept was also applied by McCune and Grace (2002) in their study. Abundance data for different life form of vegetation were derived from visual cover estimation by counting individuals or encounter rate rather than biomass measurements. This practice was cautioned by Chiarucci et al. (1999), who suggested that some suitable aspects of community structure may be less apparent when using cover rather than biomass derived data. Though this study considered vegetation community separately for different plant life forms, assigning different weight would explain forest diversity pattern in a better way.

4.6 SCOPE

As such, the mapping and modeling of community should be considered using a variety of different spatial datasets appropriate to their needs. This will require that each of the datasets uses a common classification scheme. Analysis of the IRS-1C LISS III data for broad scale land-cover mapping and, more specifically for mapping of landscape mosaics of different heterogeneity and graininess can be used in landscape ecology. Evaluation of 14 most common types of landscape mosaics identified within the study area demonstrated that despite its relatively coarse ground resolution, LISS III data provides an excellent tool for land-use/ cover mapping. Using habitat specific data at individual species level this can be further used for landscape level ecological applications.

Chapter 5
Distribution and population structure

5.1. INTRODUCTION

Modeling species distribution finds its utility in the understanding of species biology, simple inventory assessment of a geographical region, defining specific management action and thereby implementation of adequate conservation strategies. An index to population size (or abundance) is simply any "measurable correlative of density" (Caughley 1977) and is therefore presumably related in some manner to actual abundance. Census surveys of non-human primate populations are an integral part of primate field studies for two reasons. First, population density estimates are important to determine conservation priorities and creating management plans for primate populations (Ganzhorn *et al.* 1996, 1997). Second, these estimates are valuable to researchers trying to understand socioecological differences between primate populations (Butynski 1990)..

The primary method for estimating primate populations is to conduct line transects surveys (Cant 1978, Green 1978, Peres 1990, Gonzalez-Kirchner 1998, Wallace *et al.* 1998). Line transect surveys have advantage of giving information on primate population in relatively shorter duration from larger landscapes (Strushaker 1981). As the area in this study was relatively small, total count method was also tried at the end of every season.

Although the distribution of a species in a geographical range or larger landscape is studied well, very few research works addressed the distribution pattern of primates at a micro scale. To study the distribution of a species, the entire area was divided into grids based on the patch size and typical home range of the study species described in earlier literature. For the simplicity the area was considered as square grid as it is not feasible to enumerate irregular patches in the field. In context of conservation, the question is obscured by the seemingly overwhelming proximity importance of human cultural traditions (e.g. hunting), patterns of colonization, and economic development, which suggests that species endangerment might be entirely a function of human, behaviour. Similar biotic impacts on a habitat are likely to affect species differently and some species are hunted or trapped in preference to others. Therefore it can usually be asked whether a species 'rarity or vulnerability to extinction' is at least partly a function of its own biology.

Whereas density is described in relation to the administrative area under the jurisdiction of wildlife warden, ecological density is described with relation to the major habitat types described by land-use types. As in the absence of external biotic interference in a continuous landscape, food is highly correlated with the cover, this analysis was restricted to land-use types while calculating ecological density of different study species.

This chapter discusses issues like- spatial distribution of study species, seasonal pattern of distribution in the study species of ISA, predictive covariates including limiting factors responsible for distinct distribution pattern of study species, typical population structures of study species in the area, and attempts to answer whether it is possible to predict the dynamics of population for study species from the data.

Although distribution of a species in a geographical range or larger landscape is studied well, no previous research on the study species of primates addressed the distribution pattern of these animals in the same continuous landscape of their habitat.

5.2 METHODS

To study the distribution of a species, the entire area was grided based on the home range of a species described in secondary published literature (Roonwal and Mohnot 1977). For the simplicity of model, area was grided in a square shape. Whereas density is described in relation to the administrative boundary or a geographical unit, ecological density is described with relation to the major habitat types characterized by usable/available/potential landuse types in a continuous landscape

5.2.1 Field method

5.2.1.1 Transect surveys

Transect method (Buckland *et al* 1993, Burnham *et al* 1980, Eberhardt 1968) was used to determine abundance of study species in the intensive study area. Six (6) permanent transects (2 to 3.2 km) covering all major vegetation types were monitored between November 2002 and July 2004. In case of primates, once any of the study species was spotted, the group was observed from the transect path for up to 10 minutes to determine the group identity or to ascertain whether the individual was solitary individual or a member of an all-male band. Each transect was walked at least six times in a season (summer and winter). Following parameters were recorded for each study species observed along the transect: (a) time of sighting (b) initial indication to detection (c) segment of the transect (b) sighting angle (by compass), sighting distance (by range finder or ocular estimation if line of sight is obstructed by plant canopy), (c) group size and (d) sex and age class of the individuals.

5.2.1.2 Total count

For hoolock gibbon, capped langur and pig-tailed macaque, apart from transects, individual groups of study animals were identified and total count method were used for the determination of seasonal population structure. The entire ISA was surveyed once at the end of each season for the presence-absence information and was plotted in species-specific grid to estimate the area used by different species in that particular season. Areas inside ISA with different groups were surveyed in a block of 5 to 6 consecutive days.

5.2.2 Analytical method

The group structures for each study species were tabulated for each season. The mean group size for study species in each season was estimated and subjected to ANOVA and Tukey's – HSD test (Zar 1984). The typical group size of gaur was calculated following Jarman's (1974) guideline. Line transect data could not fulfill the minimum number of sightings required to use DISTANCE programme. Hence data from the line transect surveys was analysed by using transect width after getting average visibility of each transect to calculate ecological density and then the results were compared with the seasonal total count of study species in ISA. Mean group spread for study species (primate) was calculated from the data collected during scan sampling.

5.2.2.1 Estimation of group size and density

Mean group size for the study species was obtained from the seasonal total counts. For each study species mean group size and its standard error was estimated, seasonally, in different habitat types. For comparing group densities of different species, percentage of observed groups in different categories based on group size was determined. One-way analysis of variance (ANOVA) (Sokal and Rohlf 1981) using Tukey's – HSD test was done to test whether the mean group as well as individual density differed among the different seasons and habitats.

5.2.2.2 Population Structure

With an assumption that the proportion of age-sex classes in the population does not differ within a habitat, information collected during line transect, *adlibitum* sightings and opportunistic sampling was used for classifying primates and gaur. Classification keys for each study species is listed in the.

Two-way analysis of variance (ANOVA) in a randomized block design, using seasons and habitat as a block, was used to test whether the arc-sine transformed proportions (Sokal and Rolf 1995) of age-sex classes for each species differed in different habitat types. The point estimates were derived from the seasonal total counts for primates and total of all counts for gaur. Mean biomass densities of all the study species were estimated for ISA in kg km^{-2}. Mean biomass density was derived by multiplying mean ecological density (D) of each species by its average unit weight which was estimated from published data on body weights and population structure data from the present study.

5.2.2.3 Age and Sex categories of study primate species

At the beginning of 1^{st} and 2^{nd} year, each individual of the habituated groups was identified and listed under different age-sex category. Each individual was given a name and code for easy operation during analysis. As the number of individuals was more (26) for pigtailed troop, unique name could not be given to them but they were well categorized under different age-sex class. Broad categories of the age-sex class are given below. Age and sex categories of primate species were decided based on studies by Gupta (1996) in Sepahijala Wildlife Sanctuary.

Neonate From birth until about one and half months. They remain dependent on mothers and other adult females in the group for caring.

Infant From end of neonate stage until about 5 to 14 months. The individuals feed independently, but keep close to the mother and cling to her during travel. They never rest or sleep alone.

Juvenile These are between infant and subadult stage, ranging in their age from about 14 to 24 months. ,These are totally independent of their mother and may even select a separate tree for roosting.

Subadult This is the next stage after juvenile, but before the individuals attain adulthood, ranging in their age from 24 to 36 months. These differ from their adult counterpart only in body size, which is three quarter that of adult body-size.

Adult female The nipples are more conspicuous than in adult males. Age from more than 36 months.

Adult male Fully grown in size, and distinguishable from adult females in body size and by the presence of descended testes in all three study primate groups. Age more than 36 months.

5.2.2.4 Age-Sex categories of Gaur

Visible morphological structures such as horns, as used by Fuller (1959) for the American bison (*Bison bison*) were used for age and sex determination of gaur in this study.

Bulls, are more massive than cows with well developed dorsal ridge, widely sweeping horns forming approximately a right angle with the head having transverse ridges at the base. The tips of the horns terminate abruptly and usually lies outside the head. The bulls which are 5 or more years old usually have darker pelage and well developed dewlaps than young adult bulls whose pelages are less dark and more ash in colour. Identification of bulls was further confirmed by the presence of abdominal penis.

Cows, on the other hand have sharp inwardly curved horns, emerging from the head at an angle of less than 90°. The tips of the horns usually lie above the head. The vulva, situated below the anus, further facilitated recognition of the cows.

Yearling / Juveniles, usually of 1-3 years, were identified by their smaller body size, straight horns and occasional association with mothers.

Calves, less than one year old, always associated with mothers having a golden brown to dark brown coat and with or without small protuberances of horns.

5.3 RESULTS

5.3.1 Spatial distribution of gibbon, pigtailed macaque and capped langur

Out of fifteen species so far recorded from India, six species representing the only ape of the country i.e. hoolock gibbon; two species of langur namely, capped langur and Phayres' langur; two species of macaque, pigtailed macaque and rhesus macaque; and slow lorries are found in the ISA (76.6 km^2). Though all the species are not uniformly distributed in the entire area there is only one continuous patch in the core of ISA where all the species were recorded. Not all of the fourteen landuse classes observed in the study area were used by study species.

5.3.2 Population size and Structure

5.3.2.1 Pigtailed macaque

Other then rhesus macaque which occupied most of the buffer or the periphery of the ISA boundary, pigtailed macaque is the primary stakeholder of the core and were found in relatively undisturbed parts of the TWS. Population estimate of pigtailed macaque within the ISA showed that the total population was 107 individuals in the beginning of the study period and subsequently decreased to 80 in summer 2004 (Fig. 5.1). Mean group size was 21.4 with standard error of 4.56 but gradually decreased to 16 individuals with standard error of 2.14. The minimum group size was almost constant at 11 individual throughout the study period, yet the maximum size decreased from 34 individuals in a group to 21 individuals. There were 5 groups within the ISA and none of the groups really splited. Skewness of the group size was positive during the winter whereas during the summer it was negative. Two way ANOVA and Tukey's test showed that the group size or different age and sex category of pigtailed macaque within ISA, across the seasons did not show any significant variation (Fig. 5.3).

Table 5.1 Population structure of pigtailed macaque in two consecutive breeding and non breeding seasons in Trishna Wildlife Sanctuary.

Season	Group identity	Am	Af	Sa	Inf	Neo	Uni	Number	Seasonal Total
Breeding season-1 (November 2002 - March 2003)	Joychandpur	6	8	7	2	2	9	34	
	Kasari-Teendepha	4	5	3	2	0	5	19	
	Rajnagar-Joychandpur	4	7	4	2	1	12	30	
	Durgapur	3	4	2	1	1	0	11	
	Rajnagar	3	4	2	1	0	3	13	107
Non-Breeding season-1 (March 2003-July 2003)	Joychandpur	5	7	7	5	3	0	27	
	Kasari-Teendepha	5	5	4	2	3	1	20	
	Rajnagar-Joychandpur	5	6	4	3	4	2	24	
	Durgapur	3	4	2	1	0	0	10	
	Rajnagar	3	5	2	1	0	3	14	95
Breeding season-2 (November 2003 - March 2004)	Joychandpur	6	8	5	3	4	0	26	
	Kasari-Teendepha	3	5	3	2	1	2	16	
	Rajnagar-Joychandpur	5	3	5	2	2	4	21	
	Durgapur	3	4	2	0	3	0	12	
	Rajnagar	3	3	2	1	1	1	11	86
Non-Breeding season-2 (March 2004-July 2004)	Joychandpur	4	4	8	1	3	0	20	
	Kasari-Teendepha	4	5	2	2	2	2	17	
	Rajnagar-Joychandpur	3	5	6	3	3	1	21	
	Durgapur	3	3	2	2	1	0	11	
	Rajnagar	2	3	1	2	0	3	11	80

Table 5.2 Group structure of capped langur in two consecutive breeding and non breeding seasons in Trishna Wildlife Sanctuary.

Season	Group identity	Am	Af	Sa	Inf	Neo	Uni	Number	Seasonal Total
Breeding season-1 (November 2002 - March 2003	BHB-CirRd-CL	2	3	1	0	0	0	6	
	DP-West-CL	1	1	0	1	0	0	3	
	JP-HQ-Dip-CL	1	3	2	1	0	0	7	
	JP-Mango-CL	2	0	0	0	0	0	2	
	JP-SG-CL	3	4	4	2	0	0	13	
	JP-Tower1-Entry-CL	1	1	1	0	0	0	3	
	JP-Tower1-Exit-CL	2	4	2	2	0	0	10	
	JP-Vill-lake-CL	1	0	0	0	0	0	1	
	KAS-Entry-CL	2	2	3	1	1	0	9	
	KAS-TD-CL	2	4	2	2	0	0	10	
	RAJ-AllMale-CL	5	0	0	0	0	0	5	
	RAJ-Tower2-CL	1	2	3	1	0	0	7	76
Non-Breeding season-1 (March 2003-July 2003)	BHB-CirRd-CL	2	3	1	0	0	0	6	
	DP-West-CL	1	1	0	0	0	0	2	
	JP-HQ-Dip-CL	1	3	2	1	1	0	8	
	JP-Mango-CL	2	0	0	0	0	0	2	
	JP-SG-CL	3	4	3	1	1	0	12	
	JP-Tower1-Entry-CL	1	1	0	0	0	0	2	
	JP-Tower1-Exit-CL	2	2	2	2	0	0	8	
	JP-Vill-lake-CL	1	0	0	0	0	0	1	
	KAS-Entry-CL	2	2	3	1	1	0	9	
	KAS-TD-CL	2	3	2	2	0	0	9	
	RAJ-AllMale-CL	5	0	0	0	0	0	5	
	RAJ-Tower2-CL	2	2	1	1	0	0	6	70
Breeding season-2 (November 2003 - March 2004)	BHB-CirRd-CL	2	3	1	2	1	0	8	
	DP-West-CL	1	1	0	1	0	0	3	
	JP-HQ-Dip-CL	1	3	2	1	0	0	7	
	JP-Mango-CL	1	0	0	0	0	0	1	
	JP-SG-CL	2	4	3	1	3	0	13	
	JP-Tower1-Entry-CL	1	0	0	0	0	0	1	
	JP-Tower1-Exit-CL	3	2	2	0	2	0	9	
	JP-Vill-lake-CL	1	0	0	0	0	0	1	
	KAS-Entry-CL	3	3	1	3	1	0	11	
	KAS-TD-CL	1	3	3	1	0	0	8	
	RAJ-AllMale-CL	4	0	0	0	0	0	4	
	RAJ-Tower2-CL	2	2	1	2	0	0	7	73
Non-Breeding season-2 (March 2004-July 2004)	BHB-CirRd-CL	2	3	1	2	0	0	7	
	DP-West-CL	0	1	0	0	0	0	1	
	JP-HQ-Dip-CL	1	3	1	3	0	0	8	
	JP-Mango-CL	2	0	0	0	0	0	2	
	JP-SG-CL	2	3	3	2	1	0	11	
	JP-Tower1-Entry-CL	0	0	0	0	0	0	0	
	JP-Tower1-Exit-CL	3	2	2	1	1	0	9	
	JP-Vill-lake-CL	1	0	0	0	0	0	1	
	KAS-Entry-CL	2	2	1	1	0	0	6	
	KAS-TD-CL	1	4	1	0	0	0	6	
	RAJ-AllMale-CL	4	0	0	0	0	0	4	
	RAJ-Tower2-CL	2	2	2	1	0	0	7	62

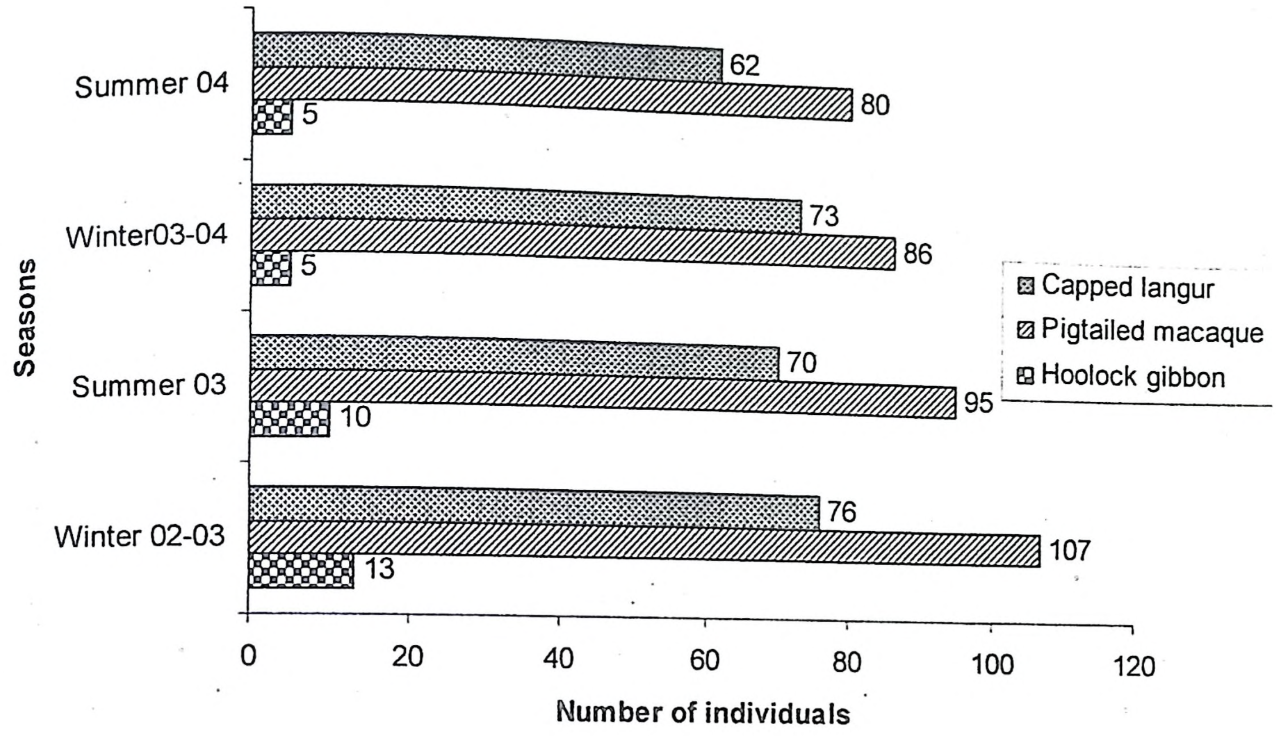


Figure 5.1 Estimates of gibbon, capped langur and pigtailed macaque within intensive study area of Trishna Wildlife Sanctuary.

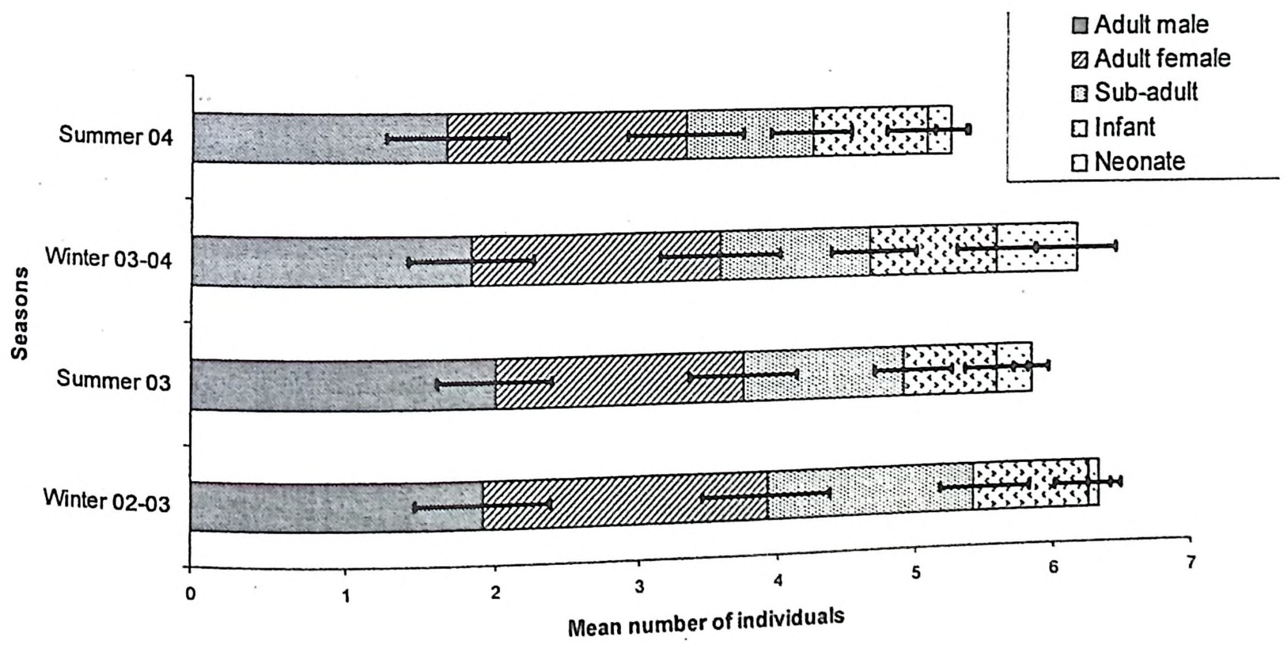


Figure 5.2 Seasonal population structure of capped langur within intensive study area. (Variations shown are standard error)

5.3.2.2 Capped langur

Population estimates for the capped langur showed that mean group size did not vary significantly throughout the study period. The mean group size ranged between 5.1 to 6.3 individuals with standard error ranging from 1.01 to 1.17. Group size varied between 2 to maximum of 13 individuals (table 5.2). In the beginning of the study, total population of capped langur was 76 and population remained almost constant during first three sampling seasons. During last sampling season total population decreased from 73 to 62 individuals. Though there was formation and merging of individuals between different groups but the total number of groups remained constant at 12 (Fig. 5.1).

Individual group size was uniformly structured and was likely to be normally distributed as the data is positively skewed up to maximum of 0.22. During the last phase, these groups showed negative skewness (- 0.061) which is an identification of drastic change in group size.

Two –way ANOVA confirmed that combination of different age and sex categories across the seasons showed no significant difference. Tukey' HSD test also confirmed that across the seasons there was no significant change for any of the age-sex category (Fig. 5.2) of the capped langur.

5.3.2.3 Hoolock gibbon

At the end of the study, total size of the hoolock population was only five (5). Though in the beginning (winter 2002) there were three groups observed. During summer 2003 the number was recorded to be 10 and in subsequent seasons the total population remained as five individuals. The largest group (n=9) could not be found after second survey season (summer 2003). Number of individuals varied between 2-3 per group (Fig. 5.1). The reasons for the disappearance of two groups with nine individuals could not be ascertained. No significant difference either in total number or in the different age and sex composition was found (Fig. 5.4)

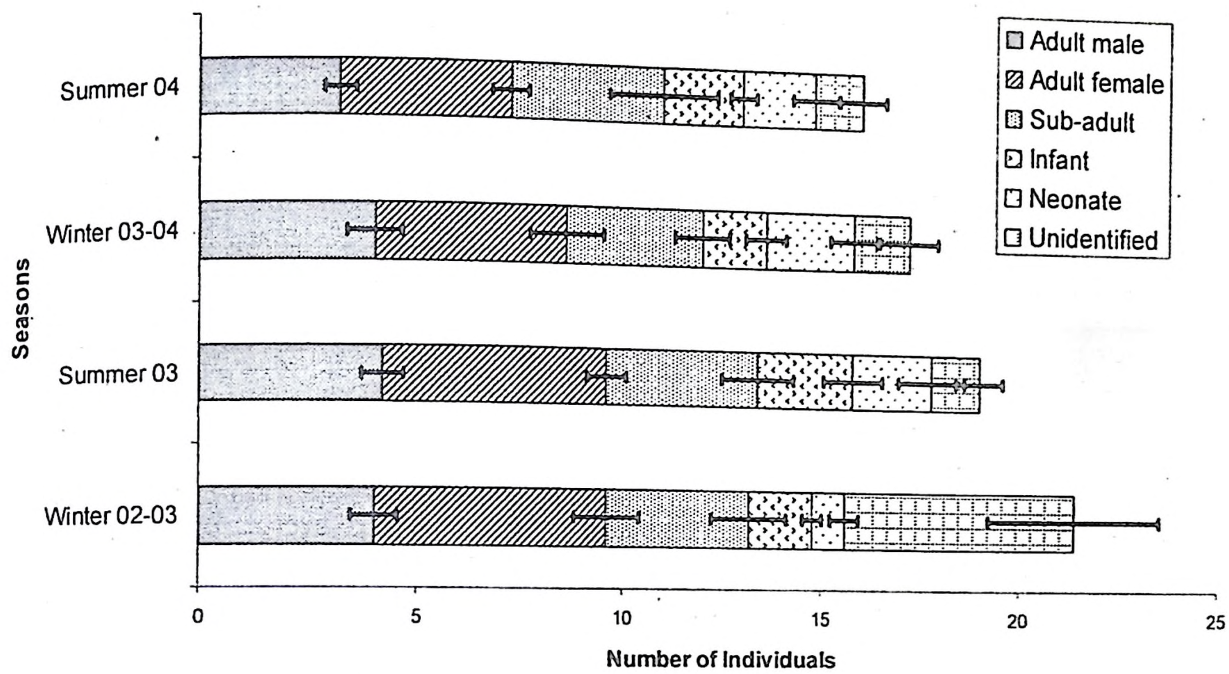


Figure 5.3 Seasonal population structure of pigtailed macaque within intensive study area. (Variations shown are standard error) 2002-2004.

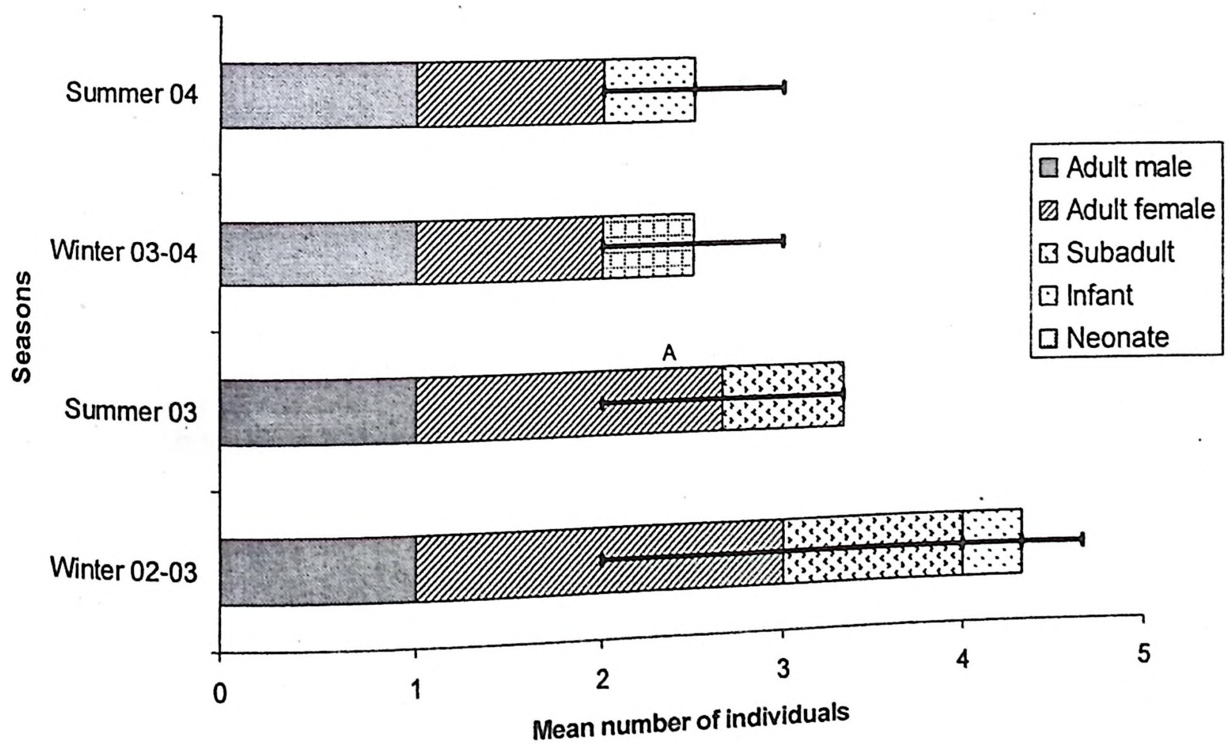


Figure 5.4 Seasonal population structure of hoolock gibbon within intensive study area. (Variations shown are standard error) 2002-2004.

Table 5.3 Group structure of Hoolock gibbon in consecutive breeding and two non breeding seasons in Trishna Wildlife Sanctuary.

