Estimating herbivore densities in the habitat mosaics of Kalakad Mundanthurai Tiger Reserve

Final Technical Report

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Final Technical Report
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FERAL

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Project Site
Kalakad-Mundanthurai Tiger Reserve

Estimating Herbivore Densities in the Habitat Mosaics of Kalakad Mundanthurai Tiger Reserve
Final Technical Report
(Project period December 2002 to December 2005)

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Contents

Executive Summary

Kalakad Mundanthurai Tiger Reserve is the southern most extent of the tiger in India. It has been suggested that the predator population in KMTR is low and this is attributed to the low prey densities and high human activity. However, no valid or benchmark density estimates for the entire reserve is available which makes it difficult for long term monitoring. The objectives of this project were

1. To carry out extensive field intensive surveys using valid methods to estimate herbivore densities.

2. To establish benchmark estimates for long term monitoring of wildlife populations

3. Prepare training material to help in monitoring wildlife populations.

4. To build local capacity to monitor wildlife populations.

5. To identify the relation between animal densities and habitat parameters.

The Major achievements of this project include: determining population estimations for the entire Tiger Reserve from substantial sampling effort using valid methods based on a spatially explicit survey designs. In addition, this study estimates patch occupancy rates for herbivores, which is the first such report for any species within the country. Given that one of the objectives was to build local capacity for monitoring wildlife populations, methods chosen for this project are simple and easily replicable. This study has established methodological protocols for KMTR and population estimates that can be used as benchmarks for long term monitoring. Training material in both English and Tamil have been prepared. During the course of this project two training programs for forest department staff, Kani field assistants, volunteers and students were undertaken.

Through the course of this project intensive field surveys were undertaken. Methods used emphasise on estimation of the probability of detection and were two pronged with patch occupancy surveys used to monitor the large landscapes and distance sampling techniques used to establish benchmark estimates in the Mundanthurai plateau. About 485 km was walked throughout the park and the total number of sightings were 256. Patch Occupancy analysis showed that some species like the sambar, giant squirrel, elephant, wild pig and Nilgiri langur, were widely distributed. Species like bonnet macaque, chital, common langur and lion tailed macaque where highly restricted (<35% of the sampled grids) in their distribution while the rest of the species were moderately distributed. Encounter rates for terrestrial herbivores was between 0.037 for gaur and 0.198 for sambar. For arboreal mammals it was between 0.095 for lion-tailed macaque and 0.318 for Nilgiri langur. Within the Mundanthurai plateau, a total of 422.6 km of transects were walked. Density estimates for herbivores within the Mundanthurai plateau was lowest for wild pig at 1.634 animals per sq km and highest for sambar at 8.882 animals per sq km. The detection probabilities also varied greatly among species between 0.15 to 0.68, clearly showing the need for an estimation method such as distance sampling that could model and estimate these variations. Herbivore-habitat relationship has been analysed using tree models and the results have been discussed in detail in this report. Among the larger prey species, sambar requires greater area under dry deciduous forests and they prefer forest interiors to open grasslands. On the other hand, gaur requires greater proportions of wet evergreen forests and areas with high edge density as is seen in shola-grassland patches. Thus, to fortify the large prey base in KMTR, conserving the core areas as well as the tourism zone and buffer areas is important.

The results from this project have significant implications for the management and conservation of KMTR and the systems approach taken here can be applied to the overall Agastyamalai landscape. KMTR has the potential to support a larger prey base and a corresponding larger predator population. Although substantial efforts have been invested in reducing human pressures from the surrounding villages, this effort needs to be strengthened by addressing issues of enclaves inside the reserve and a rigorous adaptive management model is required to restore degraded habitats within the reserve. We believe that the results from this study can be used as a benchmark and the methodological protocols setup during the course of this project will be useful to park managers to undertake long term monitoring to realise the potential of KMTR as a prime habitat for tigers, other carnivores and their prey base.

Acknowledgement

This project was catalysed and supported by Science and Society Division, Department of Science and Technology, New Delhi. We thank them for funding this project.

We are grateful to the Tamil Nadu Forest Department for giving us permission to carry out this study. We are especially indebted to the Chief Wildlife Warden (Tamil Nadu) Dr. SukhDev for his support, Field Director of the Kalakad-Mundanthurai Tiger Reserve Dr. Annamalai, the Eco-Development Officer Mr. Malleshappa, the Assistant Conservator of Forests Mr. Rajkumar, the Deputy Director, Range Forest Officers and the Forest Department Field Staff of the Kalakad Mundanthurai Tiger Reserve for the support and co-operation extended to us in the field.

Dr. Pitte, of the Indian Institute of Science, Bangalore loaned us the camera traps developed at CEDT, IISC, which were field tested and used for demonstrating techniques during the training program held in Mundanthurai. We thank him.