Season	Group identity	Am	Af	Sa	Inf	Neo	Uni	Number	Seasonal Total
Breeding season-1 (November 2002 - March 2003	JP-Rng-Core	1	4	3	1	0	0	9	
	JP-TR	1	1	0	0	0	0	2	
	JP-VP	1	1	0	0	0	0	2	13
Non-Breeding season-1 (March 2003-July 2003)	JP-Rng-Core	1	3	2	0	0	0	6	
	JP-TR	1	1	0	0	0	0	2	
	JP-VP	1	1	0	0	0	0	2	10
Breeding season-2 (November 2003 - March 2004)	JP-TR	1	1	0	0	1	0	3	
	JP-VP	1	1	0	0	0	0	2	5
Non-Breeding season-2 (March 2004-July 2004)	JP-TR	1	1	0	1	0	0	3	
	JP-VP	1	1	0	0	0	0	2	5
Breeding season-3 (November 2003 - March 2004)	JP-TR	1	1	0	1	0	0	3	
	JP-VP	1	1	0	0	1	0	3	6

5.3.3 Ecological density of gibbon, pigtailed macaque and capped langur in ISA

Area outside the Sanctuary boundary was found either under habitation or agricultural lands and no study species (primate) was found to be distributed between ISA boundary and 2 km buffer area of it. Forested area is available only inside ISA and there is no continuity between forest patches inside and outside ISA forest patches, thereby restricting the movement of studied primate species. Ecological density of the species was calculated with reference to the estimated usable area calculated after adding all the vegetation types where a particular species was recorded inside ISA during the study period. While calculating ecological density only adult male, adult female and sub-adults were taken. Based on direct evidences, encounter rate calculated was highest for capped langur, followed by pigtailed and gibbon (Table 5.4). Encounter rate for gaur was almost equal to zero, but the encounter rate with the fresh hoof marks or dung was quite high (3.193/km).

Table 5.4 Encounter rate (mean±SE) of study species in the intensive study area.

Gaur (indirect evidence/km)	Capped langur (individual/km)	Hoolock gibbon (individual/km)	Pigtailed macaque (individual/km)
3.20±0.99	1.48±0.47	0.21±0.09	1.14±0.73

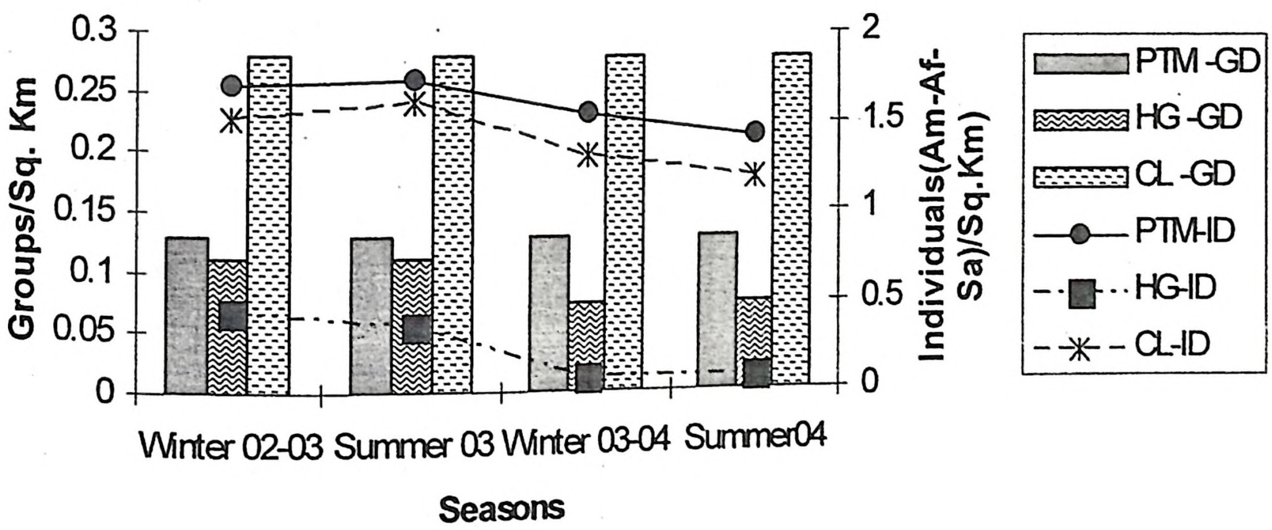
Table 5.5 Ecological density of primates in intensive study area of Trishna Wildlife Sanctuary.

Species(estimated usable area)	**Season**	**No of groups**	**Ecological-Group-Density (Gr/km²)**	**Ecological-Individual-Density (Ind/km²)**	**Ecological-Biomass-Density(kg/km²)**
Hoolock gibbon (27 km²)	Winter 02-03	3	0.11	0.44	2.88
	Summer 03	3	0.11	0.37	2.40
	Winter 03-04	2	0.07	0.07	0.48
	Summer 04	2	0.07	0.07	0.48
Pigtailed macaque (39 km²)	Winter 02-03	5	0.13	1.69	7.95 to 26.06
	Summer 03	5	0.13	1.72	8.07 to 26.46
	Winter 03-04	5	0.13	1.54	7.23 to 23.69
	Summer 04	5	0.13	1.41	6.63 to 21.72
Capped langur (43 km²)	Winter 02-03	12	0.28	1.51	15.12 to 19.35
	Summer 03	12	0.28	1.61	16.06 to 20.54
	Winter 03-04	12	0.28	1.30	13.02 to 16.67
	Summer 04	12	0.28	1.19	11.86 to 15.18

Note: Individual body biomass estimate for all the species was taken from Gupta and Chivers 1999.

Number of groups which was estimated at the end of each season showed that there was no new group formation observed in the study area. Individual and group density of hoolock gibbon, pigtailed macaque and capped langur is given in the table 5.5. At the beginning of the study there were three (3) groups of gibbon with an estimated ecological density of 0.1 groups per km² and 0.4 individuals km². The biomass of hoolock gibbon estimated was 2.9 kg per km². The disappearance of one hoolock gibbon group resulted in decrease of biomass to 0.5 animal/km². In total, five (5) groups of pigtailed macaque were recorded in the study area with an estimated density of 0.1 groups per km². Individual density of PtM was 1.7 per km² at the beginning of the study and it gradually decreased to 1.2 per km² at the end of summer 2004. In spite of having 12 groups of capped langur in the ISA, individual density did not vary much for pigtailed macaque. With almost double the density that of pigtailed macaque, capped langur had 1.6 individuals per km². This increased a little in the next season but showed decline in the next two seasons.

Bar graphs in the figure 5.5 shows group density whereas lines show individual density of three study species (primates) in ISA. Throughout the study period no new group was formed for any of these primate species. Though there were immigration and emigration of adult males in case of capped langur but no new group was identified till the end of each season. As identification of individuals was not possible for the pigtailed, it could not be confirmed whether there was any migration of individuals between the groups.



Note: **NHM**- Non human primates, **TWS**- Trishna Wildlife Sanctuary, **Am**- Adult male, **Af**- Adult female, **SA**- Sub-adult, **PTM**-Pigtailed macaque, **HG**-Hoolock gibbon, **CL**-Capped langur.

Figure 5.5 Individual and group densities of hoolock gibbon, capped langur and pig-tailed macaque at the end of different seasons between year 2002 and 2004 within intensive study area.

5.3.4 Biomass of Gibbon, pigtailed macaque and capped langur in ISA

Biomass is a function of both species and the area. Body mass (kg) estimate of 4.7 to 15.4 for pigtailed macaque, 10.0 to 12.8 for capped langur and 6.5 for hoolock gibbon is used for the estimate of biomass density in ISA. Biomass density was highest for the capped langur followed by pigtailed macaque and hoolock gibbon. With the loss of one hoolock gibbon group, which otherwise had the largest number of adults and sub-adults, the biomass was reduced from 2.9 kg/km² to 0.5 kg/km². This decrease in the biomass (83%) is definitely alarming for the conservation of gibbon in TWS. Estimated biomass for the pigtailed was 7.9 kg to 26.1 kg/km² in the beginning of the study. This estimated biomass decreased by 16.6% at the end of the study period. Decrease in biomass was second highest for capped langur. During 2 years of time 3.3 kg to 4.2 kg/km² of biomass of capped langur was lost from the area. This loss is about 21.5% of the primary population estimated in the beginning of year 2003 (Table 5.5).

5.3.5 Gaur

Gaur uses almost the entire ISA either for resting or grazing. Overall mean (±SE) group density of gaur in the study area was found to be 1.5 (±0.3) per km², whereas individual density was found to be 5.9 (±1.5) per km².

Table 5.6 Seasonal variation of gaur density in intensive study area.

Sampling season	N	Group density **(Gr/km²)** (Mean±SE)	Individual density **(Ind/km²)** (Mean±SE)
Winter 02-03	N=35	2.223±0.777	6.82±3.01
Summer 03	N=39	1.147±0.555	4.57±2.58
Winter 03-04	N=39	1.508±0.642	7.38±3.30
Summer 04	N=37	1.193±0.576	5.10±2.93
Over all	N=150	1.503±0.318	5.96±1.47

During winter 2002-03, group and individual density (mean±SE) of gaur was estimated to be 2.2±0.8 groups/km² and 6.8±3.0 individuals/km² respectively.

Second season onwards the group density remained almost constant but there was a fluctuation in the individual density (Table 5.6). Tukey's test showed that group density as well as individual density of gaur did not vary significantly if compared between winter (df=1,F=1.14,p=0.288) and summer (df=1,F=0.60,p=0.439). Result was similar even for sampling seasons and there was no significant difference either for group density (df=3, F=0.58, p=0.627) or individual density (df=3, F=0.21, p=0.890). However, across six different habitats there was significant difference in both group (df=5, F=5.25, p=0.001) as well as individual density (df=5, F=4.50, p=0.001).

5.3.5.1 Population structure of gaur

Group size of gaur ranged between 2 to 14 with isolated bulls in the study area. There was a clear seasonal variation in the group size which was estimated to be 4.6 animals (S.E =0.26) during winter and 3.1 (S.E =0.51) animals during summer (table 5.7). No bachelor herds were observed in any seasons, though solitary black bulls were seen (n=19) in the ISA. A total of 113 groups sighted during the study period pooled together gave an estimate of mean 4.0 individuals in a group with standard error 0.21.

Table 5.7 Mean group size of gaur in different seasons in intensive study area. (2002 -2004)

Season	Groups sighted (n)	Mean group size	Standard error
Winter	68	4.6	0.26
Summer	45	3.1	0.51
Total	113	4.0	0.21

A total of 613 individuals were classified during the course of study. The ratio of bulls and cow in winter (56 bulls : 100 cows) and summer (61 bulls : 100 cows) remained almost constant. There was a clear seasonal variation in the cow and calf ratio between winter and summer (table 5.8). Calf-cow ratio dropped to 9 calfs : 91 cows during winter from 21 calfs : 79 cows during summer. For age and sex ratio and group size distribution, data recorded in the entire sanctuary was used. Total 107 groups were sighted between March 2002 and June 2004. Sex ratio of gaur is given in the table 5.9. Total 11.8 % sightings were of isolated individuals. Highest number of gaur group (36.8%) in the TWS falls into the category of 5 to 7 individuals. Details are given in the table 5.10.

Table 5.8 Sex ratio and cow-calf ratio of gaur in different seasons in intensive study area. (n= total number of individuals sighted)

Season	Winter (n=313)	Summer (n=140)
Bull : Cow	56	61
Calf : Cow:	9	21

Table 5.9 Proportions of age and sex classes of gaur in Trishna Wildlife Sanctuary, Tripura. (2002 -2004)

Seasons	Total group classified (n)	Adult Male/Bull	Adult Female /Cow	Yearling /Juveniles	Calves
Winter	107	24.0	42.8	29.4	3.8

Table 5.10 Group size distribution of gaur in Trishna Wildlife Sanctuary, Tripura. (2002 -2004)

Total groups recorded (n)	% in each group size class				
	1	2-4	5-7	8-10	10+
107	11.8	27.6	36.8	22.4	6.6

5.4 DISCUSSION

In context of conservation, the question is obscured by the seemingly overwhelming proximate importance of human cultural traditions (e.g hunting), patterns of colonization, and economic development, which suggests that species endangerment might be entirely a function of human behaviour. Biotic impacts on a habitat are likely to affect species differently. Therefore, it can usually be asked whether a species rarity or vulnerability to extinction is at least partly a function of its own biology. Here distribution is discussed with relation to different habitat types and seasons.

5.4.1 Distribution of study species in TWS

Although distribution of study species in a geographical range or larger landscape is studied well (Roonwal and Monhot 1977, Mukherjee 1986 *et al.* 1988, Alfred and Sati 1990, 1994, Choudhury 1991, Srivastava 1999, Fooden 1969, Medway 1970, Schaller 1967, Chandi Ramani 1980, Vairavel 1998, Sankar *et al.* 2001), no long term research in the past on these species addressed the distribution pattern of these animals in a continuous landscape of their habitat in the same temporal scale. Species specific home range size based grid sampling in studying species distribution was found to be useful in optimizing sampling effort. Hoolock gibbon, capped langur and pigtailed macaque showed significant variation in distribution pattern compared to the uniform grid sampling. This can be justified by the differences in the habitat requirement of these species. Isolated patches of primate habitats are distributed mostly in the periphery and northern part of the TWS. Depending on the habitat specialization, extent of dispersion of these species radiates from the centre to periphery. This radiating dispersion nature is likely to be influenced by the distribution of habitat types. Though all the species are not uniformly distributed in the entire area there is only one continuous forest patch in the core of ISA where all the species were recorded.

5.4.2 Covariates of distribution of study species

Covariates favouring study species differ considerably from species to species but most of the negative factors which are likely to be responsible for restricting the distribution of study species were common. Covariates which have significantly restricted the distribution of study species are, felling of trees, extraction of bamboo, uncontrolled grazing and high density of trails inside ISA. Specific covariates which were found to favour gibbon population are fruit availability throughout the year, complex structure of vegetation composition (measured in terms of plant diversity and density) in combination with less anthropogenic disturbances (Appendix-3).

5.4.3 Limiting factors of distribution of study species

The only ape of the Sanctuary, the hoolock gibbon, which is otherwise also the only ape species of India is facing high threats from fragmentation and depletion of forest resources. Possibility of poaching or capture for transporting them across the border cannot be ruled out. During study period people were found attempting to capture male hoolock gibbon to sell them across the international border. Given that there was no carcass or remains of hoolock gibbon during the study period, the probability of individuals dyeing of disease or predation appeared remote. Pigtailed macaque is primarily a frugivorous species and the constant significant decrease in the number of individuals and their mean group size showed that either their habitat and food resources are decreasing sharply or the predation pressure remained above the threshold level. Fragmentation of habitat, especially total absence of large trees and thereby discontinuity in the canopy cover and large tracts of agricultural fields are the responsible factors for the restricted distribution of capped langur. Gaur was fund to cross agricultural lands but being a shy animal always avoided any close contact with the humans. Human habitation all around the Sanctuary is likely to split the inside and outside gaur population of the area. There is a immediate need to restore the corridor between Sidihnagar gaur population and inside Sanctuary population. Hunting of gaur in the northern part of TWS is an added threat to this population. As a result, in spite of having suitable ground cover the northern part has almost lost gaur population in the area. Shortage of thick tree cover or the resting places in the northern part also could be one of the reasons behind shrinking gaur distribution in the TWS.

5.4.4 Characteristics of population structures of study species

Variation in the capped langur mean group size (±SE) between 5.1(±1.01) to 6.3 (±1.17) individuals with maximum of 13 individuals is comparable with the other studies from similar areas by Stanford (1987). As the temporal scale is too small, concluding anything on the population dynamics of capped langur would be difficult. Thus decrease in the total population from 76 to 62 and drastic change in individual group size though shows significant variation, if divided in breading season atleast for one generation, it might show some different trend. No increase or decrease in the group size of capped langur though indicates maintenance of the group density but shrinkage in the peripheral habitat are forcing them to move in the centre of ISA or in the isolated peripheral patches. Moving towards central part is in one way putting threat by increase in the competition for resources which are commonly used by the other groups of the same species or by the Phayres' langur. This however, requires detailed investigation.

About 25% decrease in the total population of pigtailed macaque in ISA is alarming. Though the mean group size got reduced but still they are with in the comparable range with the other studies. However, the five groups within the ISA did not split up. There were of course evidences of individual movement between groups. Unusually in one case two adult females were found to move from one group to another. Within the single scan period of 4 days, both the individuals were accepted in the study group. It is extremely difficult to analyze any trend related to very small population. Hoolock gibbon in ISA is totally isolated with minimum chance of their migration to any other forest having gibbon population. Abrupt change in the gibbon population in ISA indicate that either individuals were directly removed or there was migration to other forest areas through unexpected canopy cover i.e through human habitation which is unlikely to happen. Inspite of total decrease in the gibbon population, two groups successfully bred. Their long term survival needs to be ensured by providing undisturbed suitable habitat. A better way of judging the decline of gibbons is by comparing the amount of available habitat between different studies. And if compared with the other studies, the density of gibbon in this area is comparable with any other sites in the north east. Looking into the present status of the species and recent report on status of gibbon the NE India (Gupta 2005), it is clear that the isolated population in fragments need special conservation efforts.

5.4.5 Population status of study species

Habitat fragmentation between ISA and northern part of TWS in terms of upper canopy continuity is restricting the movement of study species in few potential primate habitats of TWS. Though ecological density of individuals declined for all the study species in the area but their group density remained same during study period. No new group formation was observed for the study species which could be due to limited resource availability or due to reduced the predation pressure. Over all biomass decrease for all the species is certainly a matter of concern as far as their conservation status is concerned. Inspite of immigration and emigration of adult males between groups no new group formation was observed for the study species. Total 83% decrease in the biomass of gibbon in the ISA is definitely an alarm towards the conservation of gibbon in ISA. Pigtailed showed second highest decrease in biomass.

Gaur density did not show any significant change and therefore the population is not facing any immediate threat of extinction unless removed directly by poaching, hunting or epidemic.

5.4.6 Prioritizing conservation strategies

The uncritical acceptance of prioritizing conservation efforts for endangered species in an area needs to be addressed based on their local status. A situation where only 5 individuals of a species remain in forest fragments tends to reinforce the view that ex-situ management and intrusive management is vital to the conservation of hoolock gibbon. Rehabilitation and release of confiscated gibbons in isolated forest areas without a resident wild gibbon population may be a way to solve the dilemma of what to do with gibbons held in captivity, but should not be used as a conservation strategy.

5.5 LIMITATION

Since the visibility distance on the line transects were estimated visually, there were some bias in density estimation. The edge effect is one of the main phenomena that needs to be studied in landscape ecology, since it plays a decisive role in determining the structure and dynamics of ecological patches. This study did not consider edge effect while discussing density parameters and distribution of study species. Most conservation issues involving spatial considerations (design of reserves, land use planning, etc.) require implicitly or explicitly an analysis of the edge effects under operation and of their consequences.

5.6 SCOPE

Presence-absence data collected in the present study can further become baseline for a detailed study of individual study species. Species distribution information at micro-scale would help to develop habitat suitability mapping. There is a very bright scope to setup experimental plots in the area provided anthropogenic disturbance is completely removed from some parts of the intensive study area. Detailed monitoring can also be made by using seasonal distribution database generated for the study species.

Chapter 6

Habitat use and feeding ecology

6.1 INTRODUCTION

This chapter addresses habitat use in spatial and temporal scale and estimates occupancy and detection probabilities for non-human primates in different habitat types. Modeling of co-occurrence/co-existence patterns for macaque, langur and gibbon was also attempted in this chapter. The patterns of plant species richness in woody vegetation cover was studied within ISA to evaluate the habitats of primates and gaur to understand how landscape structure, woody vegetation cover, and species richness is related to the study species. Understanding the mechanisms relating species richness variations to habitat heterogeneity is an important issue in ecology and conservation biology. Tree cover is a primary indicator of any habitat characteristics. Being arboreal, most of the primates are highly dependent on the tree cover of any habitat for their food and roosting places. For species like gibbon, trees are even more important for their locomotion. Despite the ubiquity of highly fragmented habitats and their implications for biodiversity, there is little understanding as how community diversity varies from sites within large, contiguous habitat areas to those within smaller, fragmented areas. Recent theoretical works have shown that the decline of species richness with habitat loss is a non-linear process, with species extinctions becoming more frequent as habitat continues to disappear (Tilman *et al.* 1994, Stone 1995). However, these studies did not use spatially explicit models, making it difficult to infer relationships between spatial patterns of habitat arrangement and species richness. Many tropical species are locally endemic and or rare and patchily distributed (Struhsaker 1975, Richards 1996). Restricted distributions predispose many forest species to an increased risk of extinction when habitats are modified (Terborgh 1992). National parks and reserves, even if effectively protected, most of the time cannot conserve species whose ranges do not fall within a protected area. Although a number of studies have examined the primate habitat and their relationship but majority have been limited to individual species at a time or in separate landscape and face methodological shortcomings while synthesizing results at a community level to understand resource use. Some studies have been conducted after management practices like logging (Plumptre and Reynolds 1994, Bennett and Dahaban 1995, Ganzhorn 1995, Rao and van Schaik 1997) and may be inappropriate for examining the effect of changes in vegetation structure on primate communities, because uncontrolled habitat modification often lowers recruitment but does not usually kill primates (Struhsaker 1997), otherwise true for illegal practice of timber removal. This study tried to evaluate changes in habitat structure vis-à-vis their use by three primate species and gaur.

Here an attempt was made to identify distinguishable characteristics of different habitats linking vegetation with the animal abundance by discussing various aspects of habitat parameters like- habitat used by study species, spatio-temporal variation in the use of different habitat, probability of site occupancy/use in a patch of particular habitat by hoolock gibbon, capped langur and pigtailed macaque, influence of change in site occupancy / use in different habitat across the seasons on detection probability of primates, competitive structure of study primate species in their habitats within ISA, species specific crucial resources etc. Distribution of critical resources in the landscape as well as in different habitats and the habitat parameters that influence their utility in fulfilling the requirements of study species are also discussed in this chapter.

6.2 METHODS

6.2.1 Field method

6.2.1.1 Quantification of Habitat variables (vegetation parameters)

Circular plots along the permanent transects at every 200 m interval were laid for quantification of vegetation and following parameters were recorded once in each sampling season for winter and summer for two years during study period.

- Trees: Ten (10) meter radius circular plots were laid for total enumeration of tree species, GBH, canopy cover in percentage (using densiometer) and tree height.
- Shrubs: Five (5) meter radius nested circular plots were laid to record number of individual shrub species including the seedlings and their individual height.
- Herbs and grasses: One (1) meter radius nested plots were laid to estimate the percentage of herbs, grasses, litter, bare soil etc., using `Point Intercept' method.

At each sampling point, vegetation type, terrain type (flat, gentle slope and steep slope) and distance to nearest water source were also noted.

6.2.1.2 Animal abundance

Transect method (Buckland *et al.* 1993, Burnham *et al.* 1980, Eberhardt 1968) was used to determine abundance of study species in the intensive study area. Detailed methodology is discussed in the previous chapter section 5.2.1.1

6.2.1.3 Habitat use/occupancy

Habitat use was determined by presence and absence of all the study species, group size and structure, GPS location and sampling co-variates *viz.* anthropogenic disturbance, weather, presence-absence of other animals etc. in a site. A total of 35 sites were demarcated in the six habitat types. Size of each site was 400m X 400m and they were distributed on both sides of the animal monitoring transects. Minimum nearest distance within the habitat between any two adjacent sites was 400 meter. The size of the sites were decided on the assumption that the individuals of study species did not leave the area permanently during one sampling season and there was no removal of any individual during sampling seasons (summer and winter). Once in a season, site covariates like vegetation parameters in permanent vegetation plots, number of food trees, tree felling etc. were recorded. Once in study period topographic features like terrain, elevation above mean sea level (MSL) with location were also recorded.

6.2.1.4 Feeding ecology

Initial 3 months were utilized for habituating the selected study group of each study species. Scan animal sampling technique (Altman 1974) was followed to collect data on food plants eaten by the target species. Eight days per season per species spread over two blocks (in the 1st half and 2nd half of the season for 4 days each) were spent for collecting the information on the food habits.

Since gaur were found to be shy in the study area, they could not be followed continuously. Information on gaur food plants and parts eaten were collected during the entire study period based on *ad libitum* observations.

A list of food plants and parts eaten by all the study species during the entire study period were tabulated. Percentage time spent on feeding different plants and their parts were analyzed to assess the utility pattern of different food materials by the study species using statistical software (Minitab 13 and SPSS-11.5). The results thus obtained were correlated with the availability of different food materials inside the study area.

6.2.1.5 Phenology of food plants of study species

Phenological studies of important food plants (trees, shrubs, herbs and grasses) used by study species (gaur, hoolock gibbon, capped langur and pig-tailed macaque) were carried out throughout the study period. Selected plants were monitored once in ten days for their phenological status. In total 38 food plant species (10 for each target species) inclusive of trees, shrubs, grasses and herbs, were selected for this study. Five (5) individuals of each plant species were selected for phenological monitoring and were permanently marked/tagged in the intensive study area.

- For trees and shrubs, percentage availability of young leaves and mature leaves was recorded for vegetative phase.

- Percentage availability of flower bud, flower, unripe fruit and ripe fruit for reproductive phase was recorded based on ocular estimation.

6.2.2 Analytical method

6.2.2.1 Quantification of Habitat variables

BioDiversity professional version 2 (1997) was used for analyzing vegetation structure and composition, species diversity, richness, abundance etc.

The Shannon evenness measure

As a heterogeneity measure the Shannon index takes into account the degrees of evenness in species abundances. The maximum diversity (H_{MAX}) that could possibly occur would be found in a situation where all species had equal abundances, i.e. if $H'=H_{MAX}= \ln S$. The ratio of the observed diversity to maximum diversity can therefore be used to measure evenness (J') (Pielou 1969, 1975): $J'=H'/H_{MAX}=H'/\ln S$.

Simpson's index (D)

Simpson (1949) gave the probability of any two individuals drawn at random from an infinitely large community belonging to the same species as: $D = \Sigma\, p^2_i$ where p_i = the proportion of individuals in the i th species. The form of the index appropriate for a finite community is : $D = \Sigma\ \{ n_i (n_i-1)\} / \{N(N-1)\}$, where n_i = the number of species in the i th species, and N = the total number of individuals. As D increases, diversity decreases .Simpson is therefore usually expressed as 1/D.

Berger – Parker index (d)

The Berger – Perker is an intuitively simple dominance measure (Berger and Parker 1970; May 1975).The Berger-Perker index expresses the proportional abundance of most abundant species; $d = N_{max} / N$ where N_{max} = the number of individuals in the most abundant species. Along with the Simpson index, the reciprocal form of the Berger- Perker index also may also be adopted so that an increases in diversity and a reduction in the dominance can be discussed.

6.2.2.2 Animal abundance

Animal abundance (unit per km^2) was calculated in terms of encounter rate of study species along transects in different habitats for two consecutive years.

6.2.2.3 Habitat use/occupancy

Site occupancy/use was calculated based on model developed by Mackenzie *et al.* (2002, 2003). This Model was used to estimate site occupancy/use of study primate species. Co-Occurrence pattern was analyzed by calculating C-Score as described by Stone and Roberts (1990), The C-score measures the tendency for species assuming that study species does not occur together. V-ratio (Robson 1972, Schluter 1984) which is an index of variability in species richness in each site was also calculated for all the study primate species to calculate the variance ratio and whether the niche limitation constrains the number of coexisting species.

6.2.2.4 Feeding ecology

A list of food plants and parts eaten by all the study species for the entire study period was tabulated. Percentage time spent on feeding different plants and their parts have been reported. Data was analyzed using statistical software Minitab 13 and SPSS 11.5 to know the utility pattern of different food materials by the target species.

6.2.2.5 Phenology of food plants of target species

The quantified phenological information of different plant species are presented on a histogram and then compared with the rainfall, humidity and temperature of the study area across various months. The phenological data was also compared and correlated with the information gathered from feeding ecology of target animals.

6.3 RESULTS

6.3.1 Distinguishable habitat types

Based on the grid sampling of vegetation categories in TWS the landscape of entire ISA was divided into six distinct categories of habitat for study species. These categories are semi-evergreen (Se), degraded semi-evergreen (DSe), mixed deciduous (Md), mixed bamboo (Mb), *Bambusa tulda* dominated (BtD) and savanna woodland (Sw). Total 114 permanent vegetation plots were spread over in their six habitat types along permanent animal monitoring transects (2.2 km to 3.2 km) (Table 6.1).

Characteristic features of these habitat types were considerably different from each others vegetation / land use land cover, terrain type, diversity and evenness of plant cover. As water is not a limiting factor in any of these habitats, it was not considered while evaluating these habitat types.

Table 6.1 Habitat types, length of transects and total distance walked for estimation of animal abundance in Trishna Wildlife Sanctuary.

Habitat types Transect name (ID)	Total length (Km)	Total Dist Walked (Km)	Terrain type **(Appendix-4)**
Degraded semi-evergreen Joychand pur (T1)	2.327	58.16	Plh, Gs, Ms, Mhs, Ss
Semi-evergreen Joychandpur tower-1 (T2)	2.4	62.40	Plh, Gs
Bamboosa tulda Rajnagar lake-3 (T3)	2.075	53.95	Plv, Plh, Gs
Savanna woodland Rajnagar lake-1 (T4)	3.2	76.80	Plh, Gs, Ms
Mixed deciduous Kasari (T5)	2.2	55.00	Plh, Gs, Ms, Mhs, Ss
Mixed bamboo Gibbon point (T6)	2.2	52.80	Plv, Plh, Gs, Ms, Mhs
Total		**359.11**	

Degraded semi-evergreen type of habitat was located in areas nearby Joychandpur. The ISA has diverse terrain ranging from plain land in the valley, gentle slopes, moderate slopes, and moderately high slopes to steep slopes.