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Several local assistants have assisted us in implementing the field work we thank Ashok, Kamal Raj, Sivakumar, Sundaram, Selvakumar, Rajamani, Jaikumar and Murugan for their help in the field. Several volunteers graciously gave us their time to help in data collection. We thank them.

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Sunita, Srinivas and Dilip

June 2006, Pondicherry

Institutional involvement

Several Institutions have extended their supported to this project.

Tamil Nadu Forest Department facilitated this study. The Chief Wildlife Warden, Tamil Nadu provided the necessary permissions and support facilities at the field site. The Field Director provided full co-operation and support in implementing this project.

Department of Science and Technology, Government of India provided financial support to this project.

Foundation for Ecological Research, Advocacy, and Learning, Pondicherry administered and implemented the project. They provided analysis, technical support and took care of our off-field logistics.

Salim Ali School of Ecology and Environmental Sciences, Pondicherry University helped with the identification of plants.

Introduction

Kalakad Mundanthurai Tiger Reserve, the southern most extent of the tiger in India has been facing increasing anthropogenic pressures from surrounding human populations. Reports indicate that large-predator populations in KMTR are low and are probably declining in numbers (Ramakrishnan, 1999). Predator densities like that of the tiger have been attributed to habitat availability (Wikramanayake *et al.*, 1998), prey (or in other words resource) availability (Karanth and Stith, 1999), and poaching or protection levels (Kenny *et al.*, 1995). It has been suggested that in KMTR, low prey densities and high human activities are the causative factors for the current predator population trends (Ramakrishnan, 1999).

Studies in the Mundanthurai plateau (an area of about 60 sq km) have shown that the herbivore densities are low, have declined over years and that the change in the habitats required by the prey species have caused this decline (Viswanathan, 1996; Sankaran, 1998). Studies over larger areas and over longer periods are lacking. The park has a long history of habitat modification in the form of cultivation, teak and eucalyptus plantations, estates, encroachments, collection of fuel wood, grazing, dams, etc. Neglected over years many parts of the dry deciduous habitats have now become dense thorny vegetation. Due to frequent forest fires in the dry season vast tracts of open grasslands have been replaced by thick vegetation or by fire resistant grass species like lemon grass. It has been shown that chital do not prefer lemon grass dominant grasslands, while sambar show no discrimination across types of grasslands and a preference for forest interiors (Sankaran, 1998).

Some of these anthropogenic pressures especially fuel wood collection has reduced since 1997. A study conducted in 1996 (Pai, Unpublished.) estimates 30 to 45 kg of fuel wood extracted daily from the Mundanthurai plateau. The implementation of the eco-development project addresses these issues and there has been a substantial reduction in extraction levels (Annamalai, 2004). Given that some amount of habitat modification has reduced, it will be interesting to see how herbivore populations recover over time. Thus there is a need for long-term studies and establishing benchmark data using methods that allow comparisons of results across years.

In spite of the disturbances, it is remarkable that even today there are considerably large tracts of forest within KMTR, which have been left undisturbed. These could house a fair population of herbivores, which will be comparable with any other tropical forest. There have been very few studies that have been carried out to understand how habitat conditions or what habitat parameters govern animal densities. If one could identify the critical habitat parameters that influence population densities of predators and prey it would be a valuable tool that will help park managers to take efficient and effective measures to restore degraded habitats.

This project was undertaken to fill in this lacuna in our understanding of the ecology of herbivores in KMTR and aims to study the relationship between herbivores and habitat parameters. Also, this project establishes a standard and a point of reference for future monitoring of wildlife populations.

Objectives

The broad goals of the project were to determine the relationship between herbivore populations and habitat parameters in the Kalakad Mundanthurai Tiger Reserve, to establish benchmark estimates and to build local capacity for long term monitoring of wildlife populations.

The specific objectives are:

1. To carry out extensive field intensive surveys using valid methods to estimate herbivore densities.

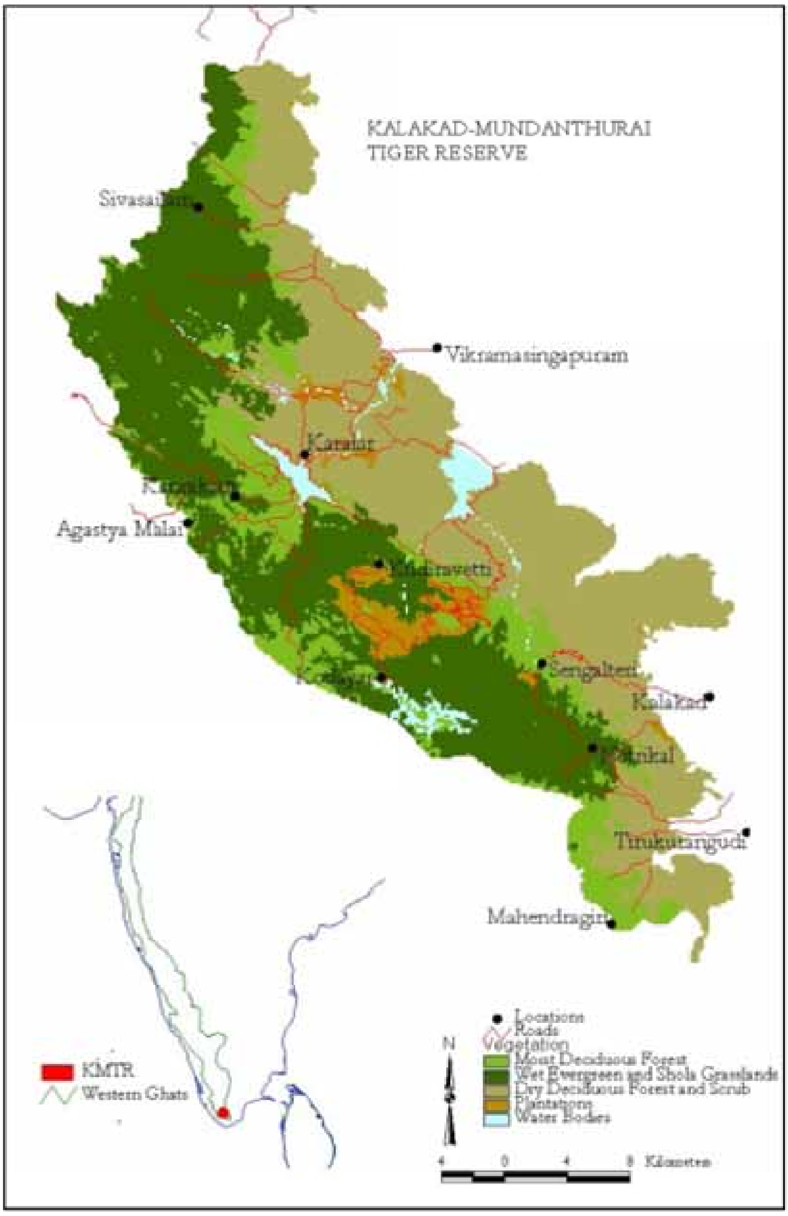
2. To establish benchmark estimates for long term monitoring of wildlife populations.

3. Prepare training material to help in monitoring wildlife populations.

4. To build local capacity to monitor wildlife populations.

5. To identify the relation between herbivores and habitat parameters.

Map1: Location of Kalakad Mundanthurai Tiger Reserve



Project Area

The Kalakad Mundanthurai Tiger Reserve (KMTR) located between 8° 25' N and 8° 53' N and 77° 10' E and 77° 35' E was established and brought under the purview of the "Project Tiger" in 1988. KMTR is part of a larger mosaic in combination with neighboring Reserve Forests in Tirunelveli and Kanyakumari districts in Tamil Nadu, Trivandrum district in Kerala, and Neyyar, Peppara, and Shenduruny Wildlife Sanctuaries in Kerala. These areas together comprise the landscape unit known as the Agastyamalai Range. North of this range and separated from it by the Shencottah Gap is the Megamalai Range. Located in the southern tip of the Western Ghats, KMTR covers an area of about 895 km^2 (Map 1). The area is known for its ecological and biological diversity.

Conservation History

The Papanasam Reserved Forests and Singampatty ex-zamindari Forests of Tirunelveli District were declared a Tiger Sanctuary (Mundanthurai Sanctuary), in 1962. In 1974, all the existing Sanctuaries came under the Wildlife (Protection) Act 1972. The entire Kalakad Reserved Forests was notified as a Sanctuary in 1976 for the protection of the lion-tailed macaque. These Sanctuaries came under the Project Tiger and formed part of the Kalakad Mundanthurai Tiger Reserve in Tamil Nadu in 1988. Parts of Veerapuli and Kilamalai Reserve Forests (Approx. 77 km^2) in the adjacent district of Kanyakumari were added in April 1996. About 230 km^2 of Singampatty ex-zamindari Forest is yet to be declared as Reserve Forest under Section 16 of Tamil Nadu Forest Act 1882. The legal status of this forest is Reserve Land under the Act. (Project Tiger website, 2006).

Oates (1999) gives a detailed account of the conservation efforts taken to protect KMTR.

Administrative Details

The core area comprises about 67% of the Tiger Reserve. KMTR is divided into 7 ranges for administrative purposes. These include Kadayam, Mundanthurai, Papanasam, Ambasamudram, Kodayar, Kalakad, and Tirukarangudi ranges. (see large format map enclosed with this report. Enclaves within each range is also shown in this map.)