Semi-evergreen habitat type is spread over plain land on the hillocks and gentle slopes. *Babmusa tulda* forest type is spread over same terrain type as semi-evergreen including gentle slopes. Southern most part of the ISA is spread in the plain land on the hillocks, gentle slopes and moderately sloped land of the southern most part of the sanctuary. Mixed deciduous forest type was found to be diverse and includes most diverse terrain types including almost all the categories spread uniformly over the area. Mixed bamboo type of habitat is also spread over different terrain categories (table 6.1 and Appendix-4).

Considering alpha diversity for plant diversity in different habitats, the table 6.2 clearly showed the Shannon index value (0.9), which emphasizes the richness component of diversity puts semi evergreen habitat as the most diverse compared to other habitat types. The reciprocal Simpson value (24.05) and Berger –Perker measure (7.44), which weight diversity based on evenness also support to conclude that plant assemblages in semi evergreen has the highest diversity.

Table 6.2 Plant diversity (tree) in different habitats of study species in intensive study area. (2002-2004)

Index	Simpsons Diversity (1/D)	Berger-Parker Dominance (1/d)	Shannon J'
Degraded semi-evergreen	12.59	4.19	0.83
Semi-evergreen	24.05	7.44	0.90
Bambusa tulda dominated	10.14	3.92	0.80
Savana woodland	13.50	4.91	0.89
Mixed deciduous	15.03	6.05	0.87
Mixed bamboo	13.64	6.52	0.82

6.3.2 Characteristics of different habitats and their temporal dynamics

Tree cover estimates in different habitat types showed significant variation both in time and space. Tree basal cover (m^2/hectare) was highest in mixed deciduous forest and its distribution was positively skewed (Fig.6.1A). This indicated that mature trees are more in numbers in mixed deciduous forest and are likely to be suitable habitat for primates. Girth class of trees in mixed bamboo forest was negatively skewed though it had similar central tendency as mixed deciduous habitat type. Compared to mixed deciduous habitat, degraded semi-evergreen habitat had significantly more individual tree density. For semi-evergreen habitat comparing first and second year of study in terms of tree basal area class distribution showed a shift of negative skewness to positive with minimum change in variability, though showing overall increase in total basal cover (TBC). In the first year of study distribution of TBC depicts narrow variance with skewness towards positive side for the larger girth classes. However, the second year showed improvement in the distribution as it approached towards normality with high variability towards larger girth classes. For mixed bamboo in the first year, median of the distribution of tree girth was more close to larger classes with equal variability in both sides. Second year showed increase in median thereby converting the distribution into normal with high variability for the larger girth classes. During first year the girth class of *Bambusa tulda* dominated habitat showed positive skewness with equal variability for the larger and smaller girth classes. But in the case of second year, skewness shifted towards negative side with high variability for the larger girth classes (Fig. 6.1. A and B). Temporal variation of tree cover characteristics in some habitat within a short period are definitely the results of disturbance factors in those areas.

In the first year of study, average tree height (ATH) was normally distributed with high variability in the larger height classes with regard to *Bambusa tulda* dominated habitat. In the second year, height class variation was negatively skewed with high variability for the larger girth class with no or small overall change. In the first year, ATH distribution in the degraded semi-evergreen habitat showed equitable variability for larger and smaller classes but high variability for the lower girth classes. In the next year, the average tree height increased marginally with positive skewness in distribution and high variability for the lower classes. ATH for mixed bamboo showed positive skewness with equal variability for both upper and lower classes during first year, though in second year variability shifted towards larger classes with no considerable change for the over all height class distribution in the habitat. Mixed deciduous habitat showed negative skewness with high variability for entire height class during the first year, while in the second year, the skewness showed positive tendency with high variability for the higher girth classes. In semi-evergreen habitat, ATH showed slight positive skewness with marginal variability for the lower classes. Savannah woodland showed positively skewed distribution with narrow variance in the first year.

In the second year ATH of the habitat attained normality. But variability between higher and lower classes increased (Fig. 6.1 C and D). In comparison to first year the tree density distribution for second year in degraded semi-evergreen clearly showed decrease in overall density of trees. Mixed bamboo showed positive skewness with high variability in tree density for the high density areas during first year.

Second year estimates showed considerable decrease in the overall tree density in the area with decrease in the distance between extremes of density classes. All other habitat types also showed the same pattern thereby indicating decrease in the over all tree density (Fig. 6.1 E and F).

During the first year average height of the shrubs and herbs in *Bambusa tulda* habitat showed positive skewness with high variability for the higher density classes. But in the second year overall average height decreased with prominent skewness towards smaller shrubs and herbs. In comparison to the first year, the second year estimate for shrubs/herbs in degraded semi evergreen habitat showed overall decrease with considerably equal variability for entire range of height classes. The average height of mixed bamboo habitat in the second year comparably decreased though with marginal change in the variability. Changes are not considerable if compared between height classes of shrubs/herbs of semi-evergreen habitat though the median of the distribution shifted towards lower classes during the second year. In the first year, where the individuals of shrubs/herbs with more height was skewed in savannah woodland, they approached towards normality in the second year with narrow variance and marginal decrease (Fig. 6.2 A and B).

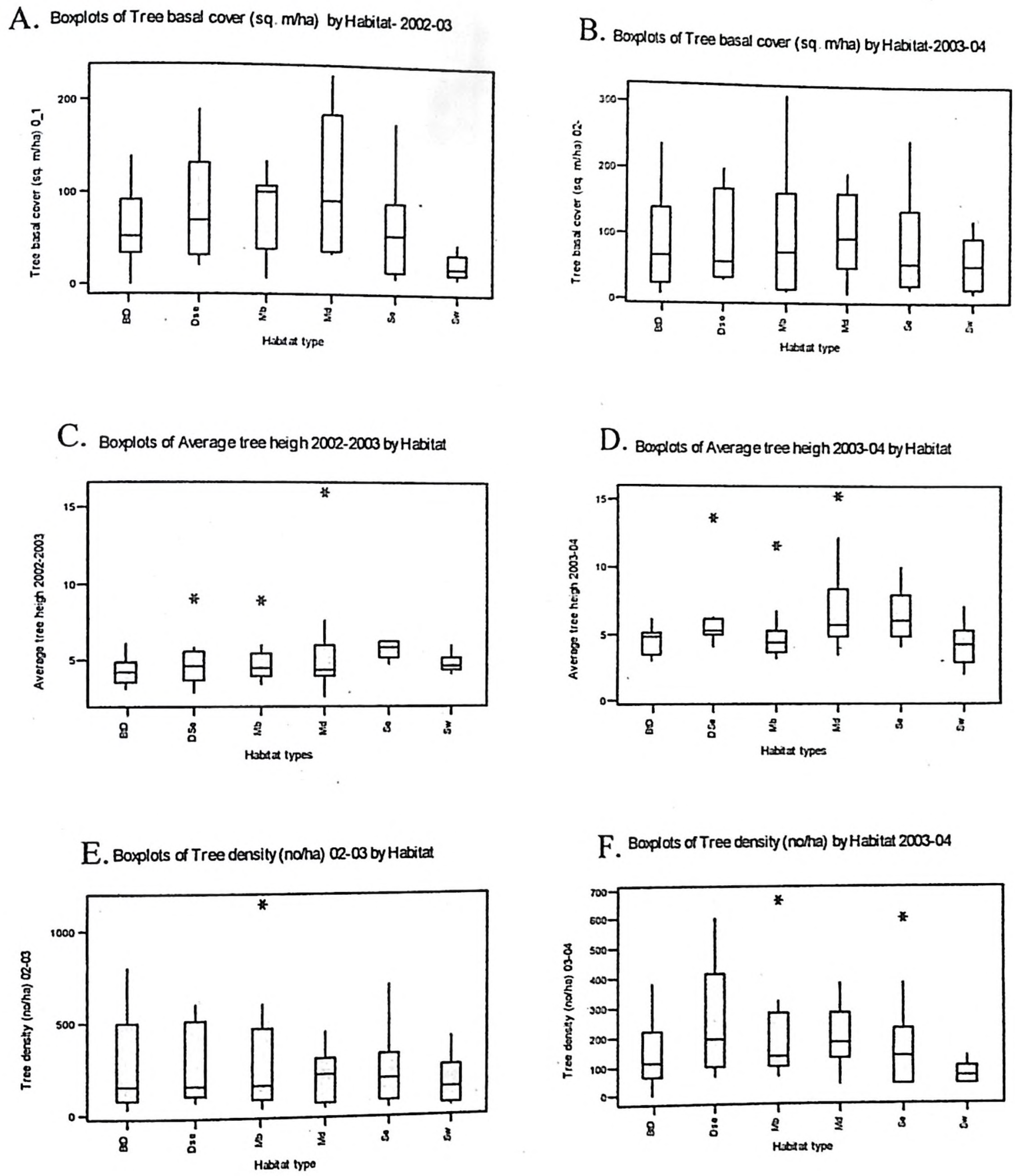


Figure 6.1 Tree characteristics at spatial scale in different habitats of intensive study area. (2002-2004)

In the first year, herb/shrub density in *Bambusa tulda* habitat showed positive variance with high variability for the denser classes. In the second year there was overall decrease though showing positive skewness with less variability for the denser classes. In the first year degraded semi-evergreen forest showed marginal skewness in the distribution for the denser classes with high variability of shrub/herb density. In the second year, density decreased considerably though there was no skewness found for the entire range of density classes.

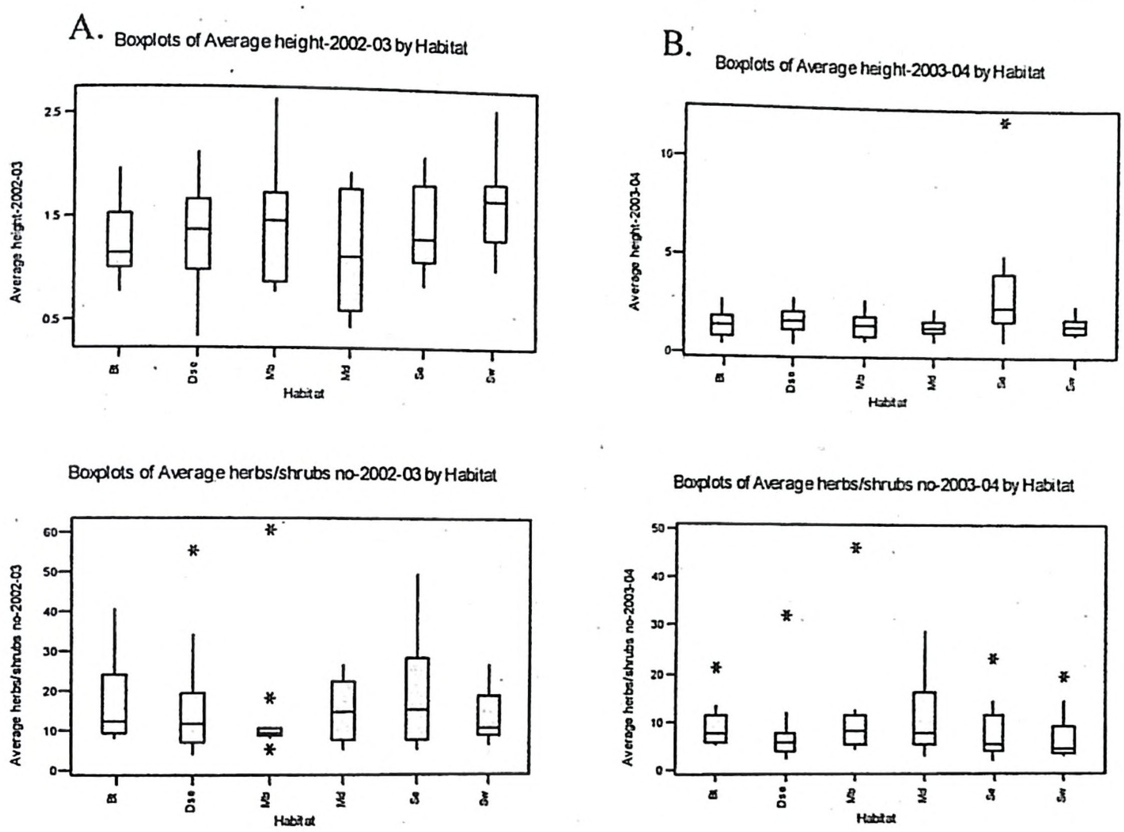


Figure 6.2 Ground cover/ herb shrub characteristics at spatial scale in intensive study area. (2002-2004)

Mixed bamboo habitat improved significantly in terms of shrub/herb density. This type of habitat was found to be most uniform in the density distribution of shrubs/herbs. Moist deciduous habitat did not show any considerable increase in the density of shrubs/herbs but the distribution of density class shifted more skewedly towards denser classes. Semi-evergreen habitat showed overall decrease in the density of the lower layer of vegetation. Also skewness shifted towards higher density classes with low variability in their density. Savannah woodland also showed same pattern, except that there was no considerable change in the skewness of density of shrubs/herbs.

Except for mixed deciduous, the overall percentage of fallen twigs/branches in the ground decreased when compared between year 2002-2003 and 2003-2004 for all the habitat sampled. While comparing grass cover percentage for all habitats in the second year, it showed decrease except for the mixed deciduous habitat (Fig. 6.3).

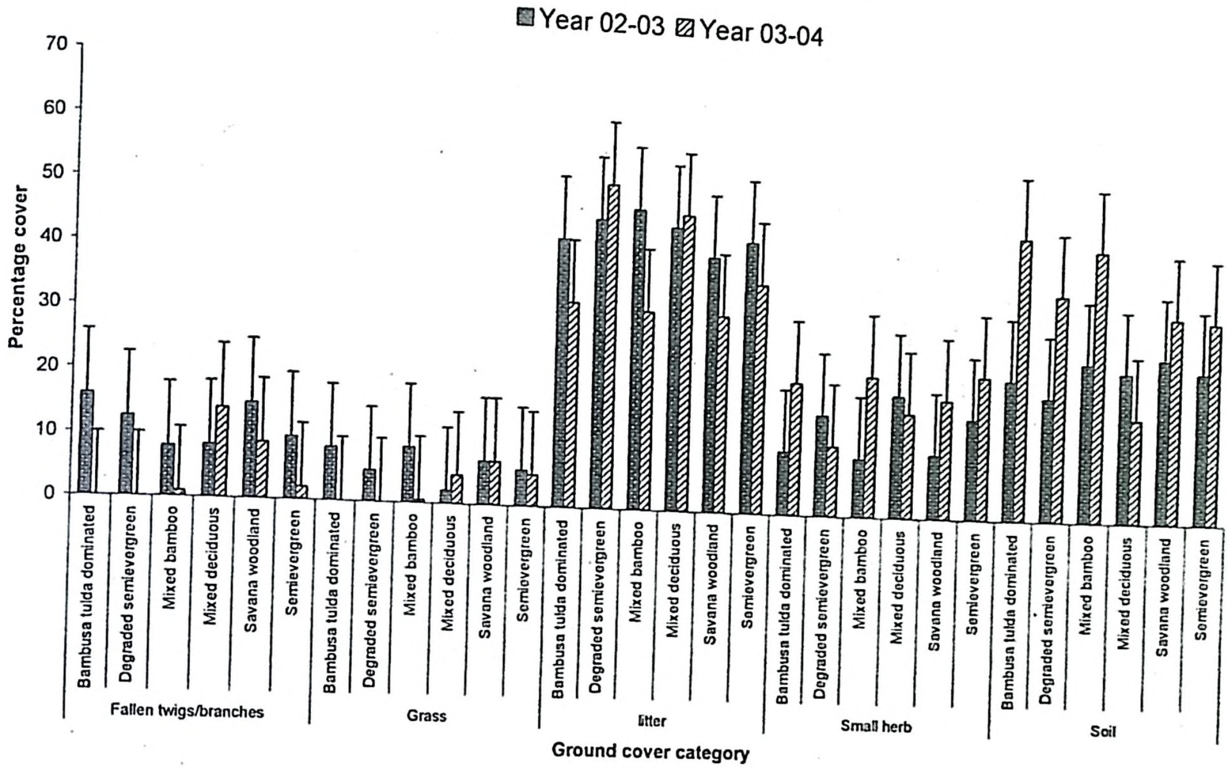


Figure 6.3 Spatial and seasonal variations in the ground cover characteristics of intensive study area. (2002-2004)

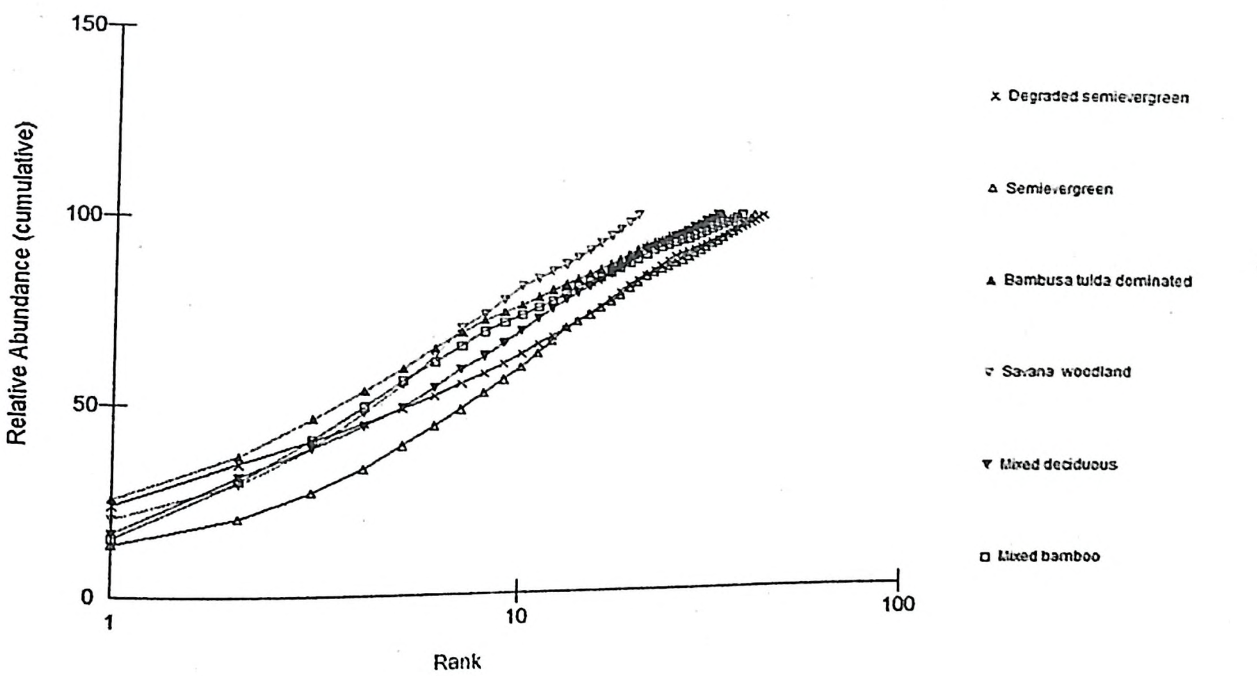


Figure 6.4 K-Dominance plot for vegetation in different habitats of study species in intensive study area. (2002-2004)

6.3.3 Specific plant indicators of six habitats

Six types of habitat as described in section 6.3.1 are distinguished by the relative abundance of different tree species and plant species diversity. *Schima wallichii* showed highest relative abundance in both mixed bamboo, degraded semi-evergreen and mixed deciduous habitats. Associated characteristic species of the mixed bamboo are *Bischofia javanica*, *Holarrhena antidysentrica*, *Terminalia bellirica* and *Microcos paniculata*. Where as degraded semi-evergreen habitat had more abundance of *Aporusa octandra, Baeocarpus aristalus, Holarrhena antidysentrica* and *Mallotus philippnensis*. Mixed deciduous habitat in the ISA is characterized by *Tectona grandis, Terminalia bellirica, Bombax ceiba* and *Syzygium operculata* with highest abundance of *Schima wallichii.* Individual density of trees in the Savanna woodland was lowest and *Ficus hispida* contributes almost 21% of the total abundance of trees in the area. Associated species of figs in the study area are *Garcinia cowa, Bombax ceiba, Terminalia bellirica, Artocrpus chama* etc. As name suggests *Bambusa tulda* was the dominant species in this habitat. But the representative trees of this habitat are *Bischofia javanica, Elaeocarpus aristalus, Terminalia bellirica, Carrya arborea, Greracaena sp.* etc.. *Microcos paniculata, Carrya arborea, Syzygium operculata, Aporusa octandra, Caesalpinia pulcherrima* were the five associated species of the semi-evergreen habitat (Fig. 6.5).

6.3.4 Presence-absence of study species in different habitats

Out of the six habitats categorized in this study, savanna woodland was never found to be used by any of the studied primate species as represented with zero encounter rate in the transects. But this habitat was found to be used by the gaur as a grazing ground. Presence-absence of study primate species in different habitats as an indicator of intensity of habitat use showed that, gibbon used semi-evergreen habitat most frequently, followed by few patches of degraded semi-evergreen types. None other habitats were found to be used by gibbon during study period. Pigtailed used both semi-evergreen and degraded semi-evergreen with equal intensity. Highest intensity of habitat use by pigtailed macaque was observed in the mixed bamboo forest. However, *Bambusa tulda* falls under least used habitat by the pigtailed macaque. Mixed deciduous habitat was almost solely used by the capped langur among other study primate species. Semi evergreen and degraded semi-evergreen habitats were also used by the capped langur with high intensity.

Gaur used entire range of habitats present in intensive study area. It was observed that gaur has specific choice of habitat type that depends on the activity pattern. Open grass lands and agricultural land was the most frequently used grazing ground during night. However, during day time they preferred bushy areas and mostly browsed on the shrubs, herbs and climbers. Gaur used perennial streams more frequently then the seasonal streams and waterholes. Smaller streams were used more then the lakes.

6.3.5 Abundance of study species in different habitats

6.3.5.1 Spatio-temporal variation of capped langur, pigtailed macaque and hoolock gibbon.

Vegetation types, terrain characteristics and effort in six transects passing through six habitat types of ISA are given in the Table 6.1. Transect length varied from 2.2 km for transect-5 in Kasari area, where as southern part of the ISA had 3.2 km long transect starting at Rajnagar lake-1. Transect 4 covered almost all degraded types of habitat for primates. In total 359.125 km of effort in recording animal abundance and their association with habitat was made along this transect in two years.

Encounter rate was used as an index of species abundance in different habitat. All the figures for encounter rate were expressed in unit per kilometer of systematic effort in transect walk. Pigtailed macaque showed seasonal shift in the use of semi-evergreen and *Bambusa tulda* habitat. Though in the beginning of the study, pigtailed was not seen in the degraded semi-evergreen habitat, they were observed in the degraded semi-evergreen habitat (Fig. 6.6A).

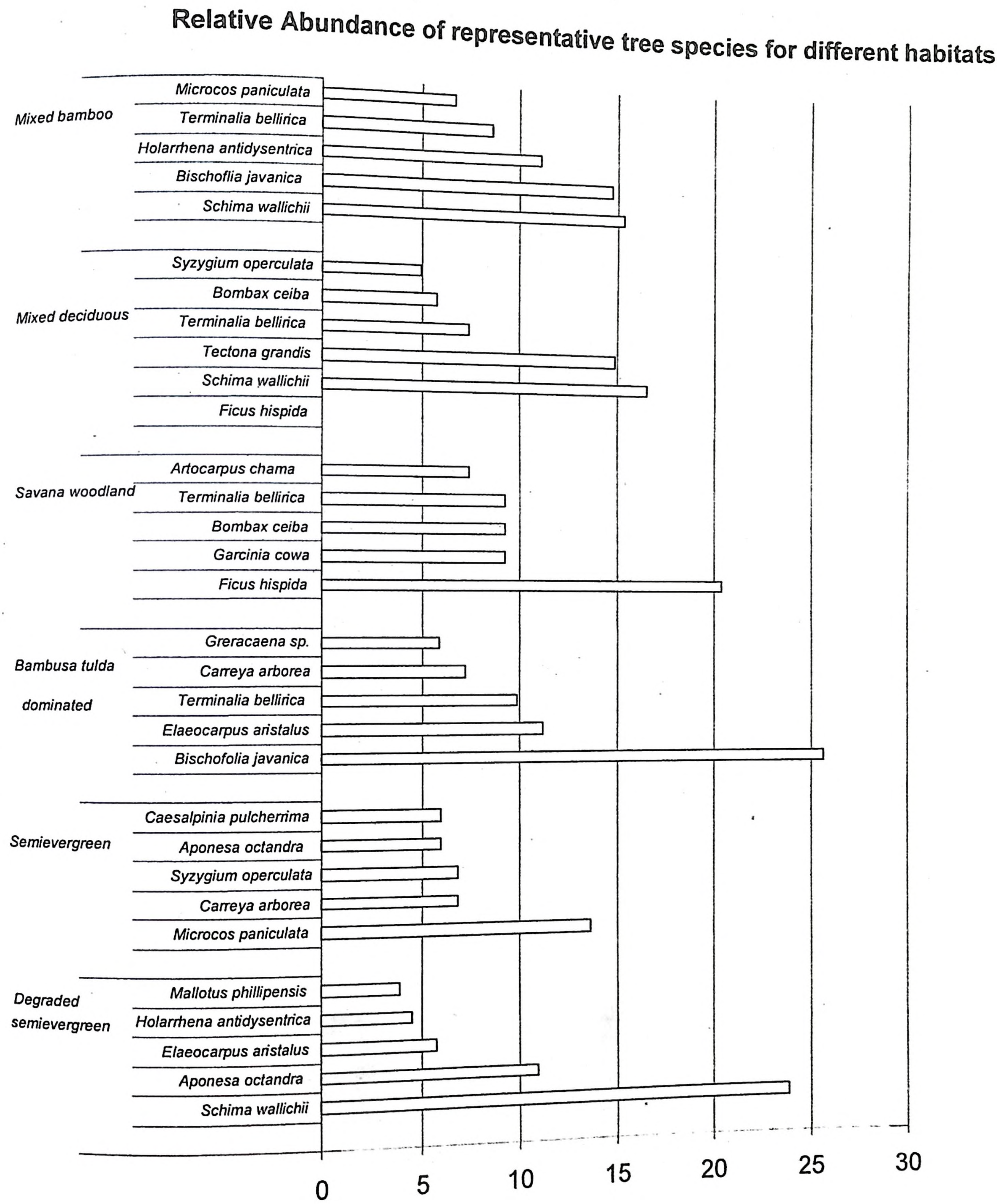


Figure 6.5 Five most abundant tree species of different habitats of study species. (2002-2004)

Overall trend in mixed bamboo habitat for pigtailed macaque was also similar. Though group encounter rate in *Bambusa tulda* habitat remained similar in the second year of study, individual encounter decreased in the summer of second year, indicating decrease in the group size or splitting of the groups (Fig. 6.7A) of pigtailed macaque. Overall there was a decreasing trend in the encounter rate of capped langur in almost all the habitat types after first year. It was almost constant in summer and winter thereafter. Relative encounter rate was higher for capped langur then pigtailed macaque (Fig. 6.6B). Similar trend was seen for individual encounter rate and it was low in the summer 2004 (Fig. 6.7B). Gibbon did not show any seasonal variation but they were not found in the degraded semi-evergreen after the first year of study. Encounter rate in the semi-evergreen forest drastically increased and it was almost equal till the end of the study period. No other habitats other than semi-evergreen and degraded semi-evergreen were found to be used by gibbon (Fig. 6.6C). Though there was an increase in individual encounter rate observed for gibbon in the semi-evergreen habitat, this could be attributed to shift of gibbon from degraded semi-evergreen to semi-evergreen type (Fig. 6.7C).

6.3.5.2 Spatio-temporal variation of Gaur

Gaur showed the highest rate of individual as well as group encounter rates in the mixed bamboo forest followed by degraded semi-evergreen. Gaur did not show any specific pattern of seasonal shift in their encounter rate. Encounter rate was significantly different between habitats being the highest in mixed bamboo forest and the lowest in mixed deciduous habitat. Winter 2003-04 showed an increasing trend in individual as well as group encounter in the *Bambusa tulda* dominated, mixed deciduous and savanna woodland (Fig. 6.8A and B). Increased encounter with calf in all the habitat types indicated an increase in the total number of gaur within ISA.

Based on the direct sightings of gaur in different habitats, their group and individual density was calculated. Looking at the ground situation of the field, this was found to be the most useful abundance estimate to discuss the use of different habitat by gaur. Mixed bamboo habitat had the highest group density (Mean±SE) of 4.37±1.27 and individual density of 19.99±6.12. This was followed by degraded semi evergreen (group density: 1.599±0.748, individual density: 6.80±3.73), *Bambusa tulda* (group density: 1.390±0.770, individual density: 5.10±3.48), Semi-evergreen (group density: 0.281±0.281, individual density: 3.81±0.201) and mixed deciduous (group density: 1.136±0.628, individual density: 4.17±2.85) (Table 6.5) habitat.

6.3.6 Site occupancy/use in different habitats

6.3.6.1 Capped langur, pigtailed macaque and gibbon

Capped langur site occupancy was 0.245 to 0.250 (Table 6.3). Among the primates, site occupancy was highest with maximum variability for gibbon and ranged between 0.120 and 0.443. Pigtailed macaque site occupancy doubled in two years and estimated to be 0.111 and 0.222 respectively for 1st and 2nd year. Semi-evergreen habitat was found to be the most important for maintaining primate species diversity as this type showed presence of all the primate species of ISA. Savannah woodland remained totally unoccupied. Mixed bamboo forest was solely occupied by pigtailed macaque. Mixed deciduous habitat was dominated by capped langur. Semi-evergreen patch was the only habitat to be occupied by all three species. In degraded semi-evergreen habitat there was no change in capped langur occupancy. The details of site occupancy of different study species are given in table 6.3.