Flora

Vegetation types ranging from thorn scrub to montane (wet) evergreen forests within an elevational range from sea level to 1866 m above sea level can be found here. The forest types found within the Reserve as listed by the Forest Department in the management plan for KMTR (classification according to Champion and Seth, 1968) include: southern hill top tropical evergreen forest, west coast tropical evergreen forest, pioneer euphorbiaceae scrub, Tirunelveli semi-evergreen forest, southern moist deciduous forests, tropical riparian fringing forest, dry teak forest, southern dry mixed deciduous forest, Carnatic umbrella thorn forest, southern euphorbia scrub, Ochlandra reed, southern montane, wet temperate forest, and grasslands at low and high elevations. This region is known for its high diversity and endemism with as many as 150 localized plant endemics (Johnsingh, 2001). KMTR has approximately 440 km2 of contiguous mid-elevation rain forests (Ramesh *et al.*, 1997b).

Fauna

The faunal diversity of this Tiger Reserve includes 33 species of fish, 37 amphibians, 81 reptiles, 273 birds, and 77 mammals. The reserve is the southernmost range of many endangered and charismatic species like the tiger (*Panthera tigris*) and Nilgiri tahr (*Hemitragus hylocrius*) (Johnsingh, 2001). It is one of the few places in south India where all five primate species namely, bonnet macaque (*Macaca radiata*), lion-tailed macaque (*Macaca silenus*), hanuman langur (*Semnopithecus entellus thresites*), Nilgiri langur (*Semnopithecus johnii*), and the slender loris (*Loris tardigradus*) can be found.

Drainage, Rainfall and Climate

This protected area has been termed the river sanctuary of Tamil Nadu (Johnsingh and Vickram, 1987) due to the many rivers that run through it. The main rivers are Kil Manimuthar, Kandamparai, Tamarabarani, Pambar, Servalar, Kadananadhi, and Ramanadhi. The Tamarabarani is the chief river of the Tirunelveli District and has a drainage area of about 525 km^2 within the Tiger Reserve. The chief tributaries of the Tamarabarani are the Pachayar, Kil Manimuthar, Peyar, Ullar, Karaiyar, Mylar, and Servalar.

The area receives the southwest monsoon from June to September and the northeast monsoon from December to February. The northeast monsoon rains are mostly confined to the first half of the season. October and November constitutes the post-monsoon months with frequent rain. The dry season is usually between February and May. Previous long term monitoring of rainfall (between 1980 and 1987) have reported an average of 1423mm in Kannikatti, 1147mm in Valayar, 1098 at the Mundanthurai plateau upper dam and 805mm at the Mundanthurai plateau lower dam.

Human Use Areas and Disturbances

As many as 28 enclaves occur within the reserve. Of these, 4 are Electricity board camps, 1 is leased by the Bombay Burmah Trading Corporation, 4 are temple complexes, and 19 appear to have pattas (Ali, 2001). Five settlements are of the hill tribe people *Kanis* (or *Kanikkarans*) also occur within the reserve. On the east, KMTR is bound by a belt of about 324 km^2 consisting of 145 villages the inhabitants of which depend heavily on the reserve for fuel, timber, fodder and as an important grazing ground for their livestock.

Between 1960 and 1990, this area has lost 85.6 km_2 to plantations, 42.0 km^2 to encroachment, and 36.4 km^2 to reservoirs (Johnsingh, 2001).

Although KMTR ranks 5th among the top 10 tourist sites among tiger reserves (Govt. of India, 2005, joining the dots, with more than 70,000 tourists visiting the Tiger Reserve in 2003-2004.), a large percentage of these visitors are pilgrims who visit various religious places within the park. The *Sorimuthaiyanar* temple in the Mundanthurai plateau alone attracts over two hundred thousand pilgrims each year.

Several dams have been constructed across the major rivers in KMTR. These include, dams across the Ramanadhi and Gadananadhi in the Kadayam range); Servalar (hydel) and the Karaiyar (upper Tamarabarani) in the Mundanthurai range; Lower Tamarabarani (Hydel) located at the base of the Mundanthurai plateau in the Papanasam range, the Manimuthar in the Ambasamudram range, the Upper Kodayar reservoir in the Kodayar range, the Vadakku Pachayar, Venganayakar and the Neterikal dams in the Kalakad range.

The construction of the Servalar dam resulted in the loss of lowland riparian habitat along the Servalar river (Sunderraj and Johnsingh, 1996). This damage was accentuated by heavy rains that inundated parts of the plateau in the second week of October 1992. On 13th October 1992, the dam sluice gates were opened to avoid the collapse of the dam. This caused a 12m increase in the river level, affecting about 6.5 km of the gallery forests. However, most of the gallery forest along the Tamarabarani River remained unaffected (Sunderraj and Johnsingh, 1996). A study undertaken in this area immediately after the flooding showed a significant reduction in availability of a number of trees. The level of damage caused is highlighted by the fact that the availability of 13 tree species out of top 15 food species of the Nilgiri langur was affected. In addition, there was loss of canopy continuity which directly affects the arboreal mammals along the

Servalar (Sunderraj and Johnsingh, 1996).

Several areas have been converted into plantations. For example within the Mundanthurai plateau plantations of *Ailanthus excelsa*, *Bombax ceiba*, *Tectona grandis*, *Santalum album*, and Eucalyptus can be found (Johnsingh and Joshua, 1994).

Photo : Srinivas V.

Large scale fuel wood extraction has reduces to stray incidents over the years in KMTR

Photo : Srinivas V.

View of the Karayar dam

Community Background

Hill tribe settlements of the Kanis (or Kanikkarans) occur within the reserve. There are five Kani settlements within the reserve located in the Mundanthurai Range -Tharuvattamparai kani kudiyiruppu, Periyamylar, Chinnamylar, Agastiyar Kani kudiyiruppu, and Injikuzhi. In addition to the Kani settlements, there are EB settlements and some encroachments within the park at Servalar, Karayar, and EB Lower Camp.

The pressure on the forest surrounding all these settlements, especially for fuelwood and grazing pressure are high (Ali, 2001)

A total of About 145 villages, mainly agricultural lie within 5 km of the eastern boundary of the reserve. The inhabitants of these villages depend heavily on the reserve for fuel, timber and fodder. KMTR is one of the sites for the World Bank funded Eco-development project. In an effort to reduce the impact of the villages surrounding KMTR on the protected area, 113 Village Forest Committees (VFC) have been set up. These committees function to reduce the dependence of the local people on the forest and have been formed as a step towards Joint Protected Area Management (JPAM). The VFC works with the eco-development project to identify village needs and determine priorities with a basic commitment to protection of the forest.

Photo : Srinivas V.

Above: Nambi Koil *Below: Kodayar*

Photo : Srinivas V.

Background Information

There have been two research studies (Viswanathan, 1996; Sankaran, 1998) that have estimated herbivore densities in the Mundanthurai plateau. The Forest Department has also been undertaking periodic census. The following points are the highlights of these reports: a) herbivore densities and especially sambar densities are low, b) both studies suggest that larger areas need to be studied and more sampling efforts are required to arrive at estimates with lower variances, c) the effort involved in these studies has been restricted to the Mundanthurai plateau, and d) Both studies have used line transect methods, but have not used a survey design to increase the spatial coverage.

Photo : Srinivas V.

Sambar

Photo : Sunita Ram

Wild Pig

Methodology

This project aims at establishing benchmark estimates of herbivore population and methods for long term monitoring of herbivores in KMTR and across large landscapes in other areas. Hence, the methodology and the systems approach adopted have been given in some detail.

Sampling Techniques

To estimate the animal densities, methods employed emphasises on estimation of the probability of detection. One of the objectives of the study was to build local capacities to monitor herbivore populations, thus the choice of methods that were adopted were those that can be easily replicated in other sites and those that require minimal use of equipment, easy to learn methods and ease of analysis. The choice of methods were two pronged - 1) Distance sampling techniques were used to establish benchmark estimates in the Mundanthurai plateau and 2) Patch occupancy surveys were used to monitor large landscapes. Details of each of these methods has been provided below:

Distance Sampling Techniques (Buckland *et al.*, 1993; Buckland *et al.*, 2001; Buckland *et al.*, 2004): This method involves counting the number of animals and estimating the area sampled. The area sampled is calculated by estimating the shortest distance or the perpendicular distance from the animal location to the transect. When an animal is sighted the following were noted: species, cluster size, distance to the animal (using a rangefinder), angle at which the animal was sighted (compass bearing to the animal from the transect) and the location of sighting (using a GPS if available or by marking distance walked along the transect).

Encounter Rates: The sampling of trails or transects can be effectively used to develop indices of animal abundances. This is low cost both in terms of manpower and money involved in data collection. But one of the key assumptions is that detection probability does not change, across years or across sites. To overcome this problem, detection probability was estimated using distance sampling technique and mark recapture techniques.

Patch Occupancy (MacKenzie *et al.*, 2002; MacKenzie *et al.*, 2003; MacKenzie and Royle, 2005): One of the problems faced while sampling is the non detection of species. This can be translated as i) absence of the species or ii) animal was not detected during that sampling occasion. One way of solving this problem is by repeated surveys. Also the first two methods employed in the study estimates animal counts (densities or relative abundances). The patch occupancy will estimate the number of sites or sampling units the species actually occupies. This measure is a good surrogate for animal abundances. The advantage of this method is that both direct and indirect animal signs (calls, hoof marks encountered while sampling) can be collected and used. While walking trails, in addition to direct sightings, all animal signs were noted. GPS locations for all these signs were taken.

Pilot survey

As a prerequisite of the project a detailed base map was required for planning all activities and to generate a sampling design. The first step involved geo-referencing and manually digitising features from 1:50000 scale Survey of India toposheets. The base map was then updated by surveys carried out to identify different habitat types and current road networks to arrive at a feasible sampling survey design. The trail and road network was mapped using a hand held GPS. This enabled the preparation of a detailed and accurate base map of the study area (See map enclosed with report), which was used in designing the survey.