6.3.6.2 Gaur

Site use for gaur was calculated based on the indirect evidences and it was 0.75 to 0.76. So, it can be concluded that gaur used areas uniformly and there is no significant change in the site use pattern by them. Model fit (MacKenzie 2002) was estimated with AIC value 258.53 and 383.65 respectively for first year and second year (Table 6.3).

6.3.7 Co-occurrence and co-existence of study species in six habitats of ISA

The non-human primate community was not competitively structured in any of the habitat types of TWS-ISA. Though hoolock gibbon, capped langur and pigtailed macaque co-existed in semi-evergreen type of forest, there was temporal separation and no co-occurrence was observed (table 6.4). This showed that niche limitations were not likely to constrain co-existence of studied primate species. Co-existence pattern of study primate species based on their presence absence in different habitat is shown in the Appendix-10.

6.3.8 Species specific crucial resources

6.3.8.1 Feeding ecology of Capped langur, pigtailed macaque and gibbon

Capped langur exploited maximum number of food items during summer, whereas both pigtailed and gibbon were found to explore more food items during winter. Total 38 food items were eaten by capped langur during summer, out of which 23 plants were eaten for their vegetative parts like leaf bud, young leaf and mature leaf, and 15 species were eaten for their reproductive parts like flower, flower bud and seeds. During winter a total of 33 plant species were eaten by capped langur, of which 26 plant species were eaten for vegetative parts (Fig. 6.9). List of frequently used food plants for study primate species recorded during the study period and studied for phenological status in TWS is given in the Appendix-9.

Pigtailed macaque showed almost equal number of plants chosen by them in their diet for vegetative and reproductive parts. Total 35 and 30 plant species contributed in the diet of pigtailed during winter and summer respectively. Out of 35 and 30 species, 19 and 16 species were exploited for their vegetative parts during winter and summer, respectively. Reproductive parts of 16 and 14 plant species were exploited for food by pigtailed during winter and summer (Fig. 6.9).

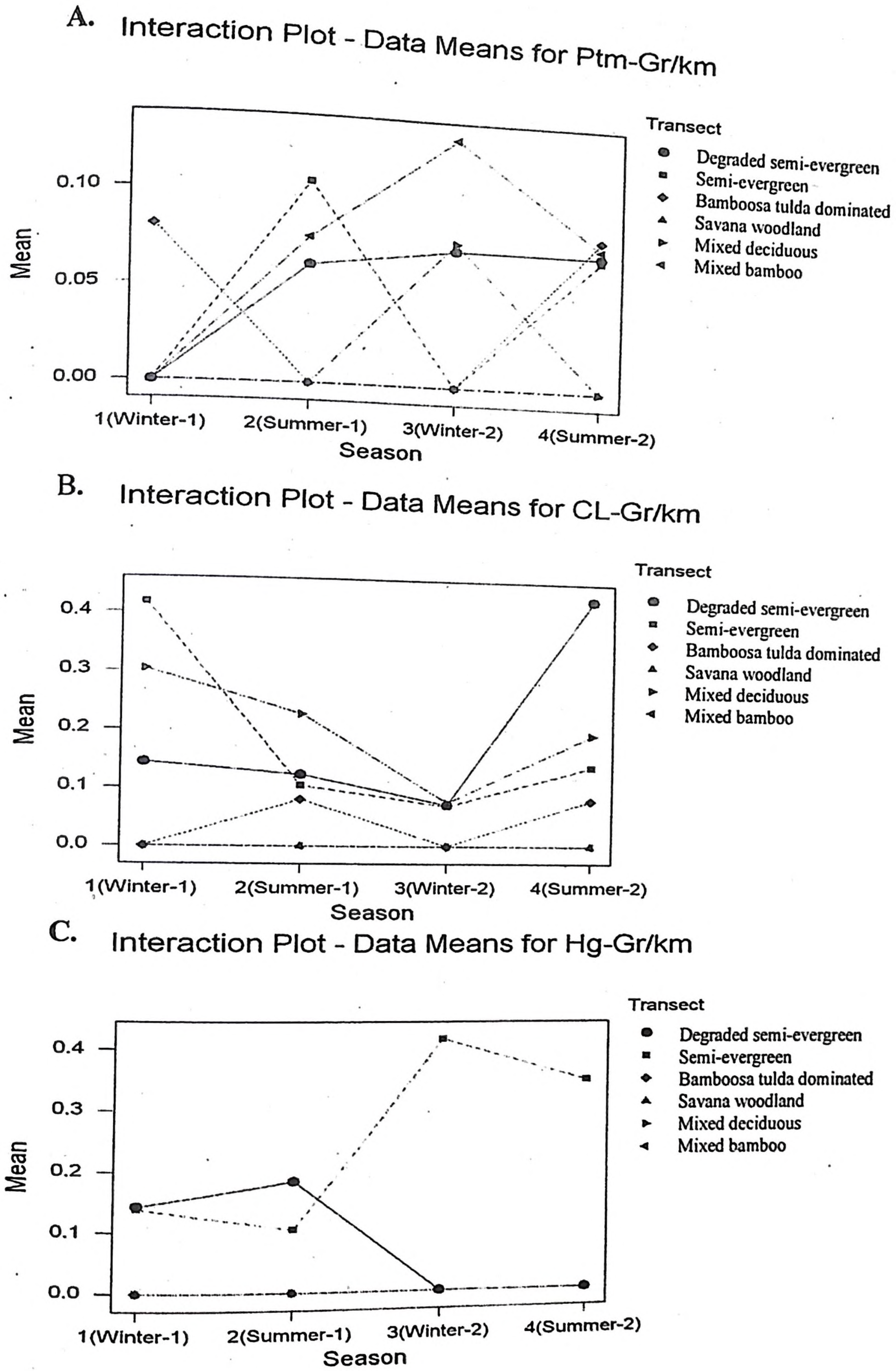


Figure 6.6 Spatial and seasonal changes in the mean rate of group encounter of non human primates in intensive study area. (Ptm- Pigtailed macaque, Cl- Capped langur, Hg- Hoolock gibbon, Gr- Group) (2002-2004)

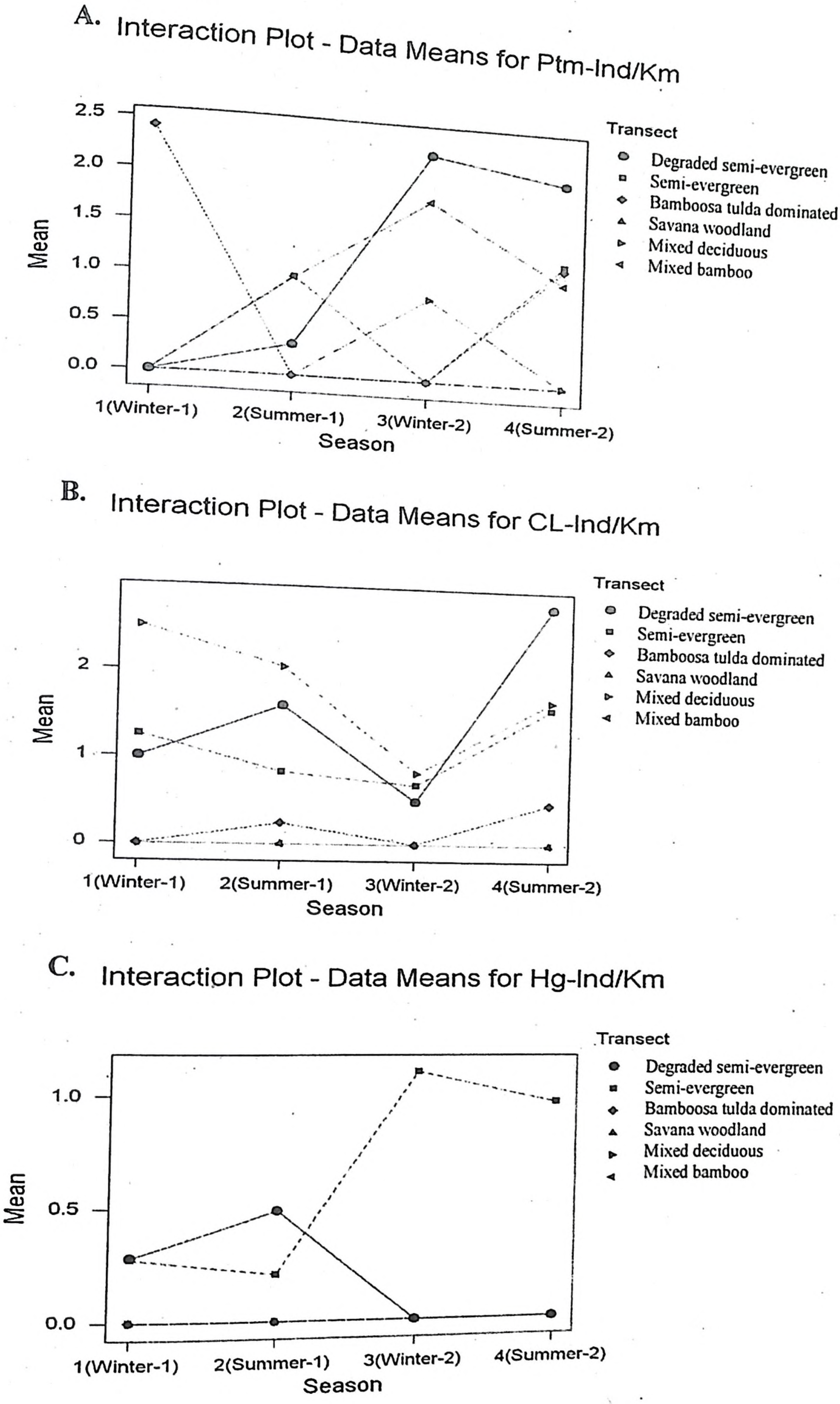
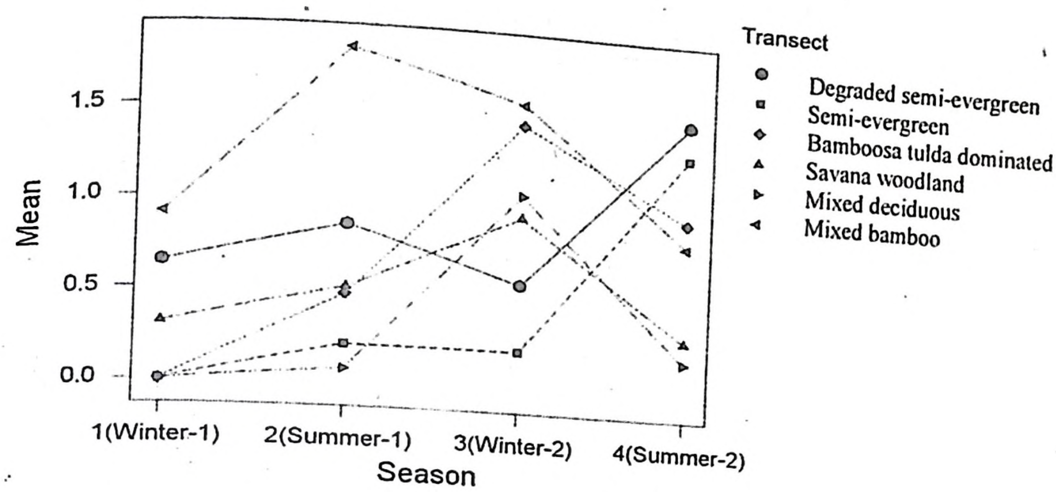


Figure 6.7 Spatial and seasonal changes in the mean rate of individual encounter of non human primates in intensive study area. (Ptm- Pigtailed macaque, Cl- Capped langur, Hg- Hoolock gibbon, Ind- Individual) (2002-2004)

A. Interaction Plot - Data Means for Ind-Er/Km



B. Interaction Plot - Data Means for Gr-Er/Km

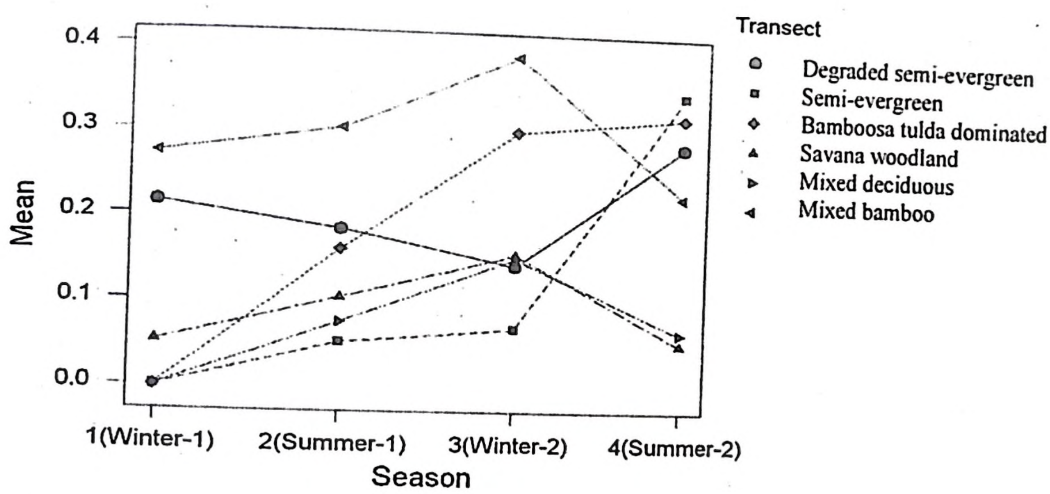


Figure 6.8 Spatial and seasonal changes in the mean of total and adult population of gaur in the intensive study area. (Ind- Individual, Gr- Group, Er-Encounter rate) (2002-2004)

Gibbon diet was contributed by minimum number of plants. Fourteen (14) and thirteen (13) plant species were used in their diet during winter for vegetative and reproductive parts respectively. *Bombax ceiba* flowers contributed a large amount of morning diet of gibbons. Total number of plants used in food were less during summer. Only 23 plant species were recorded as food during summer out of which 14 species were used for their reproductive parts, mostly for fruits (Fig. 6.9).

Though total plant species exploited by these three primates were not significantly different but it differed in terms of species. Consumption pattern (as evident from the parts preferred) is indicative of their habit as folivorous for capped langur and frugivorous for both pigtailed and hoolock gibbon. Overall contribution of fruit was much more for gibbon then pigtailed (Fig. 6.10).

Table 6.3 Temporal variation of occurrence, site occupancy (with assumption -detection probabilities are less then 1) of gibbon, capped langur, pigtailed macaque and gaur in intensive study area (2002-2004).

	-2log (likelihood)	**AIC**	**Naive estimate**	**Proportion of sites occupied**
Capped langur: Year 2002-2003	129.1809	133	0.22	0.2504 (0.0805)
Capped langur: Year 2003-2004	132.3109	136	0.22	0.2450 (0.0781)
Pigtailed macaque: Year 2002-2003	45.4199	49	0.11	1.0000 (0.0000)
pigtailed macaque: Year 2003-2004	87.4908	91	0.22	0.9602 (0.1277)
Hoolock gibbon: Year 2002-2003	86.1936	90	0.19	0.4427 (0.1770)
Hoolock gibbon: Year 2003-2004	73.6790	77	0.11	0.1204 (0.0590)
Gaur ((indirect): Year 2002-2003	254.5350	258	0.58	0.7528 (0.1060)
Gaur (indirect): Year 2003-2004	379.6511	383	0.72	0.7592 (0.0785)

There was a significant variation observed in the proportionate time spent on feeding activity during winter and summer by frugivorous study species. During winter pigtailed spent 69.9% of their activity for foraging followed by capped langur 65.12% and gibbon 53.12%. Time spent on foraging reduced in the summer for capped langur (42.3%) and pigtailed macaque (57.8%). Only for gibbon foraging time increased to 61.3% during summer (Fig. 6.11).

Table 6.4 Co-occurrence pattern of gibbon, capped langur and pigtailed macaque in different habitats of study species within intensive study area (2002-2004).

	C-Score	Mean simulated indices	p(observed >= Expected)	V-Ratio	Mean simulated indices	p(observed >= Expected)
Degraded evergreen	0.333	0.67153	0.7362	1	0.99496	0.4704
Semi-evergreen	0	0	1	1	1	1
Bamboo forest	1	0.97487	0.6656	1	0.97529	0.4632
Savannah Woodland	0	0	0	0	0	0
Mixed Deciduous	0	0.9766	1	1	0.99725	0.6306
Mixed Bamboo	0	0	0	0	0	0

Maximum observation on feeding was made in case of capped langur compared to other two species. Leaf content in the food of capped langur was 70%, of which young and mature leaves contributed for 43% and 27% respectively. This was followed by flower and flower buds (12%), seeds (7%) and ripe and unripe fruits (6%). Insects and others contributed 4% of the total diet of capped langur. About one percent of their feeding sign was recorded while eating insects as a part of their diet (Table 6.5). Ripe and unripe fruits contributed 32% and 23% of total food respectively in the diet of pigtailed macaque. Compared to young leaf (13%) they consumed more matured leaf (15%). Considerable amount of flower (7%) contributed to the diet of pigtailed. Only pigtailed was observed to feed on earth (soil) during summer near seasonal streams. Feeding events in 5.2% cases could not be identified as they occupied areas with poor visibility and lower canopy inside bamboo forest and scrubs (Table 6.5). Gibbons were found to feed on 43% ripe fruits followed by 23% unripe fruits. Consumption of unripe fruits by gibbon was found to be the same as pigtailed. Flowers contributed 10.5% of the total food items in gibbon diet. There was no sign of gibbon feeding on soil or insects. Leafs contributed 8% of their diet (Table 6.5).

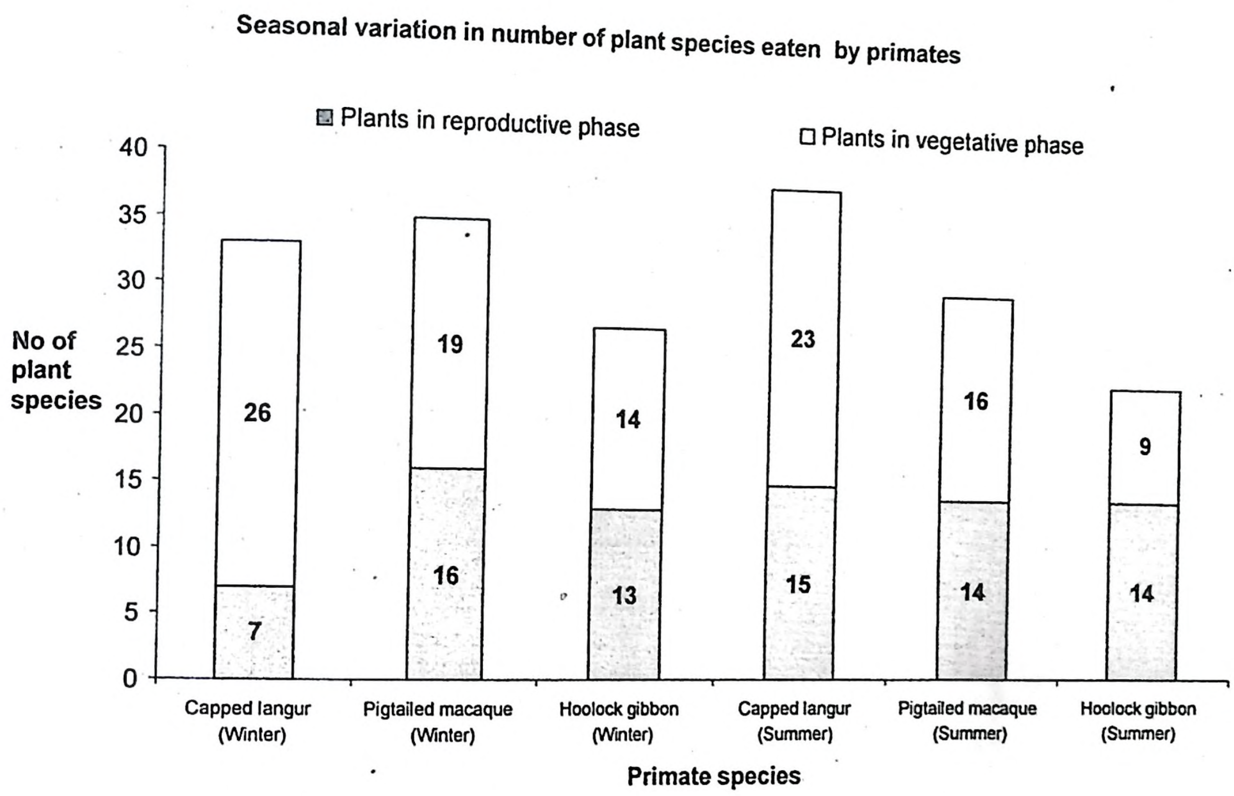


Figure 6.9 The number of plant species eaten by capped langur, pigtailed macaque and hoolock gibbon in each season at intensive study area (2002-2004). (Values in the graph are total number of species recorded during two sampling session of eight days in each season)

6.3.8.2 Feeding ecology of gaur

In total 56 food plants were recorded as gaur food plants, of which 12 were tree species, 22 shrubs and herbs, 9 climbers and 13 grasses including 4 species of bamboo. There was a seasonal variation in the food plants/parts eaten but the number of observations were not found significantly different. During winter, they were found to feed on paddy. List of food plants for gaur recorded during the study period in TWS is given in the Appendix-9.

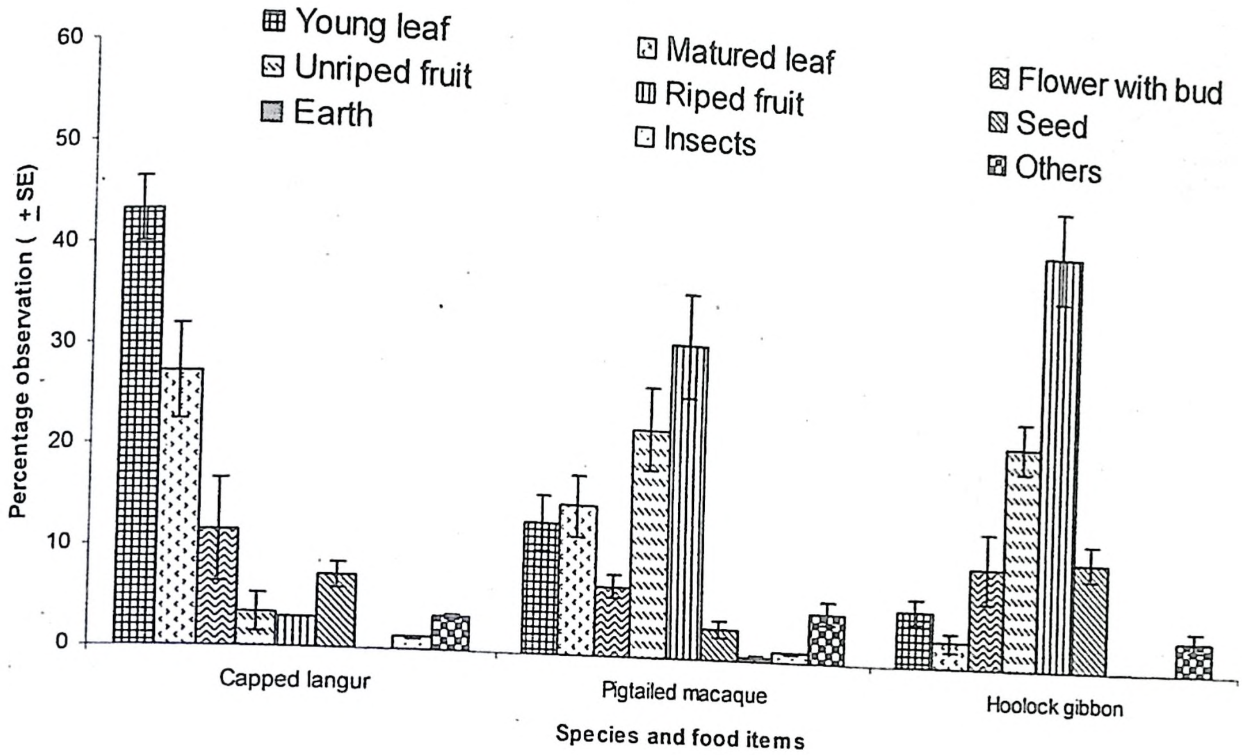


Figure 6.10 Overall variation in the composition of the diet of capped langur, pigtailed macaque and hoolock gibbon in intensive study area (2002-2004). (Values are percentages of feeding records collected for each species, according to item, **NHP-** Non Human Primates) (Vertical lines with bar is showing standard error.)

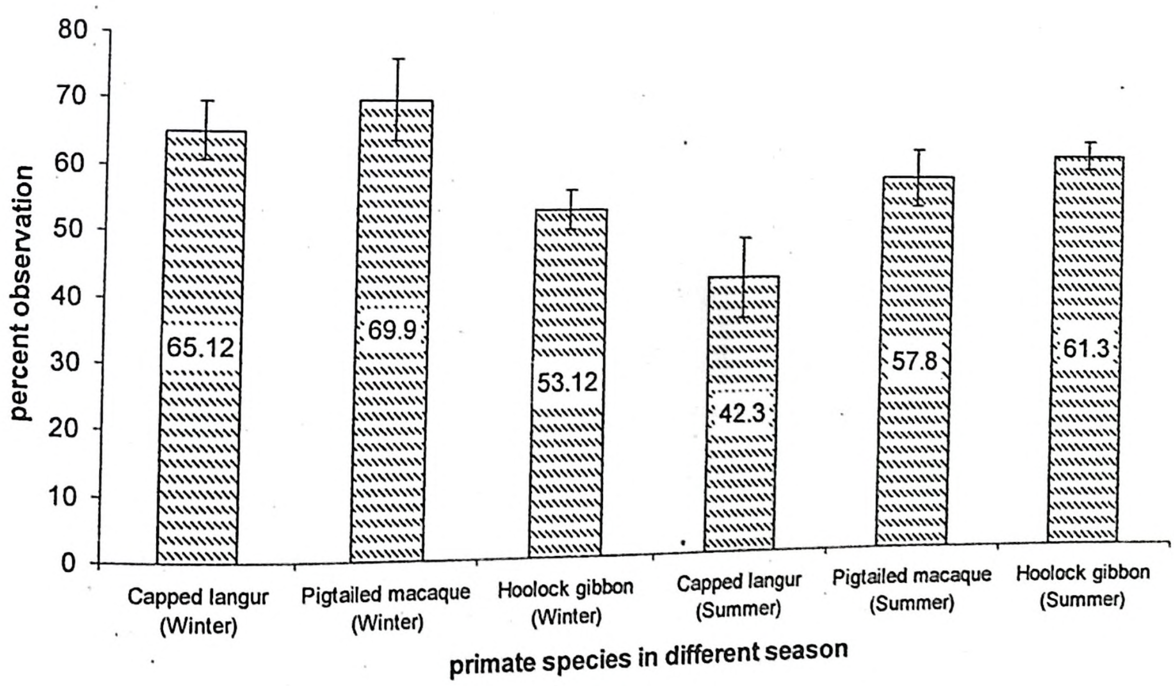


Figure 6.11 Seasonal shift in the feeding time for capped langur, pigtailed macaque and hoolock gibbon in intensive study area. (2002-2004) (Vertical lines with bar is showing standard error.)

Table: 6.5 Percent occurrence (mean ± standard error) of food items recorded in the diet of three primates in intensive study area.

Species	Young leaf	Matured leaf	Flower with bud	Unripe fruit	Ripe fruit	Seed	Soil	Insects	Others
Capped langur	43.12 ± 3.14	27.11 ± 4.65	11.51 ± 5.21	3.42 ± 1.92	2.97 ± 0.07	7.23 ± 1.21	0	1.21 ± 0.12	3.43 ± 0.19
Pigtailed macaque	13.23 ± 2.86	15.11 ± 3.1	7.13 ± 1.21	23.11 ± 4.16	31.73 ± 5.2	3.18 ± 0.88	0.34 ± 0.31	0.97 ± 0.13	5.2 ± 1.21
Hoolock gibbon	5.75 ± 1.25	2.67 ± 0.88	10.49 ± 3.65	23.12 ± 2.59	43.11 ± 4.75	11.41 ± 1.87	0	0	3.45 ± 0.99

Note: Number of total scan of all activities of individual in a study group of Capped langur, N= 4321, Pigtailed macaque, N=4699 and hoolock gibbon, N=1918.

6.3.9 Phenology of food plants of study species

Plant parts like leaves, flowers, fruits and seeds are some of the most commonly and widely used resources by the study species. The availability of these resources exhibited inter-seasonal, annual and site variations. Many species were strictly seasonal in flowering and fruiting (eg. *Bombax ceiba, Castanopsis indica*), some were seasonal (eg. *Dillenia pentagyna, Ficus ologadon*), and by being available even during pinch periods, serve as key stone resources. Seasonal species are those that could be sub-annual, annual, or supra-annual and also include those that exhibit synchronous or staggered phenophases.

The highest number of food items bearing flowers was observed during summer (14 out of 22 species) followed by winter and rainy season (5 out of 18). During rainy season, except *Terminalia bellirica* there was no flowering plant in the list of plants monitored for phenology. During summer availability of flower was highest for *Syzygium operculata* (70%) followed by *Vitex allissima* (43.33%). For rest of the species flower availability varied between 25-35% (Appendix-9). During summer fruit availability was as high as 80% for some species, but most of the species were found having 15-30% of fruits (Fig. 6.12 B). Though there were almost no flowers available but there was no lack of matured and young fruits during the rainy season (Appendix-9). Most fruit scarce period was winter. *Vitex allissima* had almost 27% matured fruit followed by *Castanopsis indica* (7.67%) and *Terminalia bellirica* (5.67%). These plants also had equal proportion of young fruit along with *Bombax ceiba* with 15% of young fruit. Almost all the species had very high amount (50-90%) of matured leaves during winter and very few plants had young leaves (Fig. 6.12 A). Rainy season had maximum amount of matured leaves with almost half of the species with leaf buds and young leaves (Fig. 6.12 C). Most of the plant species studied for phenology belonged to deciduous category and thus during winter about 26% of the branches remained without leaves. However, in some cases estimate was as high as 60-70% (Appendix-9).

6.3.10 Characteristics of roosting and resting places of study species

6.3.10.1 Roosting places of Capped langur, pigtailed macaque and gibbon

Gibbon, pigtailed and capped langur opted for roosting places which are considerably different in terms of terrain category, average tree height, spread of group in trees, and canopy cover (Fig. 6.13). Gibbon preferred more sloppy terrain followed by pigtailed and capped langur. There was not much seasonal variation for preferred terrain type. Capped langur preferred roosting places in relatively plain topography (Table 6.6). Hoolock gibbon preferred roosting places in trees with average height ranging from 6m to 8m. Pigtailed macaques were found to occupy relatively higher canopy but with high variability as compared with gibbon. Average height of roosting trees for pigtailed were found to range between 8m to 10m. Capped langurs were found to prefer larger trees and trees with heights more than other two study species (primate). Seasonal variation did not show any pattern and were not significant. Average height of trees for capped langur ranges between 9 to 11m (Table 6.6). Gibbons were always found to roost in single tree during dusk, however there are instances when they were found in two trees during dawn. On an average capped langurs occupied two trees though sometime they were found roosting in four trees after dusk.

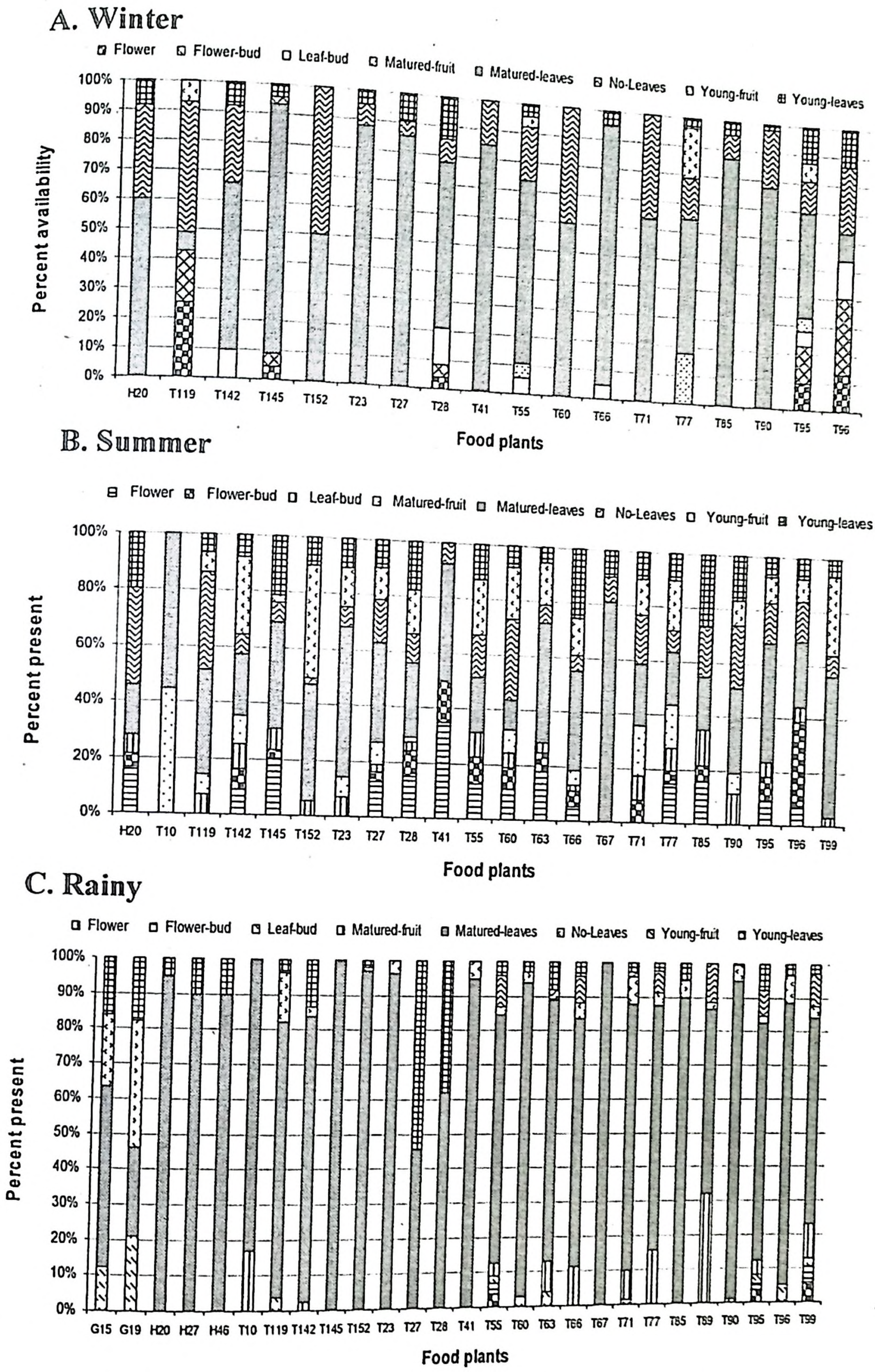


Figure 6.12 Seasonal variation in the Phenology of food plants of study species (G15- *Oxytenanthera nigrocciliata*, G19-*Bambusa tulda* , H27-*Pinanga sp*., H46-*Hedyelium Sp*. ,T10-*Garcinia cowa*, T119-*Bombax ceiba*, T23-*Ficus hispida*, T27-*Ardisia solanaceae*, T28-*Aglaia Sp*., T41-*Syzygium operculata*, T55-*Terminalia bellirica*,T60-*Dillenia pentagyna*, T63-*Macaranga peltata*, T66-*Ficus oligadon*, T67-*Emblica officinalis*, T71-*Carreya arborea*, T77-*Vitex allissima*, , T89-*Microcos paniculata*, T90-*Artocarpus chama*, T96-*Lannea coromandelica*) in intensive study area. (2002-2004)

Maximum group spread in terms of trees used by them for roosting was found for pigtailed. And almost all the time they preferred more than three trees (Table 6.6). This spread is highly correlated with the group size. More or less the canopy cover of the trees opted for roosting were uniform for all the species and across the seasons. Except in few cases, gibbon preferred denser canopy compared to other study primate species (Table 6.6).

6.3.10.2 Resting places of gaur

Ad-libitum information collected on gaur resting places showed that they used relatively flat terrain on the hillocks or in the flat land of valley with shaded cover in undisturbed areas. Resting times of gaur were recorded during bright sunlight and hot weather. Rarely even they were even seen feeding during noon. Usually gaur had chosen central parts of the ISA of the sanctuary for resting purpose.

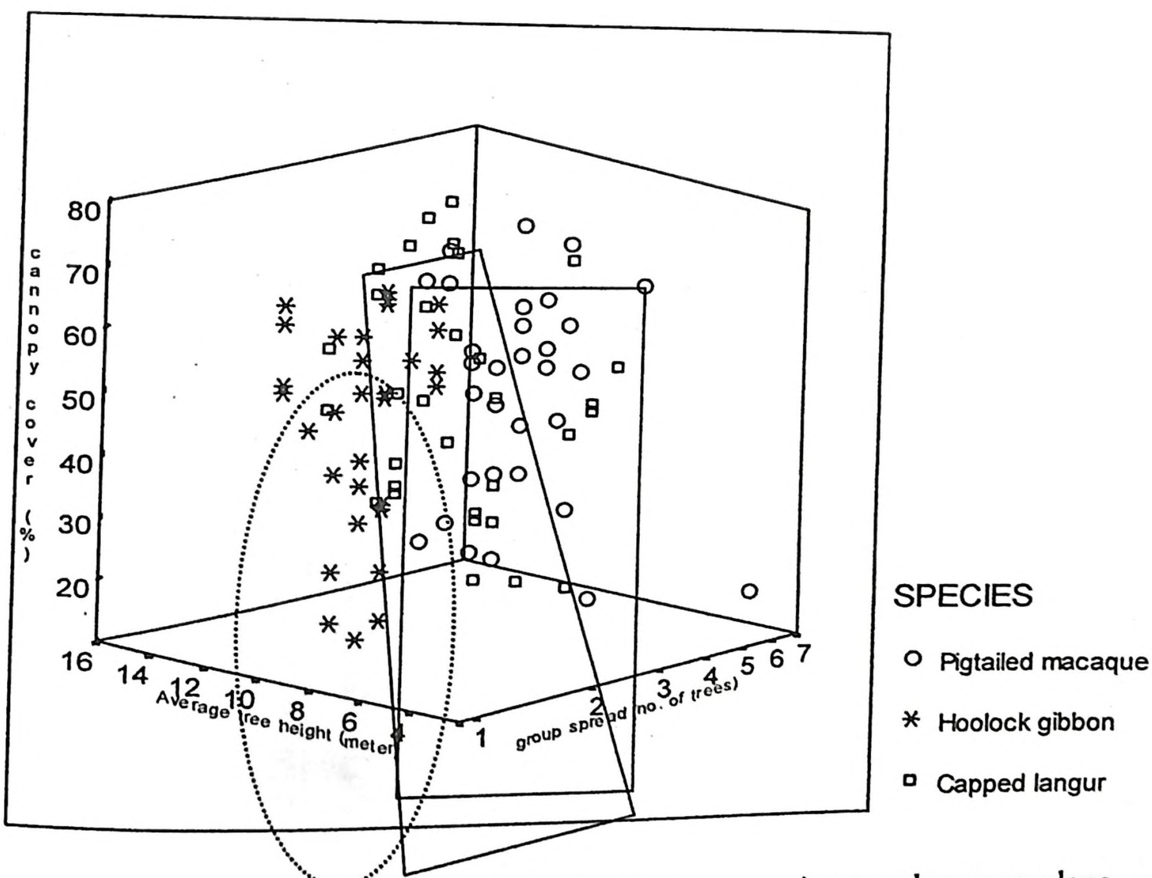


Figure 6.13 Characteristics of roosting places of three primates shown as plane in three dimensional scale representing canopy cover, average tree height and group spread in number of trees.

Table 6.6 *Characteristic features of roosting places of study (primates) species in intensive study area. (2002-2004)*

Seasons	Primate species	Terrain(category)	Average tree height (meter)	Group spread in no. of trees	Canopy cover (%)
Winter 2002-03	Pigtailed macaque (N=8)	3.00±0.00	9.88±0.85	3.50±0.2s7	41.88±5.76
	Hoolock gibbon (N=8)	3.88±0.44	7.13±0.74	1.00±0.00	45.75±8.59
	Capped langur (N=8)	2.00±0.00	10.13±0.97	2.75±0.25	50.25±6.58
Summer 2003	Pigtailed macaque (N=8)	2.63±0.18	8.25±1.10	4.00±0.33	45.38±6.48
	Hoolock gibbon (N=8)	3.50±0.57	6.50±0.53	1.00±0.00	47.75±4.72
	Capped langur (N=8)	2.63±0.18	11.25±0.96	2.75±0.16	48.13±7.56
Winter 2003-04	Pigtailed macaque (N=8)	3.25±0.25	10.00±0.53	3.75±0.16	56.25±5.30
	Hoolock gibbon (N=8)	3.88±0.64	7.13±0.72	1.00±0.00	61.88±3.64
	Capped langur (N=8)	2.25±0.16	8.63±1.08	3.00±0.27	45.75±5.93
Summer 2004	Pigtailed macaque (N=8)	2.88±0.35	9.88±0.40	3.75±0.25	40.38±5.27
	Hoolock gibbon (N=8)	3.38±0.38	6.88±0.55	1.00±0.00	54.38±5.84
	Capped langur (N=8)	2.50±0.19	9.38±1.02	2.75±0.25	47.25±5.80

Note: terrain characteristics in scale 1-5, 1=1=Plain land in the valley, 2=Plain land on the hillock (tilla), 3=Gentle slope, 4=Moderate slope, 5= Moderately high slope, 6= Steep slope.

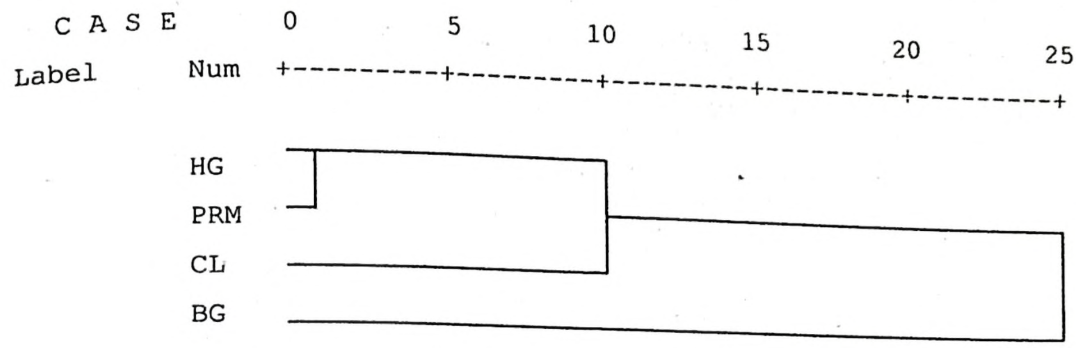


Figure 6.14: Rescaled Distance Cluster Combine: based on presence absence of study species and covariates in Trishna Wildlife Sanctuary. (HG- Hoolock gibbon, PTM- Pigtailed macaque, CL- Capped langur, BG- Gaur).(2002-2004)

6.4 DISCUSSION

6.4.1 Characteristics and dynamics of habitat types in ISA.

Six distinguished habitats, semi-evergreen, degraded semi-evergreen, mixed deciduous, mixed bamboo, *Bambusa tulda* dominated and savanna woodland formed a complex land matrix for the study species in ISA. Distinguished dimension of landscape characteristic features of these habitat types formed diverse land matrix for habitat generalists (eg. gaur) to habitat specialists (eg. gibbon). These habitats are distributed in patches of different sizes forming fragmented vegetative landscape. The Shannon index value (0.898) indicated considerable high floral diversity of the area. Semi-evergreen habitat was the most diverse in comparison with other habitats and formed an ideal place to support rich biodiversity. Diversity measures based on evenness by Simpson value and Berger–Perker measures also supported to conclude that semi evergreen habitat has the highest plant assemblages compared with other five habitat types. Many factors can influence woody plant species richness, but most can be grouped into two categories: short duration temporal change due to anthropogenic disturbances and natural dynamics of change in vegetation structure following succession. Available data analyzed here included only permanent plots with nearly similar tree cover in each habitat and showed significant variation both in short span of time and space. Temporal variation of tree cover characteristics in some habitats within a short period were definitely the results of anthropogenic disturbance in those areas. Direct removal of matured tree species would definitely reduce the basal cover of fruiting and flowering species. Whichever habitat type it may be, it is clear from the study that the tree cover is reducing drastically in the ISA and this is the immediate threat to hoolock gibbon, which is a habitat specialist. Reduction in tree cover though may be an immediate threat to other study primate species but they are not likely to affect gaur population at present. In long run, gaur may also face threat from decreasing forest cover.

Study showed that the taller trees are facing more threat of being felled. Exception in the semi-evergreen habitat is due to its present distribution in the landscape. May be due to lack of transportation facility and being in the centre of the ISA, it was difficult for the illicit fellers to fell and transport big trees. There pressure was on medium sized trees and bamboos. Most drastic change in the negative direction was found in case of mixed deciduous habitat parameters. Less vigilance and accessibility to road might be the reason for such change. Ground cover did not show any considerable variation only in case of mixed deciduous, otherwise all other habitats showed decreasing trend in grass cover. Uncontrolled grazing and removal of thatch grasses from the ISA could be the reason behind this. With the opening of upper canopy, grass cover showed considerable increase in the mixed deciduous forest.

Closed canopies reduce habitat heterogeneity within forests and suppress woody species with medium to high light requirements. As a consequence, woody plant richness can be related negatively to tree canopy cover and positively to undergrowth cover. For instance, if trees dominate in a plot, richness should be low because the number of tree species is typically moderate. Conversely, a high dominance of shrubs will often lead to higher richness.

No significant change in the hight class of woody vegetation in the *Bambusa tulda* habitat is an indicator of less anthropogenic pressure. During 1st year average height of the herb and shrubs in *Bambusa tulda* habitat showed positive skewness with high variability for the higher density classes. But in the second year overall average height decreased with prominent skewness towards smaller herbs and shrubs. In the first year herb/shrub density in *Bambusa tulda* habitat showed positive variance with high variability for the denser classes. In the second year there was overall decrease though showing positive skewness with less variability for the denser classes. As bamboo harvesting by the local people for their daily need from the study area is permitted, matured bamboos are always preferred and therefore high variability for the bamboo in the taller class is expected. Results indicated removal of trees from the bamboo forest too. As bamboo is a good colonizer, it is likely that in future these areas totally replace existing woody vegetation.

Mature trees are more in mixed deciduous forest and are likely to be suitable as primate habitat. Though in the beginning of the study mixed deciduous forest was less disturbed in relation to removal of trees but drastic change in the variability among the taller trees indicates shift of pressure on this habitat for timber. Mixed deciduous habitat did not show any considerable increase in the density of herbs/shrubs but the distribution of density class shifted more skewedly towards denser classes.

Holt *et al.* (1995) and Hanski (1999) also found that continuous areas of habitat progressively transform into a patchy mosaic of isolated "islands" of available habitat as a result of human alterations. So, the above discussed pattern of plant resources and vegetation cover in intensive study area could possibly be the result of human activity.

6.4.2 Floristic variation of different habitats

There was a significant variation in the association of plant forms. Both in structure and composition none of these six habitats were more then 20% similar. Though in some cases dominant trees like *Schima wallichii, Apurosa octandra, Baeocarpus aristalus, Tectona grandis, Terminalia bellirica, Bombax ceiba, Syzygium operculata* etc. were found to be common, but their association with herbs and shrubs changed with the change in habitat types. Fig species availability was found to be highly correlated with the frugivorous primate species. Associated species of figs are no different from the similar studies done in the region (Gupta 1996b). Bamboo clumps forms a very unique landscape matrix in the ISA and was found to be correlated with the grazing ground for gaur. Representative trees like *Bischofia javanica, Elaeocarpus aristalus, Terminalia bellirica, Carrya arborea, Greracaena sp.* etc. are crucial for primates as this adds to the diversity of food material for them. Semi-evergreen habitats are dominated by few deciduous species. This is because the evergreen trees are being removed from the area. But if we look into the under story and regeneration then most abundant species are evergreen in nature.

6.4.3 Spatio-temporal variation in habitat use by study species

Out of the six habitats categorized in this study, savanna woodland was never found to be used by any of the studied primates but the habitat was found to be used by the gaur. In such case 'species specific' management practices are not likely to affect the habitat of other study species. But in all other habitats managers need to be careful while implementing any management strategy. When gibbon habitat was fragmented and food trees were isolated, they were forced to descend from trees to cross-clearings, as already observed by McCann (1933). This in turn increases the risk of predation. Many managers would be interested in relating current richness to a reference value in order to assess the conservation status of a site or territory, hence efforts should be made to measure a ''potential richness or potential biodiversity''. But, there are conceptual and practical obstacles to this kind of measures (Smith and Catanzaro 1996). For example, information about environmental conditions, species–habitat associations and species interactions may be missing. Even if such information is available, definition of potential habitat is often subjective or dependent upon the resolution of available data. The number of species in a community depends on niche partitioning. Very similar habitats can support different number of species, depending on the available species pool (as shown in comparisons between islands and a continent, MacArthur and Wilson 1967). Communities also can be more or less saturated as a result of local biotic interactions (competition and predation), dispersal, and evolution (Cornell and Lawton 1992).

Abundance of study species varied from habitat to habitat. Seasonal shift in the encounter rate of pigtailed macaque and capped langur in semi-evergreen and *bambusa tulda* habitat may be attributed to fruit availability and young leaves in these habitats. Studies showed that pigtailed macaque is found in close vicinity of human habitat in some parts of Assam (Choudhury 1996) and is likely to have good adapting mechanism and thus their ranging pattern also vary from habitat to habitat and in different seasons. Decreased individual encounter rate observed in the later part of the present study indicates a decrease in the group size or splitting of the groups, but as total count showed there was no splitting in any of the group, so encounter rate should not be used in predicting demography of population. Relatively higher encounter rate for capped langur followed by pigtailed macaque may be due to observer bias in detecting them. In semi-evergreen habitat gibbon did not show any seasonal variation. Encounter rate in the semi-evergreen forest drastically increased and was almost constant till the end of the study period. Increase in individual encounter rate for gibbon in the semi-evergreen habitat primarily was thought of as a shift to semi-evergreen type, but in due course of time it was confirmed that they were missing from the area.

Highest rate of encounter rate in the mixed bamboo followed by degraded semi-evergreen is justified with the habitat preference of gaur for resting. As transect survey was conducted during daylight, it is expected that the encounter rate will be significantly high in their resting habitats. This does not mean that gaur used those habitats more than other habitats. There was evidence of areas used for grazing spread over the entire ISA including crop fields outside the ISA boundary.

6.4.4 Site occupancy/use in different habitats

Semi-evergreen habitat was found to be most important for maintaining primate species diversity as this type showed presence of all the primate species of ISA.

Savannah woodland remained totally unoccupied. Mixed bamboo forest was solely occupied by pigtailed macaques. Mixed deciduous was dominated by capped langur. Use of *Bambusa tulda* dominated habitat by pigtailed macaque and capped langur fluctuates in seasons. Semi-evergreen patch was the only habitat to be occupied by all three species. In degraded semi-evergreen habitat there was no change in capped langur occupancy. As pigtailed macaque occupied the patch, gibbon was not recorded in the habitat.

6.4.5 Structure of competition among study species in six habitats of ISA

As far as special uses of the resources are concerned, study species are not competitively structured in any of the habitat types of ISA. Inspite of their coexistence in semi-evergreen type of forest they do not co-occur. Thus we can conclude that there was temporal separation. Reason may be avoidance of direct conflict and niche separation in the preferred habitat characteristics. Thereby niche limitations are not likely to constrain co-existence of studied primate species. Present study showed identical choice of gibbon and pigtailed macaque habitats. Being frugivorous and preference for relatively undisturbed habitat, this is expected. There was complete overlap in Gaur and other study species in the semi-evergreen habitat of ISA. Incase the primary habitat shrinks, competition between the gibbon and pigtailed for their habitat is likely to happen and they might show co-occurence. In few cases this was evident during this study. As most of such incidences were recorded outside regular scan period, they were not considered in this analysis.

6.4.6 Species specific crucial resources

Food habits of study species reported here are from seasonal scan data from habituated groups. There were instances where *ad-libitum* information recorded extra plants/parts eaten by the study species. Capped langur exploited maximum number of food items during summer, whereas both pigtailed and gibbons were found to explore more food items during winter. In all 38 food items were eaten by capped langur during summer, out of which 23 plants were explored for their vegetative parts like leaf bud, young leaf, mature leaf and 15 species were explored for their reproductive parts like flower, flower bud, seeds. During winter a total of 33 plant species were explored by capped langur, of which 26 plant species were explored for vegetative parts. Stanford (1991) found that 35 species of trees, lianas, and vines comprised the diet of the capped langur, of which 22 species were source of leaves, 11 species were source of fruits, 7 species were source of flowers, and 6 species were source of seeds. Stanford (1991) suggests that capped langurs prefer fruit over leaves when both are available. The capped langur are found in the subtropical, broadleaf, evergreen, deciduous and bamboo forests up to 2000 m and teak and sal plantations. Maximum observation on feeding was made in case of capped langur compared to other two species. Leaf content in the food of capped langur was 70%, of which young and mature leaves contributed for 43% and 27% respectively. This was followed by flowers and flower buds (12%), seeds (7%), ripe and unripe fruits (6%). Insects and others contributed 4% of the total diet of capped langur. About one percent of their feeding sign was recorded while taking insects as a part of their diet. At Madhupur National Park, Bangladesh, Stanford (1991) found that the diet of the capped langur consisted of leaves and leaf parts (66.8%), fruits (24.4%), seeds (9.3%), and flowers (7.0%). He also reported that mature leaves and petioles accounted for 42.0% of the diet and young leaves accounted for 10.9% of the diet. In another study Stanford (1991) reported that the staple diet of capped langurs consist of 24% fruit, 22% young leaves, 20% mature leaves, 9% seeds, 7% flowers, and 1.6% animal prey. He also found that during the rainy season when fruit is abundant, 50% of their feeding is on fruits, particularly figs. But in the present study rainy seasons were not accounted for thus comparison is not possible. However as both the studies showed similar result in other two seasons, we can assume that they are feeding more on fruits during rainy season. This of course needs further investigation. And it is likely that during that period other two study primate species compete for the fruits. In the dry season; they survive on mature leaves and some seeds. Stanford found that occasionally, they eat gum and termite soil trail and come to the ground to drink water from streams and water bodies. But no such instances were recorded in the present study. In North Cachar Hill Reserve forests and other reserves of the Cachar division, Assam capped langur was found to spend considerable time feeding on bamboo shoots (Standford 1991). Daily range were found to be 555m to 657m during summer and 232m to 465m during winter. Stanford (1991) found that the home range and day travel distance is the smallest for any species of colobines with 21.6 hectares and 325m respectively and that the day range has significant correlation with percentage of mature leaves in the diet of capped langur (Shrivastav 1999, Standford 1991). In the present study no such strong correlation could be established. Here the day range was found to be correlated with the disturbance level like felling of trees (Dasgupta and Gupta 2004). The home ranges of capped langurs overlap considerably, and inter-group encounters are common with jumping displays.

Choice of almost equal number of plant species for ripe and unripe fruits is correlated with the availability of food materials. In presence of ripe fruits they were found to prefer more of ripe fruits. More number of species explored during winter is again found to be positively correlated with the number of fruiting and flowering trees in the ISA. Almost equal number of plants were explored for vegetative and reproductive parts. The habits of Pigtailed macaque is quite variable from lowland primary and secondary forests to coastal, swamp, dry land and montane forest up to 1700m (Caldecott 1986). Previous research showed that the staple diet is composed of mainly fruits and seeds (73.8%) (Rowe 1996). Ripe and unripe fruit contributed 32% and 23% of total food in the diet of pigtailed macaque. In about 50% of the cases the plants which were explored for vegetative parts were not used for their reproductive parts. But there were scattered instances when they were found feeding on insects and soil. Results of the present study are difficult to compare with the other studies as no long term studies on the species was conducted before from the region or in similar habitat. They have been reported to raid crop fields and kitchen gardens in Assam and Meghalaya (Srivastava 1999) respectively. They spend most of their time in upper canopy (Srivastava 1999). Opportunistic feeding occurs throughout the day and food sources seem to be located and exploited by small, widely separated parties; this is considered to enhance the efficiency with which small food sources are harvested. The second most important diet component is the animal prey (including insect nestling, termite egg and larva and river crabs). Besides this, the macque spent about 12.2% of the total feeding time on leaves, 5.4% on buds, 3% on flowers, and 1.1% on other plant matter, including fungus (Caldecott 1986). The macaques spend about 48% of their total activity time in the middle canopy and over 34% in the lower canopy with just about 10% on ground and remaining 8% in the upper canopy (Caldecott 1986). However, they have been reported to directly compete for fruit resources with Lar gibbons (Whitington 1992). An approximate overall average activity budget for this species is 23% resting, 61% locomotion, and 16% feeding (Caldecott 1986). The average day range length may vary from 1000 m to 3000 m (Caldecott 1986). A typical groups of pig-tailed macaque comprises of 15-40 individuals. The inter-group relation is peaceful with extensive overlap of home range and occasional group fission and associations (Rowe 1996). Pig- tailed macaques are trained to harvest ripe coconuts in Malaysia.

Gibbons diet was contributed by minimum number of plants and almost equal (14 and 13) plant species were used in their diet during winter for vegetative and reproductive parts respectively. *Bombax ceiba* flower contributes a large amount of morning diet of gibbons. Total number of plants used in food was less during summer. Only 23 plant species were recorded in the food during summer out of which 14 species were used for their reproductive parts, mostly for fruits.

Gibbons were found to feed on 43% ripe fruits followed by 23% unripe fruits. Consumption of unripe fruit was found to be same as that of pigtailed. Standard error (± 4.16%) was almost double in case of pigtailed. Flowers contributed 10.5% of the total food items in gibbon diet. There was no sign of gibbon feeding on soil or insects. Leaves contributed 8% of their diet. In addition gibbons also consume smaller quantities of flowers and insects (Alfred 1992, Feeroz and Islam 1992, Gittins and Tilson 1984, Islam and Feeroz 1992, Tilson 1979).