Survey Design

As a first step before large-scale data collection, it is necessary to generate the survey design, field test the methods, and draw protocols for data collection. The following section discusses the survey design used for various sampling techniques that were used in this project.

Survey design for line transects sampling: A sampling design is required to minimise the source of variation in the animal population estimate. There are two sources of variation. The first is space. Due to several factors surveys are limited to smaller areas and draw inferences about larger areas. Thus selection of smaller areas needs to be carried out in a fashion that permits inferences to the entire area. The second source of variation is that of detectability. Proper field protocols are required to maximise detection of animals during field surveys.

Line transect surveys were undertaken in the Mundanthurai plateau, an area of 65 sq km. To overcome the above-mentioned sources of variation we used a Systematic Segmented Grid Sampling design over the plateau. Although the design was systematic and sequential the start point for generating the design was randomly chosen. The design randomly superimposes a systematic set of segmented parallel lines onto the survey region. The criteria used for generating the design was that each transect should be spaced 1.5 km from each other. Straight lines of 2.5 km length were used. The survey design is shown in map 2.

As the transects are evenly spaced and distributed throughout the plateau the design takes care of the first source of variation that might affect the results. The question of detectability is addressed by ensuring that these transects reflect actual field conditions, (see photo). In other words there was very little vegetation cleared. Also the data collection process was streamlined, so that all observers walk at a slow pace of 1.5 km/hr and no more than two biologists were involved in data collection.

The logistic constraints for undertaking line transect surveys for the entire reserve is accessibility, determined by the availability of roads or trail network, places to stay and the rugged terrain. To assess the feasibility of conducting line transect surveys through out the park we generated a Systematic Segmented Grid Sampling design with square sampler of length 3.2 km and spaced 3km from each other. To this we applied the criteria that no sampling unit could be more than 1 km from a road and no more than 3kms from a place of stay. It was found that of the 48 transects that were generated only 10% of them were logistically impossible to sample as they failed the above set criteria. Given adequate manpower and financial resources, more than that available for the present project, line transect surveys can be easily carried out throughout the reserve.

Survey design for occupancy surveys: To determine patch occupancy rates through out the reserve, a 25 sq km hexagonal grid was superimposed over the reserve and only those hexes with greater than 10 sq km (40% of area) was sampled. Existing trails in these hexes were used to carry out surveys, although trails are non random, the use of trails in rough terrain and in dense forest is less cumbersome and sometimes the only way to get to remote parts. To avoid some of the possible biases that might arise while using trails as sampling units, a spatially explicit sampling design was adopted. Roads with regular vehicular movement were not considered in the sampling design. The design was developed on a GIS platform to satisfy the following criteria:

1. Within each hex a minimum of two trails of 3-4km of length was chosen as sampling units.

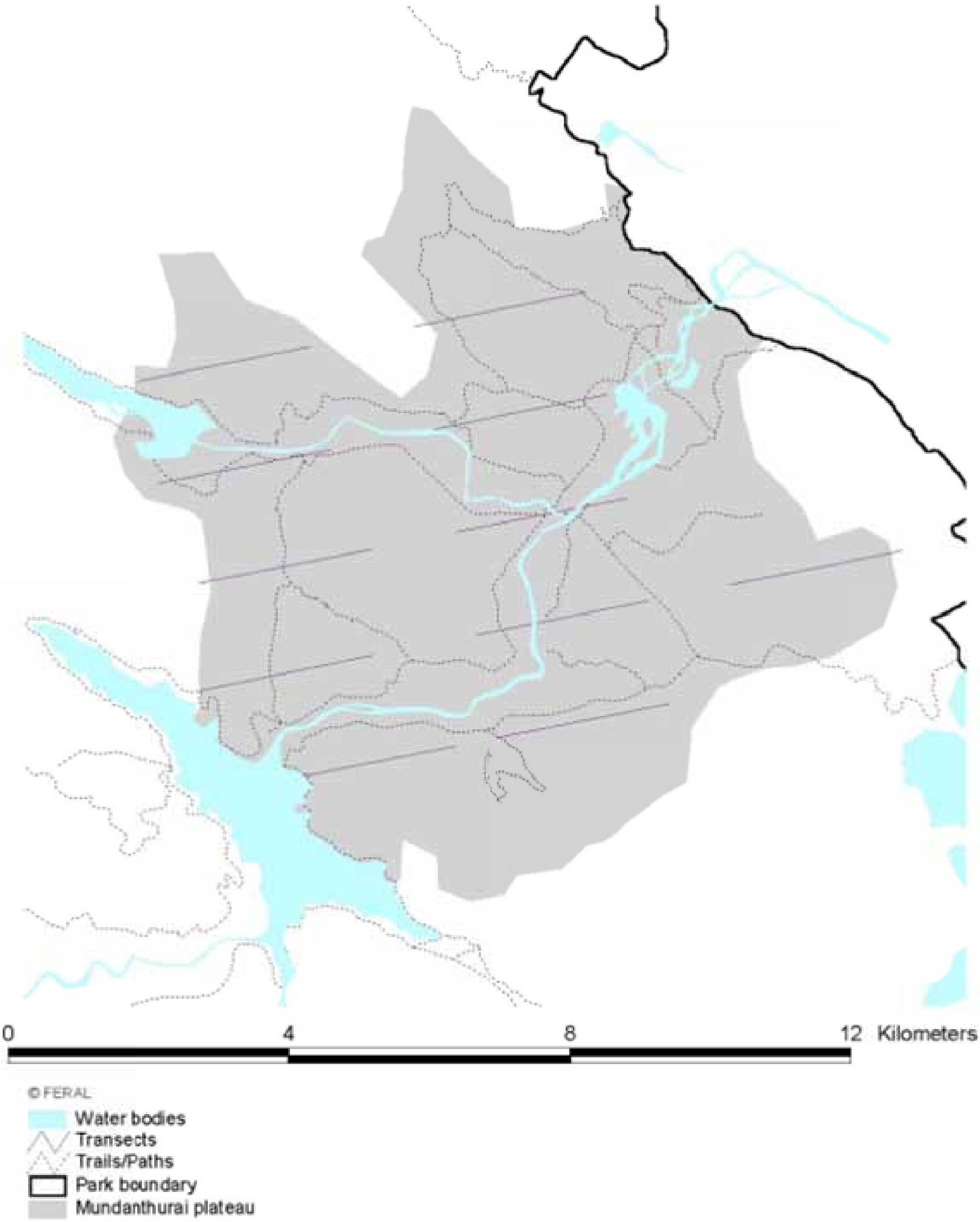
2. No two sampling units should intersect each other nor can they be contiguous.

3. Given the network of trails, sampling units were spaced at least 3 km apart.

Four temporal replicates were used to carry out surveys. All surveys were carried out between 06:00 08:30 hrs and 16:30 18:30 hrs on non rainy days.

Map 3 gives the survey design used for the entire park.

Map 2: Line transect survey design for the Mundanthurai plateau



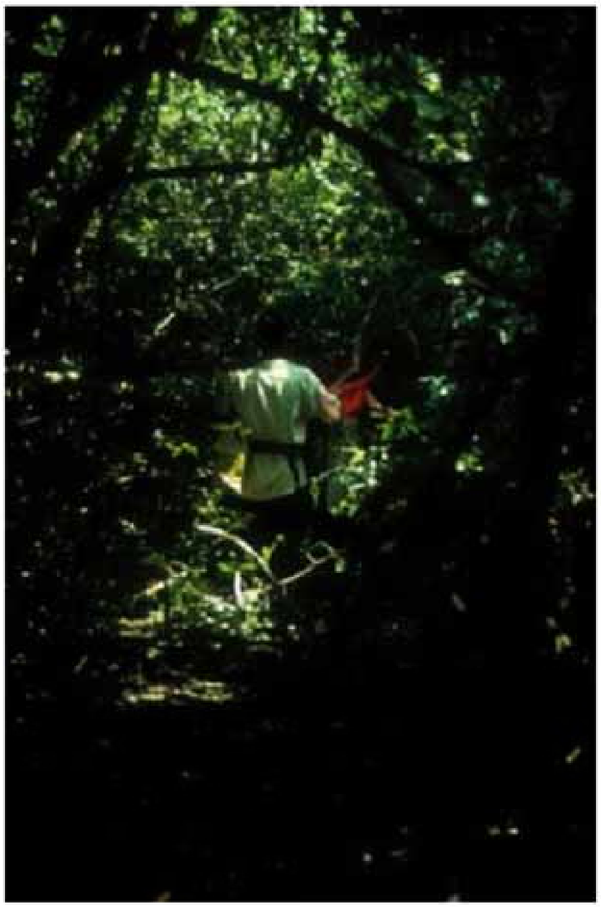


Photo : Srinivas V.

Field team marking transects

Photo : Srinivas V.

A marked line

Map 3: Hexagonal Grids (25 sq km) generated for sampling the Reserve

Habitat correlates

To identify the parameters that determine the estimated densities it is important to collect habitat information along with transect data. The parameters that were collected include vegetation, landscape composition, spatial attributes of the habitat, topography, and human interference.

The above parameters were collected using a combination of ground surveys, remote sensing techniques and GIS. Details of the methods used to derive each of these datasets are detailed below.