Gibbons are specially adapted to a diet with a high proportion of ripe fruit. Trees with ripe fruit are usually widely scattered in the forest but (especially fig trees) may carry very rich aggregates of food. Leaves and insects are also eaten, but mostly as a supplement. Gibbon dietary composition may, however, exhibit strong seasonal and local fluctuations. Gibbons spend 25-40% of the total activity time in feeding; 15-20% in locomotion; and 24% resting (Alfred and Sati 1986, Islam and Feeroz 1992). Their feeding strategy is "feeding all along the way" up to the fruit trees and back to a suitable roosting tree. It is quite likely that their travel and feeding is goal directed. They mostly feed on ripe, sugar rich juicy fruits and also figs. There is no difference in feeding by sex in adults and juveniles (Choudhury 1991). The typical diet of gibbons consists of 51- 65% fruits ; 5-23% leaves, 13% - buds, 12% - flowers, and 0.1%; animal prey (including insects and bird eggs) (Tilson 1979, Gittins and Tilson 1984). Climbers also play an equally important role in their diet, at least in the dry season. This is altered to a great extent in degraded habitats such as Gibbon Wildlife Sanctuary, Assam. In this degraded habitat they have been observed feeding on bamboo shoots. They spend 40% of time feeding on fruits, 40% on young leaves; 14% on leaf buds; and 5% on mature leaf. *Artocarpus chama, Anthocephalus kadamba, Bischofia javanica, Amoora wallichara*, etc. are most preferred fruit bearing food plant species. *Dipterocarpus macrocarpus, Mesua ferrea* and *Castonopsis indica* are preferred roosting trees (Choudhury 1991). Like other gibbons, the hoolock is an arboreal and a diurnal species; it prefers the upper canopy of the forest, and sleeps and rests in emergent trees (Leighton 1987). Like other gibbons, hoolock eat mostly fruits (51-89%), with the main supplement being leaves (6-32%); besides consuming smaller quantities of flowers and insects (Alfred 1992, Feeroz and Islam 1992, Gittins and Tilson 1984, Islam and Feeroz 1992, Tilson 1979). Mukherjee (1986) found lower quantities of fruits (30-40%) compared to leaves (40-60%) in the diet of Hoolock in Tripura (India). Among fruits, figs appear to be the most important food item and make up for about 60% of the fruits consumed by them (Alfred 1992) and about 38% of their total diet (Feeroz and Islam 1992, Islam and Feeroz 1992).

Though total plant species exploited by these three primates were not significantly different but it differed in terms of species. Consumption pattern (as evident from the parts preferred) proves their habit as folivorous for capped langur and frugivorous for both pigtailed and hoolock gibbon. Overall contribution of fruit was much more for gibbon then pigtailed. There was significant variation in the proportionate time spent on feeding activity during winter and summer. During winter pigtailed spend 69.9% of their activity time on foraging followed by capped langur (65.12%) and gibbon (53.12%). Time spent on foraging reduced for capped langur (42.3%) and pigtailed (57.8%). Only for gibbon the foraging time increases to 61.3%.

Gaur is a generalist feeder but prefers to browse in dry seasons and predominantly graze in monsoon. Their diet chiefly includes shoots and foliage of trees, shrubs, buds, fruits, herbs, tender shoots of bamboo, grasses and barks of trees. During the hot hours of the day gaur retire under the shelter thick tree cover and ruminate. Feeding is more prominent during early morning and evening hours (Schaller 1967). Crop raiding by gaur is becoming a major source of man animal conflict in the region. The intensity of damage outside the park is significantly high (Fig. 6.15)

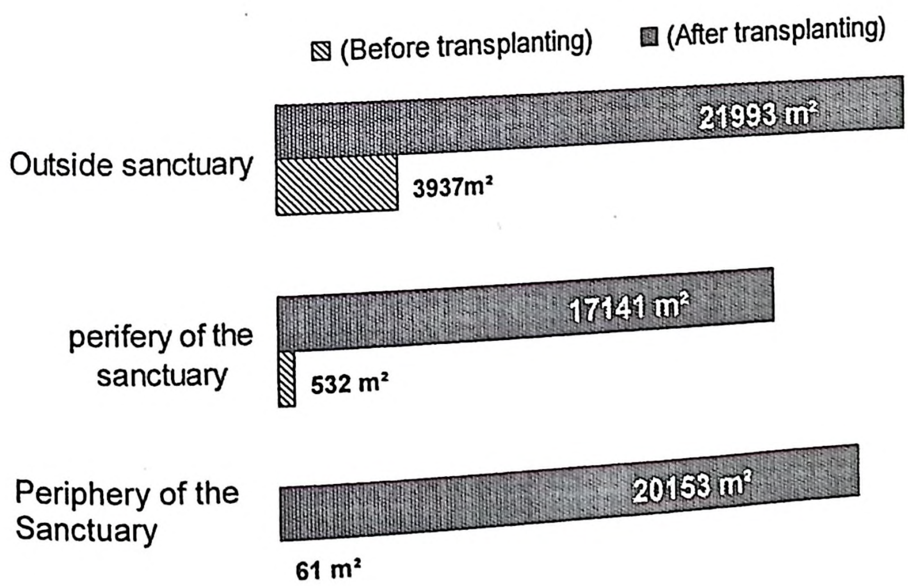


Figure 6.15 Contribution of paddy in the diet of gaur in Trishna Wildlife Sanctuary.

6.4.7 Phenology of food plants

Flowering and fruiting phenological patterns of primates and gaur food species exhibited clear peaks and troughs during the study period. The pattern suggest patterns similar to those described for other tropical and deciduous forests, where fruit availability is highly variable in both space and time. Although the variation between months in a season was not very high, there was high variation in the number of individuals and the abundance of these species as found in the phytosociological part of this study.

6.4.8 Roosting and resting places of study species

Choice of different niche characteristic for gibbon, pigtailed and capped langur is a sign of their specialization in habitat preference at different level. Segregation, thus, could reflect choice of differing microclimates because of differing physiological tolerances or choice of differing vegetation characteristics due to biotic influences. Moreover, large scale distributions (i.e., geographic ranges) are commonly mimicked on local gradients. Bird, mammal, reptile, amphibian, and insect species are commonly segregated along microclimate gradients and those gradients usually also reflect vegetation gradients (e.g., Karr and Freemark 1983, Martin 1993, 1998). Seasonal shift in the preferred habitat is not significant for any of these three species, thus a uniform management strategy can be planned for these species. Choice of relatively difficult terrain in case of gibbon is likely to be a mechanism in order to avoid predation. Because of their small group size vigilance over large area is difficult so they are likely to opt for a hiding mechanism to minimize risk. Because of the larger group size and occupancy of canopy at various levels, it is easier for pigtailed macaque and capped langur to monitor larger areas around their roosting places.

Larger body size and poor visibility of gaur is a kind of obstacle in their free movement and thereby increses risk of predation. Moreover they are likely to face increasing threat from hunting. Open areas are relatively less abundant with insects and flies. All above mentioned factors could be the reasons for choice of flat terrain on the hillocks or in the flat land of valley. Being a semi diurnal and nocturnal, this species spends most of the time resting dense cover during day to avoid encounter with other threats like predator and hunters. This phenomenon further requires investigation by continuously following them and collecting quantitative information on their behavioural changes during encounter with predators or hunters.

6.5 LIMITATION

The study did not address the habitat use with relation to availability of different resources. More detailed species specific study is required to address resource availability and answer why certain resources are preferred over others. In the present study only those food plants were analyzed which were used by the study species, but to answer why certain other species are not used, would only be possible after doing chemical analysis for used and unused food plants. Gaur could not be followed continuously and thus, results discussed here require further investigation using radio telemetry study. Though rainy season information is very important, this could not be collected due to lack of infrastructural facility, so the study fails to discuss how the study species uses different habitat during the rainy season.

6.6 SCOPE

Further investigations are required to know whether animals shift their distributions with changing abiotic (climate) conditions independent of vegetation and biotic interactions, and whether distributional shifts incur demographic costs from biotic interactions. Microclimate gradients provide a powerful system to study relative roles of abiotic vs. biotic interactions on microhabitat segregation among coexisting/co-occurring species, as well as questions about possible demographic costs of shifting distributions. This needs to be addressed to understand energy and material cycling in the interacting systems of the study species and their biotic and abiotic habitat elements.

Chapter 7
CONSERVATION RECOMMENDATIONS

Wildlife professionals need better ways to integrate ecological and human dimensions of wildlife management. A focus on impacts, guided by a structured decision process, will orient wildlife management towards rigorous, integrative decision making. Impacts are important socially defined effects.

RILEY *et al.* 2003

7.1 INTRODUCTION

It is typically assumed that a habitat selection analysis indicates which habitats are most important for the overall fitness of an animal (Morris 1987, White and Garrott 1990). Ultimately, the important question for wildlife managers is whether the presence, absence, or abundance of certain habitats affect populations. The findings of my research suggested that several habitat characteristics that are important to one species were not necessarily found so important for others, and a few habitat characteristics were observed to be very important for all the study species. In this scenario loss of one habitat could affect the entire structure of primate and gaur populations. Although reliable trend analyses were beyond the scope of this research but decreasing trend of all the study primate species is alarming. Since study species are designated as endangered, both at the regional and national level, there is an impetus to act conservatively to ensure that it will have sufficient habitat over the long term.

The results of this study clearly showed that primary forests are important for study species at every spatial and temporal scale. Although this study identified the important habitat characteristics for study species, determining how much of the important habitats are required to maintain study species populations could not be done. Study species may also require enough good quality habitats to avoid predators. For example, gibbons are thought to avoid predators by existing at low densities, since predators tend to hunt in areas with high densities of prey (Bergerud *et al.* 1984, Bergerud and Page 1987). If sufficient habitat is not available, study species may be forced to migrate in their preferred habitat (Smith *et al.* 2000). This was evident in the present study as all the animals are concentrated in the same central area of ISA. This could lead to higher predation levels (Bergerud and Page 1987), and population declines (Cumming and Beange 1993). When planning for habitat modification, it will be necessary to take into account not only the forest stand characteristics affected by timber harvesting, but also the implications of other industrial activities (such as oil and gas exploration and development by ONGC, Govt. of India) and disturbances such as fire. These factors may compound the effects of habitat change over time (Dyer *et al.* 2001, Oberg 2001). This suggests that habitat supply planning must also occur at multiple scales. Sufficient habitat must be maintained for study species throughout the entire range, and also within subsets of the range.

Analyses of habitat selection in the summer and winter indicated that study species may require different habitats depending on climatic condition and food availability (also see Chapter 5 and 6). Managers must therefore maintain the suitability of habitats required by study species. Although harsh winters may only occur occasionally, these winters may limit study species populations if sufficient critical habitats are not maintained.

Philosophical background of recommendation process and implementation are discussed below:

7.1.1 Prioritize conservation issues

To ensure that the interests of an appropriate range of stakeholders are represented the very act of discussing priorities were based on stakeholders' priority as well as sensitizing them to the role and value of study species at local, regional and international level. Key challenges are the scope of the issues under consideration (i.e. complex versus focused) and their long-term conservation (i.e. 'current' versus 'traditional').

7.1.2 Analyze information needs

Solutions to ecological problems are usually complex and there is no single measure to determine what information is needed to support policy and management goals. This is particularly true when decision-makers are in dilemma and start with hazy ideas of their requirements. However, the price for not pursuing this challenge is heavy. Without the 'right' information, there is a risk that stakeholders will make inappropriate decisions, with potentially damaging consequences for living resources. Information needs analysis is the process whereby needs are expressed in a variety of ways like- narrow, broad, technical or bureaucratic, and are followed by consistent, mutually agreed, set of information objectives.

7.1.3 Designing products and services

Results are called information products rather than information sources, reinforcing the idea that they provide a specific service to their users. Decision makers may be too busy or lack the technical background to process large amounts of data or apply themselves to difficult interpretation tasks. Brief summaries of complex issues need to be presented in such a way that they can be absorbed quickly without the need for special tools or expertise. Emphasis was given in the work on issues such as clarity, timing and method of delivery of information products by rendering information and making them usable by its intended audience.

7.2 MANAGEMENT IMPLICATION

Species specific recommendations as proposed here are decided in isolation and did not consider its probable effects on the other species. However, attempt was made to provide landscape scale recommendation with minimum conflict in resource sharing among the study species.

7.2.1 Proposed conservation initiatives for hoolock gibbon

- The semievergreen patch is the only habitat where all the study species are found, there is an immediate need of providing protection to this habitat. As all the permanent monitoring plots showed high level of anthropogenic disturbance in terms of removal of trees and presence of cattle, imposing a total ban in the movement of villagers in these areas should be given highest priority.
- As the tree species of Moraceae family provided more than 50% of the fruit supply to the gibbon, plantation of tree species like *Ficus glomerata*, *F. oligadon* etc. of Moraceae family and ensuring successful establishment of their natural regeneration is needed.
- *Bombax ceiba* needs to beprotected from illegal felling as they were found to provide platform for the brachiation of gibbon and supply of food during scarce period (winter) when less amount of figs are in fruiting stage.
- Climbers and bamboo breaks linking small patches of the dense semievergreen habitat used by gibbons for foraging need to be protected. It is suggested to avoid the practice of removal of climbers and bamboos and to improve tree cover through afforestation in the gibbon habitat to ensure movement of gibbon between smaller patches. However, certain potential gibbon habitat patches in the periphery of the Sanctuary should not be connected with the current gibbon habitat patches, as it might increase the chances of their encounter with villagers.
- There is an immediate need to develop potential areas adjacent to the present population to facilitate two sub adults of the two group to establish their own territory on attaining adulthood so that they do not face scarcity of food and space.
- The present population of gibbon (n-6) in TWS is small and isolated in nature. Hence chances of inbreedings in the present population cannot be ruled out. It is recommended that a few (2-3) isolated females in the state can be translocated to ISA with due care to enhance the genetic viability.
- Continuous monitoring of the neonates and subadults should be undertaken to ensure that their territory is not falling short of food supply. There are few fruiting

trees present in the vicinity of Joychandpur tower but not used by gibbons due to the presence of visitors. So, this tourism place can be closed for few months when there is a food scarcity.

7.2.2 Proposed conservation initiatives for pigtailed macaque

- The pigtailed macaque though preferred undisturbed areas during this study but their adaptability makes them survive in close proximity with humans. The present agricultural practices near their habitat should be discouraged as it may result in human-monkey conflict and threaten the existence of this species.
- Tree species of Moraceae family (species are same as used by gibbon) needs to be planted in the gaps of pigtailed macaque's habitat. Considering the regeneration potential of the area, it is suggested that only protecting and /weeding operation around the available seedlings of fruiting species would be sufficient to support the existing pigtailed macaque population in the ISA.
- Illegal felling of *Ficus* species in the ISA needs to be prevented. With the shortage of figs it is likely that in future the competition between gibbon and pigtailed may increase. As most of the *Ficus* species provide year round supply of fruits, there is an immediate need to increase the fruit species cover in the adjoining areas inside the TWS.

7.2.3 Proposed conservation initiatives for capped langur

- Broad leaved tree species which are spread in the eastern periphery of the ISA are the prime constituents of capped langur habitats. Moreover being a folivorous species they can also survive in less diverse areas where the plant species are evergreen or semi-evergreen in nature. So, there is an immediate need to protect the peripheral areas of ISA, especially areas near Kasari, Joichandpur and Rajnagar lake no 1 & 2.
- Water body associated vegetation serves as a good reservoir of both young and matured leaves. It is suggested to improve vegetation around water bodies by discouraging tourism activities around lakes.

- Reducing disturbance such as illegal felling of big trees (like Bahera), burning of grasslands in small patches inside langur habitat for thatch grasses by local people during dry season must be stopped to ensure natural succession of vegetation.

7.2.4 Proposed conservation initiatives for gaur

- After local extinction of large herbivore like elephant from the TWS in the 1970s, gaur occupied the dominant position amongst the ground living herbivores. Protecting gaur needs to ensure grassy glades, dense cover, perennial streams and 'salt-licks'.
- As planting of all the food plants of gaur is difficult, it is suggested that an attempt should be made to maintain the available grasslands for the use of gaur and no grazing by domestic livestock should be allowed inside the TWS. If necessary, control burning of some of the areas in savannah woodland (found in the east and south of ISA) during winter can be practiced .
- Free grazing of domestic cattle as evident from the habitat use monitoring plots, not only disturbs the grazing grounds of gaur but can also spread contagious disease such as foot-and-mouth disease (FMD). In one case death of gaur (adult female) due to FMD was suspected in the ISA during the study period. Vaccination of domestic livestock in villages around TWS, against FMD and Rinderpest should be implemented by the park authorities.
- The interface between villages and ISA is likely to be the most sensitive zone as clearly evident from highly degraded habitats spread over the periphery of the sanctuary boundary (showed in the land use map). In these areas human animal conflict may take serious turn due to crop raiding by gaur. Thus raising grass species in the periphery of ISA will act as a barrier and reduce the chance of future conflict.

When it comes to the implementation of above mentioned species specific management implication, it is suggested that they shall be applied at landscape scale. Following are the landscape scale recommendations

7.2.5 Landscape scale conservation recommendations

A detailed analysis of land use coverage of TWS revealed that it is undergoing the process of degradation. Distributional surveys at different sites and detailed line-transect censuses at six habitat demonstrated that primate abundance in primary forest was found to be high as compared with secondary and disturbed habitats and the relationships between primate abundance and habitat disturbance were complex. Understanding the effect of disturbance on primate communities requires careful selection of control sites and documentation of primate abundance over a number of sites in each habitat. Reduction in the primate populations and forest clearing and degradation during the study clearly illustrated the importance of protecting land. A review of the literature suggested that the biomass of primates in ISA is high compared to other similar locations in the state, reinforcing the importance of conserving natural resources of TWS for conservation.

- Primates of TWS shared the available resources with birds as evident from the present study. As the cover and food plants of study primate species declined from first year to second year due to anthropogenic disturbance it is recommended that a detailed study on human dependency on forest resources should be given foremost priority. Compared with the number of plant species present in the TWS, very few are used by the study species and they need to be conserved. Even though most of the key-food speies are non-timber species they are subjected to lopping and felling to meet the needs of local people.
- Gupta (1996b) reported that the primates (langurs) have survived a long history of habitat degradation in Sepahijala Wildlife Sanctuary, Tripura, due to their high degree of adaptability. But species like gibbon got locally extinct from that area, which again supports the fact that even if langurs and macaques continue to survive in TWS, the gibbon may go extinct if immediate conservation measures are not taken. In presence of leopard, clouded leopard and dhole, study species again face increasing threat of being predated by them. So, there is a need

to improve the prey base for large and medium predators. Detailed study shall be taken in this regard to quantify the existing status of prey and predators in TWS.

- Significant change in the total basal cover and increase in regeneration in the semi-evergreen habitat during the present study indicated increase in anthropogenic pressure on the forest in terms of direct removal of trees from this habitat type. As there are indications of good regeneration of major tree species in the TWS, the management needs to consider implementation of effective strategies to support and protect these patches.
- Based mainly on the forest cover it was estimated that 43 km² of area inside ISA can be a potential habitat for the primate species (Table 7.1). Without considering patch size and disturbance factor species-specific maximum area that can be considered for immediate habitat for gibbon was estimated to be 27.5 km², for pigtailed macaque 39 km² and 43 km² for capped langur.
- Even though habitat improvement measures are suggested, change in landuse pattern as a part of habitat improvement measures needs to be minimized inside ISA.
- As the wildlife warden has administrative control over area outside the notified Sanctuary, it is difficult to put equal importance to the entire area. Therefore all that should be brought under the same management.
- Strict and regular patrolling in the prime habitat of primates (ISA) is of immediate need ensuring minimal disturbance to the animals.

Table 7.1 Potential primate habitat in ISA

Habitat category	**Area (Km²)**
Total study species (primate) habitat	42.99
Gibbon habitat	27.55
Capped langur habitat	42.99
Pigtailed macaque	39.20
Total Gaur habitat	66.23

- Conversion of low lying lands (*lungas*) into lakes is further fragmenting the landscape and might pose a problem for the dispersal of study species. So, instead of big lakes smaller waterholes can be created.
- There are several trails which cut across the entire Sanctuary. Some of these paths are used for illegal transportation of forest resources. Routes connecting Joychandpur and Rangamura, Kasari and Bhavanipur, Rajnagar and Durgapur, Joychandpur and Radhanagar, Kasari and Teendepha among others need regular patrolling and attempt should be made to disconnect these routes.
- Being a Sanctuary status of protected area and looking into the economic status of the people around the TWS, stopping local people to collect NTFPs are almost impossible. Thus protection in this scenario is more challenging. It is strongly recommended to enhance the protected area status of the TWS and if feasible it is recommended to convert the ISA as a National Park.

There are several other flora and fauna which are also an integral part of the system and before implementing above mentioned recommendations we need to understand interdependency of those living organisms in detail.

7.3 IMPLEMENTATION GUIDELINES

7.3.1 Agreed roles and responsibilities

The aim is to build trust and confidence between network partners, who may include scientists, policy-makers and resource managers, leading to improved uptake of scientific information in policy and planning. The success of a network depends on its partners understanding how they are expected to contribute to the network's goals and, equally importantly, how they stand to benefit from its existence. The information needed to conserve and sustainably use forest resources is multi-disciplinary in nature, even when confined to a single species, and may be required on a dynamic and variable set of topics. The datasets generated thus may be scattered amongst many organizations and sources, making the task of integration and interpretation difficult. Further challenge arises when access to data is restricted. Information networks, which are simply assemblies of individuals, groups and organizations with common information objectives, must focus on cooperation. The roles and responsibilities for information sharing should be defined clearly and reviewed as necessary.

7.3.2 Build capacity

Clear priorities for capacity building are needed, and the greatest challenge is deciding how and where to focus investments. The later should, wherever possible, be based on an assessment of where existing capacities are located and how readily these can be mobilized for specific tasks. Typically, some information objectives will be achieved simply by improving coordination between organizations and by sharing scarce resources. The aim should be to extract the greatest benefit from existing resources as a first step, but to facilitate access to additional resources as required for specific tasks like GIS needs to be ensured.

7.3.3 Supporting good decisions

The fact that available information does not guarantee its use, no benefit may be obtained unless there is an effective dialogue between those involved in the process of generating the information (e.g. scientists, researchers and other information professionals) and those who are expected to use it (e.g. policy-makers and planners). Clearly, information may fail to achieve a significant impact on decision-making when it is developed outside of mainstream decision-making processes, rather than emerging from within. Organisations of all kinds, whether governmental, commercial or community-based, are driven by their own priorities and needs. Sometime decision makers may see information as a distraction and, more probably, as a waste of precious time. This helps to explain why information generated outside of decision-making circles is often ignored, misunderstood or viewed as a threat. An important justification for increased attention to information management is that the contexts in which policies on forest resources are formulated are usually complex, and do not respond well to simple solutions.

7.4 DISCUSSION

It is ecologically indefensible and shortsighted to attempt to manage for the conservation and recovery of species without considering the biological organism from different strata.

First we must recognize that management of natural areas and ecosystems will require inclusion of organisms in addition to plants. We must also recognize that the purposeful introduction of exotic species (as demonstrated in the importance of exotic species in primate conservation by Gupta (1996) in Sepahijala Wildlife Sanctuary) is one of our most powerful technologies, and coarse mistakes are irreversible and sometimes devastating. So, before introducing exotics we must go through proper trial in similar sites. In many cases it has been found that though fragmented patches of different habitat are still available and habitable for study species, only a fraction of these were inhabited by them. Most of the unoccupied patches were patches isolated or fragmented by other habitats including barren hills or agricultural practices. While killing and poaching by the locals has dwindled the population of study species in many places, it is not the case in TWS and thus concentration on the protection of habitat with little effort in the habitat improvement measures has potential of conserving these species in long run.

When wrestling with problems like conservation ecology *vis-a-vis* deforestation, loss of biodiversity and a fragile food supply to the endangered species, decision-makers faces major challenges relating to discrimination between information sources, which may carry different messages and vary in quality and integrate different types of information to formulate a proper perspective on the issues concerned. To address these challenges fully may require decision-makers to liaise effectively with the scientific community and make appropriate use of information technology. Brookes *et al.* (1982) point out that rationality becomes difficult when subjective concepts such as 'quality of life' and other cultural values influence the decision-making process. Of course, subjective influences do not always work in opposition to the environment. Many indigenous people, for example, have belief systems (e.g. sacred grooves) which are naturally sympathetic to conservation goals.

To avoid subjectivity in defining habitats or species preferences, we must use statistical approaches, based on large data sets that combine spatially explicit empirically derived information on richness, habitat and community structure. Two approaches are conceivable. One is to define habitats using a set of values for a number of variables. Then, absence–presence of species could be associated with each defined habitat. Then areas potentially occupied by each species could be predicted elsewhere. This reduces subjectivity in relating habitats and species, but may be misleading because biotic interactions, biogeographical factors and habitat size are not fully considered. The second approach is the one proposed in this study. We knew the entire range of richness values observed in a very large set of plots. These values were empirically, not theoretically derived potential values: even our richest plots could have contained more species under other conditions, e.g. different management histories in other parts of north east India. In fact, observed richness for some individual plots greatly exceeded the calculated maxima because we used averages for the 20% plots with the highest richness, not the maxima. A potential improvement to our approach, which could be easily accomplished using GIS, would be to discount for the effect of habitat sizes. In conclusion, statistically obtained maximal richness of woody species appears more useful for predicting diversity distribution patterns, diversity hotspots, and biodiversity status than potential richness obtained from hypothetical individual species distributions. Although our approach can be used only as a heuristic tool to detect zones with anomalous (high or low) richness values, local deviations from maximal averages can be individually analysed. This procedure, however, might never become a substitute for the knowledge about species composition at each site and its dynamics. It is believed that active interaction among park authorities, key-stakeholders of TWS and research organizations (ecologists, sociologists and economists) can only bring success to above mentioned suggestions at implementation stage.

7.5 CONCLUSION

It is clearly evident that the species specific conservation methods are not sufficient enough for an area where the situation is like that an of island. In absence of continuity of different habitats, the complex mosaic of different habitat characters are unable to maintain the ideal interaction at different tropic level. Thus use of any one species as a key species and linking it with others may not be possible while prioritizing conservation goals. The best way is to understand the synergies and incompatibilities if any among the needs of key species at different level of resource use as also at different strata of the canopy and optimize the chance of survival of isolated endangered species.

7.6 LIMITATION

The information which is now available to decision-makers should help them arrive at sounder, faster and more transparent decisions. However, these expected benefits often do not materialize in practice. One reason is that although the amount of ecological information that has been developed following this study has the apparent complexity of the single species *vs* multi species/area based conservation approach issues which need to be tackled carefully so that conservation priorities are derived carefully. This may further be complicated by different groups of stakeholders with diverse expectations. Realistically, ecological information is only one factor influencing the way in which decisions on forest resources are made, and it is not always the most significant. Personal opinions, political and economic dogma, market pressures, and legal necessities also influence decision-making which may not be in agreement with scientific recommendations.

7.7 SCOPE

Incorporating socio-economic information into conservation planning is likely to improve greatly the chances of success in achieving conservation goals if it can help avoid conflicts with people's other needs.

Information generated here has the power to be more objective than other influences, especially because they were generated by recognized means. Prediction of species distribution is an important element of conservation biology. Thus, the study provides an opportunity to use these crucial information in day to day planning of the habitat management initiatives. Management initiatives for endangered species, ecosystem restoration, species re-introductions, population viability analyses and human–wildlife conflicts often rely on habitat suitability modeling for which the present study can become sound baseline information and management can further continue focused monitoring and modeling to address specific problems. Multivariate models can be used to define habitat suitability and, combined with geographical information systems (GIS), can further allow management to design potential conservation strategies. Problem solving arises from the superimposition of socio-economic structure and landscape level information and is rife with possibilities and scope for imaginative and pragmatic thinking.

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Note

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Appendix 1

CHECKLIST OF ACTIVITY IN PRIMATES:

SL NO.	*SIGN*	Code	*SL NO.*	*SIGN*	Code
0(A)	**Feeding**		0(D)	**VOCALIZATION**	
1	PETIOLE	**PT**	29	SINGING	**SI**
2	YOUNG LEAVES	**YL**	30	SCREAMING	**SC**
3	MATURED LEAVES	**ML**	31	OTHERS	**OV**
4	TENDER SHOOT OF TREE	**TS**	31(A)	KHRU-KHRU	**KK**
5	CLIMBER SHOOT	**CS**	31(B)	KHUK-KHU	**KKU**
6	FLOWERS	**FL**	31(C)	CHI-CHI-CHI---CHI-CHI	**CC**
7	YOUNG FRUITS	**YF**	31(D)	WHOO—WHOO—WHOO	**WW**
8	MATURED FRUITS	**MF**	31(E)	CHENG-KOG--CHENG-CONG	**CK**
9	SEEDS	**SD**	31(F)		
10	DRINKING	**DR**	31(G)		
11	NURSING	**NR**	31(H)		
12	INSECTS	**IN**	0(E)	SOCIAL INTERACTION	
13	OTHERS	**OF**	32	APPROACHING	**AP**
13(A)	FLOWER BUDS	**FB**	33	TOUCHING	**TC**
13(B)	MALE EJACULATE	**ME**	34	CARRYING	**CR**
13(C)	LICKING/SUCKING SAP	**LS**	35	RETRIEVING	**RT**
13(D)			36	GROOMING	**GR**
13(E)			37	PLAYING	**PL**
0(B)	**Movement**		38	MILD THREATENING	**MT**
14	WALKING	**WK**	39	CHASING	**CH**
15	RUNNING	**RN**	40	BITING	**BI**
16	JUMPING	**JM**	41	ATTACKING	**AT**
17	OTHERS	**OM**	42	OTHERS	**OSI**
17(A)	SWIMMING	**SW**	42(A)	GRINDING / GNASHING OF TEETH	**GT**
17(B)			42(B)	ADOPTING	**AD**
17(C)			42(C)	BRANCH SHAKING	**BS**
0(C)	**MOTIONLESS BEHAVIOR**		42(D)	POUT -FACE	**PF**
18	STANDING, RELAXED	**SR**	42(E)	CANINE DISPLAY	**CD**
19	STANDING, ALERT	**SA**	42(F)	OPEN MOUTH THREAT	**OMT**
20	LYING, RESTING	**LR**	42(G)	AGGRESSIVE STARE	**AS**
21	LYING, ASLEEP	**LA**	42(H)	FEAR GRIN	**FG**
22	SCANTING	**SC**	42(I)	EMBRACES	**EM**
23	OTHERS	**OMB**	42(J)	KISSES	**KS**
23(A)			42(K)		
23(B)			42(L)		
0(D)	**MAINTENANCE / BODY FUNCTION**				
24	URINATING	**UR**	0 (F)	BREEDING BEHAVIORS	
25	DEFECATING	**DF**	43	ERECTING PENIS	**EP**
26	SELF LICKING	**SL**	44	INGESTING GENITAL SECRETION	**IG**
27	SELF NUDGING	**SN**	45	SCRATCHING	**SC**
28	OTHERS	**OB**	46	MOUNTING	**MT**
28(A)			47	HEAD DUCKING	**HD**
			48	SNIFFING SEX ORGANS	**SG**
			49	OTHERS	**OBB**
			49(A)		
			49(B)		

Appendix 2

PRIMATE SCAN SAMPLING DATA SHEET:- DATE: SHEET NO:

ANIMAL UNDER OBSERVATION				INTERACTION (DISTANCE)	NEAREST NEIGHBOUR		
TIME	ANIMAL	ACTIVITY	HEIGHT		ANIMAL	ACTIVITY	HEIGHT

Appendix 3

CHECKLIST OF BIOTIC PRESSURE IN TRISHA WILDLIFE SANCTUARY:

Sl. no	Sign	Code
(i)	**Extraction of timber (direct evidence)**	
A	**Felling trees**	
1	Using axe	Fa
2	Using saw	Fs
B	*Processing of felled tree*	
3	Using axe	Pa
4	Using hand saw	Ps
5	Using ara (two way big saw)	Par
C	*Carrying timber*	
6	On shoulder in a group	Csg
7	Single on shoulder	Cs
8	On bicycle	Cb
9	On rickshaw	Cr
10	On motor vehicle	Cm
11	By rafting/floating in stream	Cf
(ii)	**Extraction of timber (indirect evidence)**	
12	Cut stump	Ec
13	Felled tree	Ef
14	Processed timber	Ep
15	Sound of felling tree	Es
(iii)	**Extraction of ntfps**	
A	*Extraction of bamboo*	
16	Direct sighting of bamboo cutting	Esb
17	Collecting bamboo and making bunches	Ecb
B	*Transportation of bamboo*	
18	On shoulder	Tbs
19	On bicycle	Tbb
20	On motor vehicle	Tmv
21	Floating in stream / river	Tf
C	*Extraction of firewood*	
22	Cutting standing shrubs / trees (live)	Etl
23	Cutting standing shrubs / trees (dead)	Etd
24	Collecting deadwood / cut branches	Edc
D	*Transportation of firewood*	
25	On shoulder	Tfs
26	On bhar	Tfb
27	On bicycle	Tb
28	On rickshaw	Tr
29	On motor vehicle	Tmv
30	Head load	Thl
E	*Other ntfp collection*	
31	Mushroom	Tm

Sl. no	Sign	Code
32	Grass for thatching	Tg
33	Seeds	Ts
34	Miscellaneous produces	Tmp
(iv)	Grazing / browsing	
A	*Direct sign*	
35	Cows / buffalos	Gcb
36	Goat	Gg
B	*Indirect sign*	
37	Dung	Gd
38	Pellets	Gp
39	Grazed grasses / herbs / shrubs	Gh
40	Hoof marks	Gf
(v)	**Fire incidence**	
41	Lighting fire	Fl
42	Recently burnt area	Fr
(vi)	**Hunting**	
43	Direct sighting while hunting	Hd
44	Indirect evidences	Hi
45	Fishing	
(vi)	**Human presence**	
46	Walking for joy	Hj
47	Going for collection of mfp	Hcm
48	Going for felling trees (with axe)	Hft
49	Going with bicycle	Hb
(vii)	**Others**	
50		

Appendix 4

CHECKLIST FOR TYPES OF TERRAIN IN TRISHA WILDLIFE SANCTUARY:

Numeric code	Types of terrain	Alphabetic code	Description
1	**Plain land in the valley**	Plv	In the valley, agricultural land etc. Slope below 5%
2	**Plain land on the hillock (tilla)**	Plh	On the top of the hillock (tilla) Slope below 5%
3	**Gentle slope**	Gs	Slope between 6% to 15%, on the plain land or at the edges of hillocks (tilla)
4	**Moderately slope**	Ms	Slope between 16% to 25%, on the plain land or on the slope of hillocks (tilla)
5	***Moderately high slope***	Mhs	Slope between 26% to 40%, specially on the slopes of tilla land.
6	**Steep slope**	Ss	Grater then 40% slope

Appendix 5

CONSERVATION ECOLOGY PROJECT (TRISHNA) OBSERVER:

Tree / Shrub phenology

DATE________TIME__________LOCALITY_____________TRANSECT NO_____SEGMENT NO______

Sl no	*Plant species*	Tag no	Vegetative phase (%)			Reproductive phase (%)				Remarks
			YL	ML	NL	FB	FL	YF	MF	

YL (YOUNG LEAF) **ML** (MATURED LEAF) **NL** (NO LEAF)
FB (FLOWER BUD) **FL** (FLOWER) **YF** (YOUNG FRUIT) **MF** (MATURED FRUIT)

Appendix 6

CONSERVATION ECOLOGY PROJECT (TRISHNA) OBSERVER:

Grass phenology

DATE________TIME__________LOCALITY_____________TRANSECT NO_____SEGMENT NO______

Plot no	Grass species	Phenophase (%)				% grass colour					Remarks
		YL	ML	FL	SD	GR	GRYL	YL	YLBR	BR	

YL (YOUNG LEAF) **ML** (MATURED LEAF) **FL** (FLOWER) **SD** (SEED)
GR (GREEN) **GRYL** (GREEN-YELLOW) **YL** (YELLOW)
YLBR (YELLOW BROWN) **BR** (BROWN)

Appendix 7

List of mammals recorded in Trishna Wildlife Sanctuary, Tripura.

	Common Name	Scientific Name
ORDER: Artiodactyla: Even-toed Ungulates		
Family Bovidae: Bovids	Gaur	*Bos gaurus*
Family Cervidae: Deer	Barking Deer/Munjtac	*Muntiacus muntjak*
Family Suidae: Pigs	Indian wild boar	*Sus scrofa*
ORDER: Carnivora: Carnivores		
Family Canidae: Canines/Dogs		
	Jackal	*Canis aureus*
	Dhole	*Cuon alpinus*
	Indian fox	*Vulpes bengalensis*
	Red fox	*Vulpes vulpes*
Family Felidae: Felines/Cats		
	Leopard	*Panthera pardus*
	Tiger	*Panthera tigris*
	Clouded leopard	*Neofelis nebulosa*
	Leopard cat	*Prionailurus bengalensis*
	Fishing cat	*Felis vierrinus*
	Jungle cat	*Felis chaus*
Family Herpestidae: Mongooses		
	Common mongoose	*Herpestes edwardsii*
	Small Indian mongoose	*Herpestes javanicus*
	Crab-eating mongoose	*Herpestes urva*
Family Mustelidae: Mustelids [Weasels, Martens, Wolverine, Badgers, Skunks, Otters]		
	Common otter	*Lutra lutra*
Family Viverridae: Civets		
	Spotted linsang/Tiger cat	*Prionodon pardicolor*
	Large Indian civet	*Viverra zibetha*
	Small Indian civet	*Viverricula indica*
ORDER: Lagomorpha: Hares, Rabbits, Pikas		
Family Leporidae: Hares		
	Hispid hare	*Caprolagus hispidus*
	Indian hare	*Lepus nigricollis*
ORDER: Pholidota: Pangolins		
Family Manidae: Pangolins		
	Indian pangolin	*Manis crassicaudata*

ORDER: Primates

Family Cercopithecidae: Old World Monkeys

Rhesus macaque	*Macaca mulatta*
Pigtailed macaque	*Macaca nemistrina*
Phayres' langur	*Presbytes phayrei*
Capped langur	*Trachypithecus pileatus*

Family Hylobatidae: Apes

Hoolock gibbon	*Bunopithecus hoolock*

Family Lorisidae: Lorises, Tarsiers

Slow loris	*Nycticebus bengalensis*

ORDER: Rodentia

Family Hystricidae: Old World Porcupines

Indian porcupine	*Hystrix indica*

Family Murinae: Old World Rats, Mice

Indian mole rat	*Bandicota bengalensis*
Bandicoot rat	*Bandicota indica*
Bower's rat	*Berylmys bowersii*
Bay bamboo rat	*Cannomys badius*

Family Pteromyidae: Flying squirrels

Giant red flying squirrel	*Petaurista petaurista*

Family Sciuridae: Squirrels

Malayan giant squirrel	*Ratufa bicolor*
Indian giant squirrel	*Ratufa indica*

Appendix-8

Checklist of flora in Trishna Wildlife Sanctuary, Tripura.

Family	Genus	Species
Acanthaceae	*Adhatoda*	*zeylanica*
Acanthaceae	*Andrographis*	*prionitis*
Acanthaceae	*Barleria*	*tprionis*
Acanthaceae	*Codonacanthus*	*sp.*
Acanthaceae	*Dicliptera*	*sp.*
Acanthaceae	*Dipteracanthus*	*sp.*
Acanthaceae	*Eranthemum*	*sp.*
Acanthaceae	*Hemigraphis*	*sp.*
Acanthaceae	*Hygrophila*	*sp.*
Acanthaceae	*Justicia*	*gendarussa*
Acanthaceae	*Lepidagathis*	*sp.*
Acanthaceae	*Ruellia*	*sp.*
Acanthaceae	*Rungia*	*sp.*
Acanthaceae	*Strobilanthes*	*sp.*
Aquifoliaceae	*Ilex*	*umbellatas*
Alangiaceae	*Alangium*	*salvifolium*
Amaranthaceae	*Achyranthes*	*aspera*
Amaranthaceae	*Alternanthera*	*philoxeroides*
Amaranthaceae	*Alternanthera*	*sessilis*
Amaranthaceae	*Amaranthus*	*gracilis*
Amaranthaceae	*Amaranthus*	*spinosus*
Amaranthaceae	*Amaranthus*	*tricolor*
Amaranthaceae	*Celosia*	*argentea*
Anacardiaceae	*Mangifera*	*indica*
Anacardiaceae	*Anacardium*	*occidentale*
Anacardiaceae	*Lannea*	*coromandelica*
Anacardiaceae	*Spondias*	*axillaris*
Anacardiaceae	*Spondias*	*pinnata*
Annonaceae	*Alphonsea*	*ventricosa*
Annonaceae	*Anona*	*reticulata*
Annonaceae	*Anona*	*squamosa*
Annonaceae	*Desmos*	*chinensis*
Annonaceae	*Desmos*	*dumosus*
Annonaceae	*Desmos*	*longiflorus*
Annonaceae	*Goniothalamus*	*sesquipedalis*
Annonaceae	*Miliusa*	*roxburghiana*
Annonaceae	*Polyalthia*	*longifolia*
Annonaceae	*Polyalthia*	*simiarum*
Annonaceae	*Saccopetalum*	*tomentosum*
Catharanthaceae	*Alstonia*	*scholaris*
Catharanthaceae	*Carissa*	*sp.*
Catharanthaceae	*Ervatamia*	*coronarea*
Catharanthaceae	*Holarrhena*	*antidysenterica*

Family	Genus	Species
Melastomaceae	*Memecylon*	*celastrinum*
Melastomaceae	*Memecylon*	*umbellatum*
Melastomaceae	*Osbeckia*	*chinensis*
Melastomaceae	*Osbeckia*	*nepalensis*
Melastomaceae	*Sonerella*	*macuata*
Meliaceae	*Aglaia*	*edulis*
Meliaceae	*Aglaia*	*spectabilis*
Meliaceae	*Aphanamixis*	*polystachia*
Meliaceae	*Azadirachta*	*indica*
Meliaceae	*Chisocheton*	*paniculatus*
Meliaceae	*Chukrassia*	*tabularis*
Meliaceae	*Dysoxylum*	*binectariferum*
Meliaceae	*Dysoxylum*	*procerum*
Meliaceae	*Melia*	*azadirach*
Meliaceae	*Munronia*	*pinnata*
Meliaceae	*Swietinia*	*macrophylla*
Meliaceae	*Toona*	*ciliata*
Meliaceae	*Trichillia*	*connaroide*
Meliaceae	*Walsura*	*robusta*
Menyanthaceae	*Nymphoides*	*cristata*
Menyanthaceae	*Nymphoides*	*indicum*
Mimosaceae	*Acacia*	*auriculiformis*
Mimosaceae	*Albizzia*	*Indica*
Mimosaceae	*Albizzia*	*lebbek*
Mimosaceae	*Albizzia*	*odoratissima*
Mimosaceae	*Albizzia*	*procera*
Mimosaceae	*Leucaena*	*leucocephala*
Mimosaceae	*Mimosa*	*pudica*
Mimosaceae	*Pithecllobium*	*dulce*
Mimosaceae	*Pithecllobium*	*heteropylum*
Mimosaceae	*Samanea*	*saman*
Apiaceae	*Centella*	*asiatica*
Apiaceae	*Hydrocotyle*	*javanica*
Apiaceae	*Hydrocotyle*	*silthorpoides*
Apiaceae	*Mollugo*	*pentaphylla*
Moraceae	*Artocarpus*	*chama*
Moraceae	*Artocarpus*	*heterophyllus*
Moraceae	*Artocarpus*	*lakoocha*
Moraceae	*Ficus*	*benghalensis*
Moraceae	*Ficus*	*cunea*
Moraceae	*Ficus*	*curtipes*
Moraceae	*Ficus*	*drupacea*
Moraceae	*Ficus*	*fistulosa*

Family	Genus	Species
Catharanthaceae	*Plumeria*	*alba*
Catharanthaceae	*Plumeria*	*rubra*
Catharanthaceae	*Rauwolfia*	*serpentina*
Catharanthaceae	*Thevetia*	*peruviana*
Catharanthaceae	*Catharanthus*	*rosea*
Araliaceae	*Brassaiopsis*	*glomerulata*
Araliaceae	*Heteropanax*	*fragrans*
Araliaceae	*Schefflera*	*venulosa*
Araliaceae	*Trevesia*	*palmata*
Asclepiadaceae	*Calotropis*	*gigantea*
Asteraceae	*Ageratum*	*conyzoides*
Asteraceae	*Bidens*	*biternata*
Asteraceae	*Blumea*	*balsamifera*
Asteraceae	*Blumea*	*lacera*
Asteraceae	*Blumea*	*laciniata*
Asteraceae	*Blumea*	*lanceolaria*
Asteraceae	*Cathemus*	*tinctora*
Asteraceae	*Cotula*	*hemispherica*
Asteraceae	*Enhydra*	*adinophorum*
Asteraceae	*Enhydra*	*cannabiaum*
Asteraceae	*Enhydra*	*fluctuans*
Asteraceae	*Enhydra*	*odoratum*
Asteraceae	*Enhydra*	*triplinerve*
Asteraceae	*Elephantopus*	*Sp.*
Asteraceae	*Gangrea*	*maderaspetana*
Asteraceae	*Ganaphalium*	*luteo album*
Asteraceae	*Ganaphalium*	*polycarlon*
Asteraceae	*Guizotia*	*abyssinica*
Asteraceae	*Laggera*	*flava*
Asteraceae	*Senecio*	*araneosus*
Asteraceae	*Sonchus*	*brachyotus*
Asteraceae	*Spilanthes*	*paniculata*
Asteraceae	*Synedrella*	*nodiflora*
Asteraceae	*Vernonia*	*cinera*
Asteraceae	*Xanthium*	*indicum*
Averrhoaceae	*Averrhoea*	*carambola*
Balsaminaceae	*Impatiens*	*balsamina*
Balsaminaceae	*Impatiens*	*chinensis*
Balsaminaceae	*Impatiens*	*sp.*
Balsaminaceae	*Impatiens*	*sp.*
Begoniaceae	*Begonia*	*barbata*
Bignoniaceae	*Millingtonia*	*hortensis*
Bignoniaceae	*Oroxylum*	*indicum*
Bignoniaceae	*Spathodia*	*campanulata*
Bignoniaceae	*Stereospermum*	*personatum*
Bombacaceae	*Bombax*	*ceiba*
Bombacaceae	*Bombax*	*insigne*

Family	Genus	Species
Moraceae	*Ficus*	*hederacea*
Moraceae	*Ficus*	*heteropleura*
Moraceae	*Ficus*	*hirta*
Moraceae	*Ficus*	*hispida*
Moraceae	*Ficus*	*ischonopoda*
Moraceae	*Ficus*	*microcarpa*
Moraceae	*Ficus*	*oligadon*
Moraceae	*Ficus*	*racemosa*
Moraceae	*Ficus*	*religiosa*
Moraceae	*Ficus*	*rumphi*
Moraceae	*Ficus*	*sinnata*
Moraceae	*Ficus*	*squamosa*
Moraceae	*Ficus*	*virens*
Moraceae	*Streblus*	*asper*
Moringaceae	*Moringa*	*oleifera*
Musaceae	*Musa*	*acuminata*
Myristicaceae	*Horsfildia*	*amygdalina*
Myristicaceae	*Knema*	*angustifolia*
Myristicaceae	*Knema*	*linifolia*
Myrsinaceae	*Ardisia*	*floribunda*
Myrsinaceae	*Ardisia*	*paniculata*
Myrsinaceae	*Maesa*	*chisia*
Myrsinaceae	*Maesa*	*indica*
Myrsinaceae	*Maesa*	*montana*
Myrtaceae	*Eucalyptus*	*spp.*
Myrtaceae	*Eugenia*	*macrocarpa*
Myrtaceae	*Eugenia*	*praeox*
Myrtaceae	*Psidium*	*guajava*
Myrtaceae	*Syzygium*	*cerasoides*
Myrtaceae	*Syzygium*	*cuminii*
Myrtaceae	*Syzygium*	*fruticosum*
Myrtaceae	*Syzygium*	*jambos*
Myrtaceae	*Syzygium*	*polypetalum*
Myrtaceae	*Syzygium*	*samarangense*
Myrtaceae	*Syzygium*	*syzygioides*
Nyctaginaceae	*Boerhavia*	*chinensis*
Nyctaginaceae	*Boerhavia*	*diffusa*
Nymphaeaceae	*Euryale*	*ferox*
Nymphaeaceae	*Nelumbo*	*nucifera*
Nymphaeaceae	*Nymphaea*	*micrantha*
Nymphaeaceae	*Nymphaea*	*nauchelli*
Nymphaeaceae	*Nymphaea*	*pubscens*
Onagraceae	*Ludwigia*	*adscendens*
Onagraceae	*Ludwigia*	*oclovalvis*
Onagraceae	*Ludwigia*	*perennis*
Onagraceae	*Ludwigia*	*prostrata*
Onagraceae	*Trapa*	*nutans var. bispinosa*

Family	Genus	Species
Boraginaceae	*Heliotropium*	*indicum*
Burseraceae	*Canarium*	*bengalensis*
Burseraceae	*Canarium*	*strictum*
Burseraceae	*Garuga*	*pinnata*
Celastraceae	*Celastrus*	*monospermum*
Cannabaceae	*Cannabis*	*sativa*
Capparaceae	*Cleome*	*viscosa*
Capparaceae	*Crateva*	*nurvala*
Caryophyllaceae	*Drymaria*	*cordata*
Caryophyllaceae	*Polycarpon*	*prostratum*
Casealpiniaceae	*Caesalpinea*	*digyna*
Casealpiniaceae	*Caesalpinia*	*mimusoides*
Casealpiniaceae	*Cassia*	*alata*
Casuarinaceae	*Casuarina*	*equisetifolia*
Combretaceae	*Terminalia*	*arjuna*
Combretaceae	*Terminalia*	*bellirica*
Combretaceae	*Terminalia*	*chebula*
Combretaceae	*Terminalia*	*citrina*
Convolvulaceae	*Evolvulus*	*alsinoides*
Convolvulaceae	*Evolvulus*	*nummularius*
Convolvulaceae	*Merremia*	*emerginata*
Convolvulaceae	*Merremia*	*hederaceae*
Convolvulaceae	*Merremia*	*vitifolia*
Datiscaceae	*Tetrameles*	*nudiflora*
Dilleniaceae	*Dillenia*	*pentagyna*
Dilleniaceae	*Dillenia*	*scabrella*
Dilleniaceae	*Dillenia*	*indica*
Dipterocarpaceae	*Dipterocarpus*	*turbinatus*
Dipterocarpaceae	*Shorea*	*robusta*
Ebenaceae	*Slynax*	*serrulatum*
Borapinaceae	*Cordia*	*dichtoma*
Boraginaceae	*Cordia*	*grandis*
Ehretiaceae	*Ehretia*	*acuminata*
Ehretiaceae	*Ehretia*	*fragrantissima*
Elaeocarpaceae	*Elaeocarpus*	*floribundus*
Elaeocarpaceae	*Elaeocarpus*	*obtusus*
Elaeocarpaceae	*Elaeocarpus*	*prunifolia*
Elaeocarpaceae	*Elaeocarpus*	*robustus*
Elaeocarpaceae	*Sloanea*	*dasycarpus*
Elaeocarpaceae	*Sloanea*	*sterculiaceus*
Elagnaceae	*Erythropatum*	*confolta*
Erythropalaceae	*Erythropatum*	*scandens*
Euphorbiaceae	*Antidesma*	*acidum*
Euphorbiaceae	*Antidesma*	*acuminatum*
Euphorbiaceae	*Antidesma*	*bunius*
Euphorbiaceae	*Antidesma*	*ghaesemibilla*
Euphorbiaceae	*Aporusa*	*dioica*

Family	Genus	Species
Oxalidaceae	*Oxalis*	*corniculata*
Papavaraceae	*Argemone*	*mexicana*
Plumbaginanceae	*Plumbago*	*auriculata*
Plumbaginanceae	*Plumbago*	*indica*
Plumbaginanceae	*Plumbago*	*zeylanica*
Polygonaceae	*Polygonum*	*sp.*
Polygonaceae	*Rumex*	*maritimus*
Polygonaceae	*Rumex*	*vesicarius*
Portulaccaceae	*Portulaca*	*oleraceae*
Portulaccaceae	*Portulaca*	*quadifida*
Rhamnaceae	*Gouania*	*tilaejaha*
Rhamnaceae	*Leea*	*robusta*
Rhamnaceae	*Rhamnus*	*nepalensis*
Rhamnaceae	*Ventilego*	*maderaspetana*
Rhamnaceae	*Ziziphus*	*funiculosa*
Rhamnaceae	*Ziziphus*	*mauritania*
Rhamnaceae	*Ziziphus*	*nepalensis*
Rhamnaceae	*Ziziphus*	*oenoplia*
Rhamnaceae	*Ziziphus*	*rugusa*
Rhamnaceae	*Ziziphus*	*xylopyra*
Rhizophoraceae	*Carallia*	*brachiata*
Rosaceae	*Eriobotrya*	*bengalensis*
Rosaceae	*Eriobotrya*	*japonica*
Rosaceae	*Pygeum*	*acuminatum*
Rosaceae	*Rubus*	*ellipticus*
Rosaceae	*Rubus*	*haniltonii*
Rosaceae	*Rubus*	*niveus*
Rosaceae	*Rubus*	*rosifolius*
Rubiaceae	*Anthocephalus*	*chinensis*
Rubiaceae	*Canthium*	*angustifolium*
Rubiaceae	*Canthium*	*dicoceum*
Rubiaceae	*Cephalanthus*	*occidentalis*
Rubiaceae	*Coffea*	*arabica*
Rubiaceae	*Gardenia*	*coronaria*
Rubiaceae	*Hedyotis*	*corymbosa*
Rubiaceae	*Hedyotis*	*costata*
Rubiaceae	*Hedyotis*	*diffusa*
Rubiaceae	*Hedyotis*	*glabra*
Rubiaceae	*Hedyotis*	*lineata*
Rubiaceae	*Hedyotis*	*scandens*
Rubiaceae	*Hyptianther*	*stricta*
Rubiaceae	*Ixora*	*sp.*
Rubiaceae	*Ixora*	*subsessilis*
Rubiaceae	*Meyna*	*spinosa*
Rubiaceae	*Mitragyna*	*parviflora*
Rubiaceae	*Mitragyna*	*rotundifolia*
Rubiaceae	*Morinda*	*angustifolia*

Family	Genus	Species
Euphorbiaceae	*Baccaurea*	*ramiflora*
Euphorbiaceae	*Baliospermum*	*sp.*
Euphorbiaceae	*Balliospermum*	*montanum*
Euphorbiaceae	*Bischofia*	*javanica*
Euphorbiaceae	*Breynia*	*vitisidaea*
Euphorbiaceae	*Bridelia*	*assamica*
Euphorbiaceae	*Bridelia*	*pubescens*
Euphorbiaceae	*Bridelia*	*retusa*
Euphorbiaceae	*Bridelia*	*stipularis*
Euphorbiaceae	*Bridelia*	*tomentosa*
Euphorbiaceae	*Bridelia*	*tomentosa*
Euphorbiaceae	*Codiaeum*	*variegatum*
Euphorbiaceae	*Cresmore*	*javanica*
Euphorbiaceae	*Croton*	*bonplandianus*
Euphorbiaceae	*Croton*	*joufra*
Euphorbiaceae	*Croton*	*oblongifolius*
Euphorbiaceae	*Drypetes*	*assamica*
Euphorbiaceae	*Drypetes*	*roxburghii*
Euphorbiaceae	*Emblica*	*officinalis*
Euphorbiaceae	*Glochidion*	*assamicum*
Euphorbiaceae	*Glochidion*	*heyneanum*
Euphorbiaceae	*Glochidion*	*multiloculare*
Euphorbiaceae	*Macaranga*	*denticulata*
Euphorbiaceae	*Mallotus*	*philipensis*
Euphorbiaceae	*Mallotus*	*repandus*
Euphorbiaceae	*Mallotus*	*roxburghianus*
Euphorbiaceae	*Mallotus*	*tetracoccus*
Euphorbiaceae	*Ostodes*	*paniculata*
Euphorbiaceae	*Phyllanthus*	*acidus*
Euphorbiaceae	*Phyllanthus*	*amarus*
Euphorbiaceae	*Phyllanthus*	*urinaria*
Euphorbiaceae	*Phyllanthus*	*virgatus*
Euphorbiaceae	*Sapium*	*baccatum*
Euphorbiaceae	*Tragia*	*involucrata*
Euphorbiaceae	*Trewia*	*nudiflora*
Fabaceae	*Aeschynomene*	*indica*
Leguminosae	*Alysicarpus*	*tetragonolobus*
Leguminosae	*Alysicarpus*	*vaginalis*
Fabaceae	*Cajanus*	*scarabaeoides*
Caesalpinaceae	*Bauhinia*	*malabarica*
Caesalpinaceae	*Bauhinia*	*purpurea*
Caesalpinaceae	*Bauhinia*	*variegata*
Caesalpinaceae	*Butea*	*monosperma*
Caesalpinaceae	*Caesalpinia*	*pulcherrima*
Caesalpinaceae	*Cassia*	*fistula*
Caesalpinaceae	*Cassia*	*nodosa*
Fabaceae	*Crotalaria*	*juncea*

Family	Genus	Species
Rubiaceae	*Morinda*	*tinctoria*
Rubiaceae	*Nauclea*	*sessillifolia*
Rubiaceae	*Ophiorrhiza*	*rugusa*
Rubiaceae	*Ophiorrhiza*	*tingens*
Rubiaceae	*Ophiorrhiza*	*turida*
Rubiaceae	*Ophiorrhiza*	*villosa*
Rubiaceae	*Psychoria*	*spp.*
Rubiaceae	*Psychotria*	*calocarpa*
Rubiaceae	*Psychotria*	*denophylla*
Rubiaceae	*Psychotria*	*denticulata*
Rubiaceae	*Psychotria*	*monticola*
Rubiaceae	*Randia*	*racemosa*
Rubiaceae	*Randia*	*faciculata*
Rubiaceae	*Randia*	*longiflora*
Rubiaceae	*Spermacoce*	*ocymoides*
Rubiaceae	*Spiradictis*	*bifida*
Rubiaceae	*Wendlandia*	*grandis*
Rubiaceae	*Wendlandia*	*tinctoria*
Rubiaceae	*Wendlandia*	*wallichii*
Rubiaceae	*Xeromphis*	*spinosa*
Rutaceae	*Acronychia*	*pedinculata*
Rutaceae	*Aegle*	*marmelos*
Rutaceae	*Citrus*	*maxima*
Rutaceae	*Citrus*	*medica*
Rutaceae	*Citrus*	*reticulata*
Rutaceae	*Glycosmis*	*arborea*
Rutaceae	*Micromelum*	*integerrimum*
Rutaceae	*Murraya*	*paniculata*
Rutaceae	*Zanthoxylum*	*budrunga*
Rutceae	*Clausena*	*pentaphylla*
Rutceae	*Glycosmis*	*arborea*
Rutceae	*Glycosmis*	*cymosa*
Rutceae	*Glycosmis*	*mauritiana*
Rutceae	*Murraya*	*koenigii*
Sabiaceae	*Meliosma*	*simplicifolia*
Sapindaceae	*Allophythus*	*cobbe*
Sapindaceae	*Allophythus*	*racemosa*
Sapindaceae	*Allophythus*	*serrata*
Sapotaceae	*Manilkara*	*achrus*
Sapotaceae	*Mimusops*	*elengi*
Sapotaceae	*Palaquium*	*polyanthum*
Sapotaceae	*Xantolis*	*assamica*
Saurauriaceae	*Saurauia*	*roxburghii*
Scrophulariaceae	*Adenosma*	*sp.*
Scrophulariaceae	*Angeloma*	*sp.*
Scrophulariaceae	*Bacopa*	*hamiltoniana*
Scrophulariaceae	*Bacopa*	*monnieri*

Family	Genus	Species
Fabaceae	*Crotalaria*	*spectabilis*
Fabaceae	*Crotalaria*	*verrucosa*
Fabaceae	*Crotolaria*	*albida*
Fabaceae	*Crotolaria*	*calycina*
Fabaceae	*Crotolaria*	*ferruginea*
Fabaceae	*Crotolaria*	*sp.*
Fabaceae	*Dalbergia*	*slipulacea*
Fabaceae	*Dalbergia*	*volubilis*
Caesalpinaceae	*Delonix*	*regia*
Fabaceae	*Derris*	*robusta*
Fabaceae	*Desmodium*	*caudatus*
Fabaceae	*Desmodium*	*gangeticum*
Fabaceae	*Desmodium*	*griffithianum*
Fabaceae	*Desmodium*	*heterocarpon*
Fabaceae	*Desmodium*	*heterophyllum*
Fabaceae	*Desmodium*	*motorium*
Fabaceae	*Desmodium*	*pulchellum*
Fabaceae	*Desmodium*	*triflorum*
Fabaceae	*Desmodium*	*triquetrum*
Fabaceae	*Erythrina*	*arborescens*
Fabaceae	*Erythrina*	*fusca*
Fabaceae	*Erythrina*	*subumbrans*
Fabaceae	*Erythrina*	*variegata*
Fabaceae	*Flemingia*	*eruticulosa*
Fabaceae	*Flemingia*	*stricta*
Fabaceae	*Flemingia*	*strobilifera*
Fabaceae	*Indigofera*	*atropurpurea*
Fabaceae	*Indigofera*	*cassiodes*
Fabaceae	*Indigofera*	*purpureus*
Fabaceae	*Melilotus*	*albus*
Caesalpinaceae	*Peltophorum*	*pterocarpum*
Fabaceae	*Pongamia*	*pinnata*
Caesalpinaceae	*Saraca*	*asoca*
Fabaceae	*Sesbania*	*cannabina*
Fabaceae	*Sesbania*	*grandiflora*
Fabaceae	*Sesbania*	*sesban*
Fabaceae	*Tamarindus*	*indica*
Fabaceae	*Tephrosia*	*candida*
Fabaceae	*Uraria*	*crinita*
Fabaceae	*Uraria*	*rufescens*
Fabaceae	*Uraria*	*sp.*
Fabaceae	*Vicia*	*hirsuta*
Fabaceae	*Zornia*	*gibbosa*
Fagaceae	*Castanopsis*	*armata*
Fagaceae	*Castanopsis*	*indica*
Fagaceae	*Castanopsis*	*tribuloides*
Fagaceae	*Lithocarpus*	*spicata*

Family	Genus	Species
Scrophulariaceae	*Limnophila*	*spp.*
Scrophulariaceae	*Lindernia*	*sp.*
Scrophulariaceae	*Macardonia*	*spp.*
Scrophulariaceae	*Nelsonia*	*spp.*
Scrophulariaceae	*Scoparia*	*dulcis*
Scrophulariaceae	*Torenia*	*sp.*
Simarubaceae	*Ailanthus*	*integrifolia*
Simarubaceae	*Picrasmia*	*javanica*
Solanaceae	*Datura*	*metal*
Solanaceae	*Datura*	*stramonium*
Lamiaceae	*Elsholtzia*	*sp.*
Varbenaceae	*Lantana*	*camera*
Solanaceae	*Phogocenthus*	*turnifolis*
Solanaceae	*Psysalis*	*minima*
Solanaceae	*Solanum*	*sp.*
Staphyleaceae	*Turpinia*	*pomifera*
Sterculiaceae	*Firmiana*	*colorata*
Sterculiaceae	*Kleinhovia*	*hospita*
Sterculiaceae	*Pterospermum*	*acerifolium*
Sterculiaceae	*Pterospermum*	*lancaefolium*
Sterculiaceae	*Pterospermum*	*semisagittatum*
Sterculiaceae	*Sterculia*	*villosa*
Sterculiaceae	*Abroma*	*augusta*
Sterculiaceae	*Dombeya*	*mnastersii*
Symplocaceae	*Symplocos*	*racemosa*
Tiliaceae	*Grewia*	*microcos*
Tiliaceae	*Grewia*	*paniculata*
Tiliaceae	*Grewia*	*serrulata*
Tiliaceae	*Grewia*	*viminea*
Theaceae	*Camellia*	*kissi*
Theaceae	*Camellia*	*sinensis*
Theaceae	*Eurya*	*acuminata*
Theaceae	*Schima*	*wallichii*
Thymeliaceae	*Aquillaria*	*malaccensis*
Tiliaceae	*Grewia*	*hirsuta*
Tiliaceae	*Grewia*	*macrophylla*
Tiliaceae	*Grewia*	*sapida*
Tiliaceae	*Grewia*	*serrulata*
Malvaceae	*Malvaviscus*	*arboreus*
Malvaceae	*Sida*	*acuta*
Malvaceae	*Sida*	*cordata*
Malvaceae	*Sida*	*cordifolia*
Malvaceae	*Sida*	*mysorensis*
Tiliaceae	*Triumfetta*	*pilosa*
Tiliaceae	*Triumfetta*	*rhomboidea*
Malvaceae	*Urena*	*lobata*
Malvaceae	*Urena*	*sinnata*

Family	Genus	Species
Flacourtiaceae	*Flacourtia*	*indica*
Flacourtiaceae	*Flacourtia*	*jangomas*
Flacourtiaceae	*Gynocardia*	*odorata*
Flacourtiaceae	*Hydnocarpus*	*kurzii*
Flacourtiaceae	*Xylosma*	*controversa*
Flacourtiaceae	*Xylosma*	*longifolium*
Gentiananceae	*Canscora*	*demoata*
Oxalidaceae	*Biophytum*	*sensiitivum*
Guttiferae	*Garcima*	*acuminata*
Guttiferae	*Garcima*	*cowa*
Guttiferae	*Garcima*	*xanthochymus*
Guttiferae	*Mesua*	*ferrea*
Holragaceae	*Myriophyllum*	*indica*
Hypocastanaceae	*Aesculus*	*assamica*
Hypoxidaceae	*Curculigo*	*latifolia*
Hypoxidaceae	*Curculigo*	*orchioides*
Hypoxidaceae	*Hypoxis*	*aurea*
Hypoxidaceae	*Mollineria*	*recurvata*
Hypoxidaceae	*Mollineria*	*recurvata*
Juglandaceae	*Engelthardtia*	*spicata*
Lamiaceae	*Coleus*	*sp.*
Lamiaceae	*Dysophylla*	*sp.*
Lamiaceae	*Gomphostemma*	*sp.*
Lamiaceae	*Hyptis*	*suaveolens*
Lamiaceae	*Leonorus*	*sp.*
Lamiaceae	*Leucas*	*sp.*
Lamiaceae	*Melissa*	*sp.*
Lamiaceae	*Meriandra*	*sp.*
Lamiaceae	*Ocimum*	*sp.*
Lamiaceae	*Orthosiphon*	*incurvus*
Lamiaceae	*Perilla*	*frutescens*
Lamiaceae	*Salvia*	*sp.*
Lauraceae	*Actinodaphne*	*angustifolia*
Lauraceae	*Actinodaphne*	*obovata*
Lauraceae	*Beilschmeidia*	*assamica*
Lauraceae	*Cinnamomum*	*camphora*
Lauraceae	*Cinnamomum*	*glanduliferun*
Lauraceae	*Cinnamomum*	*obtusifolium*
Lauraceae	*Cinnamomum*	*tamala*
Lauraceae	*Cryptocarya*	*amygdalina*
Lauraceae	*Cryptocarya*	*floribunda*
Lauraceae	*Litsea*	*cubeba*
Lauraceae	*Litsea*	*glutinosa*
Lauraceae	*Litsea*	*laeta*
Lauraceae	*Litsea*	*lancaefolia*
Lauraceae	*Litsea*	*monopetala*
Lauraceae	*Litsea*	*panamunja*

Family	Genus	Species
Ulmaceae	*Celtis*	*cinnamomea*
Ulmaceae	*Trema*	*orientalis*
Ulmaceae	*Trema*	*orientalis*
Urticaceae	*Boehmeria*	*glomerulifera*
Urticaceae	*Boehmeria*	*macrophylla*
Urticaceae	*Boehmeria*	*nivea*
Urticaceae	*Boehmeria*	*platyphylla*
Urticaceae	*Boehmeria*	*sidaefolia*
Urticaceae	*Dendrocnide*	*sinuata*
Urticaceae	*Debregesia*	*dentata*
Urticaceae	*Debregesia*	*longifolia*
Urticaceae	*Elatostemma*	*capillosum*
Urticaceae	*Elatostemma*	*lineolatum*
Urticaceae	*Elatostemma*	*platiphylium*
Urticaceae	*Elatostemma*	*rupestre*
Urticaceae	*Elatostoma*	*lineolatum*
Urticaceae	*Elatostoma*	*papillosum*
Urticaceae	*Elatostoma*	*platyphyllum*
Urticaceae	*Elatostoma*	*rupestre*
Urticaceae	*Laportia*	*crenulata*
Urticaceae	*Pilea*	*microphylla*
Urticaceae	*Pouzolzia*	*zeylanica*
Urticaceae	*Sacrochlamus*	*pulcherrima*
Verbenaceae	*Callicarpa*	*arborea*
Verbenaceae	*Clerodendrum*	*divericatum*
Verbenaceae	*Clerodendrum*	*practeatum*
Verbenaceae	*Clerodendrum*	*viscosum*
Verbenaceae	*Gmelina*	*arborea*
Verbenaceae	*Premna*	*latifolia*
Verbenaceae	*Premna*	*mucronata*
Verbenaceae	*Tectona*	*grandis*
Verbenaceae	*Vitex*	*altissima*
Verbenaceae	*Vitex*	*negundo*
Verbenaceae	*Vitex*	*penduncularis*
Verbenaceae	*Vitex*	*pubescens*
Violaceae	*Viola*	*tricolor*
Mimosaceae	*Adenanthera*	*pavonina* *
Meliaceae	*Aphanamixis*	*polystachya* *
Euphorbiaceae	*Aporusa*	*obolga* *
Araliaceae	*Aralia*	*sp.* *
Myrsinaceae	*Ardisia*	*Solanacea* *
Moraceae	*Artocarpus*	*integrifolia* *
Lauraceae	*Beilschmiedia*	*roxburghiana* *
Urticaceae	*Boehmeria*	*macrophylla* *
Caesalpiniaceae	*Caesalpinia*	*pulcherrima* *
Rubiaceae	*Chasalia*	*albiflora* *
Lauraceae	*Cinnamomum*	*inermis* *

Family	Genus	Species
Lauraceae	*Litsea*	*salicifolia*
Lauraceae	*Neolitsaea*	*zeylanica*
Lauraceae	*Persea*	*lanceolata*
Lauraceae	*Persea*	*villosa*
Lecythidaceae	*Careya*	*arborea*
Lecythidaceae	*Duabanga*	*grandiflora*
Lythraceae	*Ammannia*	*baccifera*
Lythraceae	*Lagerstroemia*	*parviflora*
Lythraceae	*Lagerstroemia*	*speciosa*
Lythraceae	*Rotala*	*densiflora*
Lythraceae	*Rotala*	*indica*
Magnoliaceae	*Magnolia*	*pterocarpa*
Magnoliaceae	*Magnolia*	*pumila*
Magnoliaceae	*Michelia*	*champaca*
Magnoliaceae	*Michelia*	*montana*
Magnoliaceae	*Talauma*	*phelocarpa*
Malvaceae	*Abutilon*	*indicum*
Malvaceae	*Gossypium*	*arboreum*
Malvaceae	*Hibiscus*	*mutabilis*
Malvaceae	*Hibiscus*	*rosa-sinensis*
Malvaceae	*Hibiscus*	*sabdanrifa*
Malvaceae	*Hibiscus*	*syriacus*
Malvaceae	*Malvaviscus*	*arbaoreus*
Malvaceae	*Sida*	*cordata*
Malvaceae	*Sida*	*cordifolia*
Malvaceae	*Sida*	*rhombifolia*
Malvaceae	*Syzygium*	*fruticosum*
Melastomaceae	*Melastoma*	*malabathricum*

Family	Genus	Species
Leguminosae	*Dalbergia*	*rimosa* *
Dracaenaceae	*Dracaena*	*sp.* *
Anacardiaceae	*Drimycarpus*	*racemosus* *
Lythraceae	*Duabanga*	*sonneratioides* *
Elaeocarpaceae	*Elaeocarpus*	*aristatus* *
Fabaceae	*Erythrina*	*indica* *
Moraceae	*Ficus*	*benjamina* *
Moraceae	*Ficus*	*deruosa* *
Malvaceae	*Hibiscus*	*macrophyllus* *
Rubiaceae	*Hymenodictyon*	*hymenodictyas* *
Leeaceae	*Leea*	*indica* *
Lauraceae	*Machilus*	*sp.* *
Myrsinaceae	*Maesa*	*ramentacea* *
Anacardiaceae	*Mangifera*	*indica* *
Tiliaceae	*Microcos*	*paniculata* *
Annonaceae	*Miliusa*	*roxburghiana* *
Rubiaceae	*Mitragyna*	*rotundifolia* *
Leguminosae	*Pithecellobium*	*monadelplum* *
Rubiaceae	*Randia*	*wallichii* *
Sterculiaceae	*Sterculia*	*foetida* *
Myrtaceae	*Syzygium*	*operculatum* *
Lecythidaceae	*Carreya*	*arborea* *
Ulmaceae	*Celtis*	*tentrandra* *

* New records compared to the earlier checklist given in "A study in the ground flora scenario, its values and food resources" by Forest survey of India, Eastern Zone in collaboration with Shri A. B. Choudhury, I.F.S. (Retd.) during 1996.

Appendix 9

Average of Summer									
Scientific name	**Tree-species**	**Flower**	**Flower-bud**	**Leaf-bud**	**Matured-fruit**	**Matured-leaves**	**No-Leaves**	**Young-fruit**	**Young-leaves**
	H20	25.00	7.50	10.00	0.00	27.50	52.50	0.00	30.00
Garcinia cowa	T10	0.00	0.00	0.00	80.00	100.00	0.00	0.00	0.00
Bombax ceiba	T119	0.00	0.00	14.63	15.00	80.00	73.00	15.00	14.25
	T142	25.83	21.17	25.71	30.00	62.81	20.77	80.00	23.50
Mengifera indica	T145	31.67	5.00	11.00	0.00	59.86	10.91	4.00	33.18
	T152	0.00	0.00	10.00	0.00	82.86	4.29	80.00	20.00
Ficus hispida	T23	0.00	0.00	10.00	10.00	77.50	10.00	20.00	15.00
Ardisia solanaceaea	T27	25.00	6.67	5.00	16.00	70.00	30.20	22.50	19.83
Aglaia Sp.	T28	30.00	18.33	5.67	3.50	54.29	21.00	31.67	34.67
Syzygium operculata	T41	70.00	30.00	0.00	0.00	85.00	15.00	0.00	0.00
Terminalia bellirica	T55	28.75	21.00	19.70	0.00	45.36	34.14	45.00	28.38
Dillenia pentagyna	T60	25.64	18.50	12.33	20.00	26.15	69.13	43.95	18.67
Macaranga peltata	T63	30.00	11.50	6.25	0.00	74.00	11.00	26.00	10.00
Ficus oligadon	T66	10.00	10.00	4.00	10.00	67.25	10.50	25.00	46.75
Emblica officinalis	T67	0.00	0.00	0.00	0.00	85.00	10.00	0.00	10.00
Carreya arborea	T71	0.00	16.67	16.67	35.71	45.00	35.00	25.56	19.55
Vitex allissima	T77	43.33	15.00	25.71	46.67	60.56	23.46	56.17	30.00
	T85	30.00	10.00	25.00	0.00	36.67	35.00	0.00	50.00
Artocarpus chaplasa	T90	0.00	0.00	18.75	12.33	52.75	38.40	15.50	27.65
	T95	14.29	13.17	8.00	0.00	67.25	22.50	15.00	11.00
Lannea coromandelice	T96	17.50	75.00	11.67	0.00	58.57	35.89	20.00	18.89
	T99	0.00	0.00	5.00	0.00	80.00	12.50	45.00	10.00
	Grand Total	**29.07**	**18.63**	**12.90**	**23.27**	**63.56**	**26.14**	**33.55**	**23.57**

Average of Rainy Season

Scientific name	Tree-species	Flower	Flower-bud	Leaf-bud	Matured-fruit	Matured-leaves	No-Leaves	Young-fruit	Young-leaves
Oxytenanthera nigrocciliata	G15	0.00	0.00	12.50		53.33	21.67		16.67
Bambusa tulda	G19	0.00	0.00	21.00	0.00	25.00	36.00	0.00	18.00
	H20	0.00	0.00			95.00			5.00
Pinanga sp.	H27	0.00	0.00			90.00	0.00		10.00
Hedyelium Sp.	H46	0.00	0.00			90.00	0.00		10.00
Garcinia cowa	T10	0.00	0.00		20.00	100.00	0.00		
Bombax ceiba	T119	0.00	0.00	4.33	0.00	93.25	17.00	0.00	4.33
	T142	0.00	0.00	0.00	2.50	82.50	2.94	0.00	15.00
Mengifera indica	T145	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
	T152	0.00	0.00			99.00	1.00		2.00
Ficus hispida	T23	0.00	0.00			96.63	3.86		
Ardisia solanaceaea	T27	0.00	0.00	0.00	0.00	40.23	0.00	0.00	59.67
Aglaia Sp.	T28	0.00	0.00	0.00	0.00	83.00	0.00	0.00	51.00
Syzygium operculata	T41					95.00	5.00		
Terminalia bellirica	T55	4.57	4.17	2.42	4.67	92.14	3.24	11.54	5.27
Dillenia pentagyna	T60	0.00	0.00	2.64	0.00	93.94	3.15	0.00	3.17
Macaranga peltata	T63	0.00	0.00	4.83	10.40	90.83	0.63	3.33	9.50
Ficus oligadon	T66	0.00	0.00	0.00	14.00	92.50	5.83	10.00	5.00
Emblica officinalis	T67					100.00	0.00		
Carreya arborea	T71	0.00	0.00	1.43	9.77	90.17	9.20	1.43	3.21
Vitex allissima	T77	0.00	0.00	0.00	20.63	94.89	5.00	8.33	3.00
	T85					90.00	5.00		5.00
Microcos paniculata	T89	0.00	0.00	0.00	56.67	96.25	3.75	20.00	0.00
Artocarpus chaplasa	T90	0.00	0.00	0.00	1.00	96.25	4.63	0.00	0.40
Castanopsis indica	T95	5.00	2.00	3.50	5.00	91.60	2.50	10.00	10.00
Lannea coromandelice	T96	0.00	0.00	5.50	0.00	88.20	8.67	0.00	3.57
	T99	8.33	6.67	3.50	15.00	89.17	5.00	14.00	4.00

Average of Winter season

Scientific name	Tree-species	Flower	Flower-bud	Leaf-bud	Matured-fruit	Matured-leaves	No-Leaves	Young-fruit	Young-leaves
	H20	0.00	0.00	0.00	0.00	70.00	36.67	0.00	10.00
Bombax ceiba	T119	53.33	36.67	0.00	0.00	13.00	93.50	15.00	0.00
	T142	0.00	0.00	11.00	0.00	64.75	30.25	0.00	9.00
Mengifera indica	T145	5.00	5.00	0.00	0.00	96.50	2.88	0.00	5.00
	T152	0.00	0.00	0.00	0.00	50.00	50.00	0.00	0.00
Ficus hispida	T23	0.00	0.00	0.00	0.00	92.50	7.50	0.00	5.00
Ardisia solanaceaea	T27	0.00	0.00	0.00	0.00	90.00	5.00	0.00	10.00
Aglaia Sp.	T28	5.00	5.00	15.00	0.00	68.00	9.50	0.00	17.50
Syzygium operculata	T41	0.00	0.00	0.00	0.00	85.00	15.00	0.00	0.00
Terminalia bellirica	T55	0.00	0.00	6.25	5.67	72.92	21.08	4.00	5.22
Dillenia pentagyna	T60	0.00	0.00	0.00	0.00	59.88	40.13	0.00	0.00
Ficus oligadon	T66	0.00	0.00	5.00	0.00	92.00	0.00	0.00	5.50
Carreya arborea	T71	0.00	0.00	0.00	0.00	63.50	36.50	0.00	0.00
Vitex allissima	T77	0.00	0.00	0.00	27.50	74.17	23.00	27.50	5.67
	T85	0.00	0.00	0.00	0.00	90.00	8.75	0.00	5.00
Artocarpus chaplasa	T90	0.00	0.00	0.00	0.00	80.06	21.13	0.00	2.00
Castanopsis indica	T95	15.00	20.00	8.33	7.67	57.00	16.75	10.00	20.00
Lannea coromandelice	T96	20.00	41.67	20.00	0.00	15.00	36.25	0.00	20.00

Appendix 10
Seasonal Presence Absence of Study animals

	Sites	Winter-02-03			Summer-03			Winter-03-04			Summer-04		
		CI	Ptm	Hg	CI	Ptm	Hg	CI	Ptm	Hg	CI	Ptm	Hg
Transect - 1 Degraded Semi-evergreen	MS-1	2/6			1/6				1/6		2/6		
	MS-2						1/6				3/6	1/6	
	MS-3						1/6	1/6			3/6		
	MS-4			2/6									
	MS-5					1/6							
	MS-6						1/6						
Transect – 2 Semi-evergreen	MS-7				1/6	1/6		1/6	1/6		4/6	1/6	
	MS-8	2/6		1/6						1/6			2/6
	MS-9	1/6								2/6			1/6
	MS-10	2/6		1/6	1/6		1/6			1/6			2/6
	MS-11						1/6						1/6
	MS-12												
Transect – 3 *Kalai* Bamboo forest	MS-13				1/6						2/6	1/6	
	MS-14												
	MS-15		1/6										
	MS-16												
	MS-17												
Transect -4 Savanna Woodland	MS-18												
	MS-19												
	MS-20												
	MS-21												
	MS-22												
	MS-23												
	MS-24												
	MS-25												
Transect – 5 Mixed Deciduous	MS-26	1/6			2/6				1/6				
	MS-27										2/6		
	MS-28	3/6			1/6			1/6			4/6		
	MS-29												
	MS-30							1/6			3/6		
	MS-31												
Transect – 6 Mixed Bamboo	MS-32											1/6	
	MS-33												
	MS-34					1/6			1/6				
	MS-35												
	MS-36								1/6				
	MS-37												

Annexure 1

Scan Sheet

During each scan the following information were recorded for developing ethograms of study species.

1. Date : DD/MM/YYYY of observation and Phase/Day of 8days continuous monitoring from dawn to dusk.

2. Time : Indian Standard Time (IST), Observation time.

3. Sun : Cloud cover and sun condition was recorded on a 1-5 scale (1 = no cloud and bright sunlight; 2 = medium cloud cover; 3 = overcast; 4 = pre and post-dawn darkness; 5 = fog).

4. Wind : recorded on 1-3 scale (1 = Strong wind, causing thick branches to swing; 2 = medium wind causing only the top canopy and terminal branches to swing; and 3 = very light wind).

5. Rain : recorded on 1 to 3 scale, with 1 = no rain; 2 = medium rain without any thunder; and 3 = heavy rain with thunder/hail storms)

6. Temperature : Minimum and maximum temperature of a day was recorded from the weather station setup at field research station.

7. Relative humidity: RH was recorded from the weather station setup at field research station.

8. Location During every scan the location of each individual was noted with reference to the quadrat number (the entire area was divided into quadrats of 25x25m).

9. Activity The activities in which each scanned individuals was found engaged at the time of recording were also noted. List of activities recorded during scan sampling is presented in **Appendix III**. Major activities identified and recorded were: sleeping, resting, feeding, grooming, playing, calling, defecating, urinating, watching, embracing, huddling, chasing, fighting, threatening, and so on. Some of these major activities were further divided into sub-categories. For computer analysis, some of the sub-categories were given a numeric code with reference to the age-sex class of the individual performing it, e.g. if in allogrooming the partners were both adult males the code was '10', but, a different code was given when other individuals of different age-sex classes participated in allogrooming. Similarly, different codes were given to sub-categories of 'play' activity depending upon the participating individuals of different age-sex classes. In the case of Phayre's langurs, five different types of calls (alarm, *huk-huk-huk*, teeth cluttering, distress, and help-seeking calls by infants) were identified, and each of these was given a separate code. Both in capped and golden langurs, only the alarm call by the adult males and help-seeking calls by the infants were identified and recorded.

10. **Food plants** When the activity was 'feeding', the name of the food species was recorded. Attempts were made to identify the food plants to species level at the very time, but when any confusion existed, specimens were collected for identification later with the help of expert botanists in Tripura University and/or with the help of local foresters. Each species was given a separate numeric code on the scan-sheet..

11. **Plant parts** For each food species consumed by the individuals in each scan, the name of the specific plant parts eaten by the subject was also recorded: leaves, flowers, fruits, and seeds. A comprehensive list of major plant parts recorded is presented in Appendix.

12. **Non-plant food material** On many occasions, the langurs were seen feeding on non-plant materials. Most common of those were the insects and soil from the termite mounds.

13. **Tree species** In some cases it was found that the individuals were sitting in a tree, but are eating a different plant species (e.g. feeding on any climber species which climbed the tree, or when the animals plucked a handful of leaves from an adjoining food tree). The name of these tree species were also recorded using the same code numbers as given to the food plant species, because most of the time individuals were using the same tree both for feeding and any other activity.

14. **Tree height** The height of the trees occupied by each individual was recorded in metres to the nearest whole number using the methods described in Chapter

15. **Bole height** The bole height was recorded as the height of the tree from the ground to a level at which the first branch leaves the main trunk, as for tree height.

16. **Animal height** The height of the subject on the tree was recorded with respect to the total tree height, as for tree height.

17. **Canopy width** The canopy spread of all those trees identified above was recorded based on average of randomly placed diameter of canopy at right angle.
18. **Canopy height:** The canopy height of the same trees used for recording canopy width or spread, as above, was computed from available measurements on tree height (TH) and bole height (BH) as:

Canopy height = TH - BH

19. **Total trees** Total number of trees used by the whole group in each scan was also recorded. It provided information as to whether the whole group was in a single tree, or was active in several trees.

20. **Sex neighbour** The age-sex classes of the nearest individual to the scanned subject was recorded. For this purpose a separate numeric code was given to each possible combination among the individuals of different age-sex classes.

21. **Distance neighbour** The distance between the scanned individual and the nearest individual was recorded in metres to the nearest whole number.

22. **Dispersion of the group** The longitudinal distance between the two most separated individuals in the group was recorded as group dispersion. Sometimes one or both of these individual were not visible, but, their location was known with reference to the substrate they were using. In those cases, the distance between those substrate (usually trees) was recorded as group dispersion distance. During feeding, when the group usually split into two or more subgroups, the distance between the centres of these subgroups was recorded as group dispersion.

23. **Other species of primates** Presence of other primate species near (within 20 to 50 m from the study group's centre) was also recorded. The criterion of using 20 m and 50 m correspond with other studies to define the distance within which the presence of different groups could be considered to be associated (Waser 1980; Struhsaker 1981). Whenever possible, the total number of individuals, their age-sex classes, and the major activities in which they were engaged, were also recorded for other primate groups close to the study group. In case of feeding activity, the details of the food plants and parts eaten were also recorded. A separate numeric code was given to different primate species (e.g. capped langur, rhesus macaque, golden langur, and so on), or in combination of two when two or three different species were present together.

24. **Other animals** Apart from other primate species, the presence of other animals was also recorded during each scan. These included both wild and domesticated animals, and were mostly mammals or birds. Among domesticated animals, most were dogs and cattle, both owned by the people in the villages surrounding the study area. Among wild animals were, wild boar (*Sus scrofa*), sambar (*Cervus unicolor*); wild crow (*Corvus macrorhynchos)*; hornbill (*Anthracoceros malabaricus*); pigeon (*Treron bicincta*); vulture (*Gyps bengalensis*); and so on. The groups of capped and golden langurs were also seen in association with some of the captive animals kept in the zoo, for e.g. chital (*Axis axis*), nilgai (*Boselaphus tragocamelus*), caged golden and capped langur.

25: **Human presence** The Presence of humans near the study groups was also recorded at each scan. Details on the total number of people, the activities in which they were engaged, and if the people were collecting forest products, the details of each of those plants and their parts, were also recorded.

26. **Distance covered from previous location** At the end of each scan, total distance covered by the group with reference to its location at the time of previous scan, was also recorded in metres to the nearest whole number. It equalled the distance between the group's centres at two different locations.

27. **Remarks** *Ad libitum* notes were taken at each scan-sampling on those activities which could not be recorded during the scanning, e.g. the time group members started their activities, the time at which the infant started suckling and the time it was over, reaction of the group members to the sound of motor vehicles, sexual behaviour, various inter- and intra-group behaviour, and so on. A few food plants, which were consumed after or before the scan for a given individual, were also recorded as running field notes.

28. **Photographic records** Attempts were made to photograph as many behavioural activities as possible. Almost all the different food plants and parts were also photographed. A EOS 66 semi automatic Cannon camera with 300 mm zoom lens was used. The camera was used on all days except those with very heavy rain.