Vegetation: Broad habitat types were derived from remotely sensed data (LandSatETM). Broad habitat types was found to be more appropriate biologically than already existing detailed vegetation maps for the area (Ramesh *et al.*, 1997a). In addition, in the Mundanthurai plateau, vegetation along transects was sampled. Quadrats of 30 x 5m size were laid 5m away from the line on either side at intervals of 300m. Within these plots, all trees and lianas greater than and equal to 30 gbh were measured and identified. Canopy cover was measured using a mirror, at every 2 meters. At each 2-meter interval, the point was also classified into shrub/herb, grass, rocks, bare soil. The dominant species of shrub/herb or grass was also noted.

Landscape composition and spatial attributes of the habitat: Landscape matrices were derived as suggested by (Rempel and Carr, 1999). The parameters that were used for analysis include proportion of forest cover under, dry deciduous, moist deciduous, wet evergreen, plantations, large water bodies, number of habitat patches and edge density.

Topography: Using a digital elevation model, a Topographic Position Index (Jenness, 2005) was developed, but only the standard deviation of the slope within each hexagonal grid was used as this was the only measure that correlated with encounter rates of herbivores. Stream density was another parameter that was derived for each sampling unit.

Photo : Gopinath S.

Moist Deciduous Forest

Photo : Srinivas V.

Teak dominated Dry Deciduous Forest in the Mundanthurai Plateau

Photo : Gopinath S.

Wet Evergreen Forest in Neterikal

Analysis

Herbivore Population Estimation

Herbivore population estimation from distance sampling data will be undertaken based on Burnham *et al* (1993) using the program Distance 5.0 (Thomas *et al.*, 2005). Patch occupancy analysis will be based on MacKenzie *et al.*, 2002; MacKenzie *et al.*, 2003) using the software Presence 2.0 (Hines, 2005) for the analysis.

Density Estimates from Line Transects: The data from the line transects were analysed using the Program Distance (ver. 5). For all species with more than 40 sightings, various models at different truncation levels were fitted and the model that best fitted the data was chosen using the minimum AIC value, minimum coefficient of variance of the effective strip width and number of terms used to fit the model. As the numbers of sightings were few, data from two years were pooled together before carrying out the analysis. For those terrestrial species with less than 40 sightings, a combined global detection function for all terrestrial species was estimated and the same was used to arrive at density estimates. The same was also carried out for all arboreal species separately.

Encounter Rates: All transects walked were tracked using a GPS, and start and end point for each line was noted for each sample. Using this information, within each hex, the total distance walked was calculated. The number of sightings (direct sightings) for each herbivore species was noted. The count statistics were calculated as number of sightings per distance walked (in km). The detection probability was estimated using a capture recapture frame work and the raw encounter rates were corrected using the estimated detection probability.

Patch Occupancy: Steps that were undertaken to estimate the occupancy rates were: The detection non-detection for each herbivore species in each of the sampling hexes were noted. The Patch Occupancy Anaysis was undertaken using different models. The AIC value was computed for each of the models. The results from the model with the lowest AIC was then chosen to give the Patch Occupancy Estimate.

Herbivore Habitat Relationship

The analysis used to determine habitat relationships will include Classification and Regression Tree (CART) analysis (see appendix 1 for more information on CART). Habitat relationship analysis was carried out on a GIS platform in ArcView 3.2 (Environmental Systems Research Institute, 2000) and S-PLUS® 6.1 for Windows.

Within each hex, an index for each of the habitat correlates was developed. The encounter rates calculated for each hex have been used. For each species a tree model was developed to determine the relative importance of each of the habitat correlates in determining the population of the given species.

Results

Herbivore Population Estimation

The distance walked for sampling the entire park was 485.65 km across the 30 hexes that were sampled. The total number of sightings was 256. This included sightings of sambar, chital, wild pig, gaur, elephant, mouse deer, cattle, goat, and arboreal mammals including bonnet macaques, common langur, lion-tailed macaque, Nilgiri langur and the Malabar giant squirrel. The total number of sightings and evidences noted when sampling across the reserve was 1761.

Patch occupancy: The direct and indirect sightings data were used to determine the presence or absence of a species within each hex. Using this, the patch occupancy rates was determined. Table 1 gives the patch occupancy for each species.

Table 1: Patch Occupancy for herbivores in KMTR

Species	Model used	Naïve Est	Prop. of sites occupied (Psi)	SE (Psi)
Bonnet macaque	1	0.11	0.16	0.17
Chital	1	0.08	0.18	0.40
Common langur	1	0.14	0.27	0.26
Lion tailed macaque	1	0.22	0.35	0.15
Gaur	1	0.31	0.39	0.11
Mouse Deer	1	0.14	0.39	0.33
Cattle	1	0.28	0.44	0.18
Sambar	1	0.50	0.62	0.11
Giant Squirrel	1	0.64	0.77	0.07
Elephant	2	0.69	0.85	0.07
Pig	2	0.69	0.87	0.08
Nilgiri Langur	1	0.83	1.00	0.00

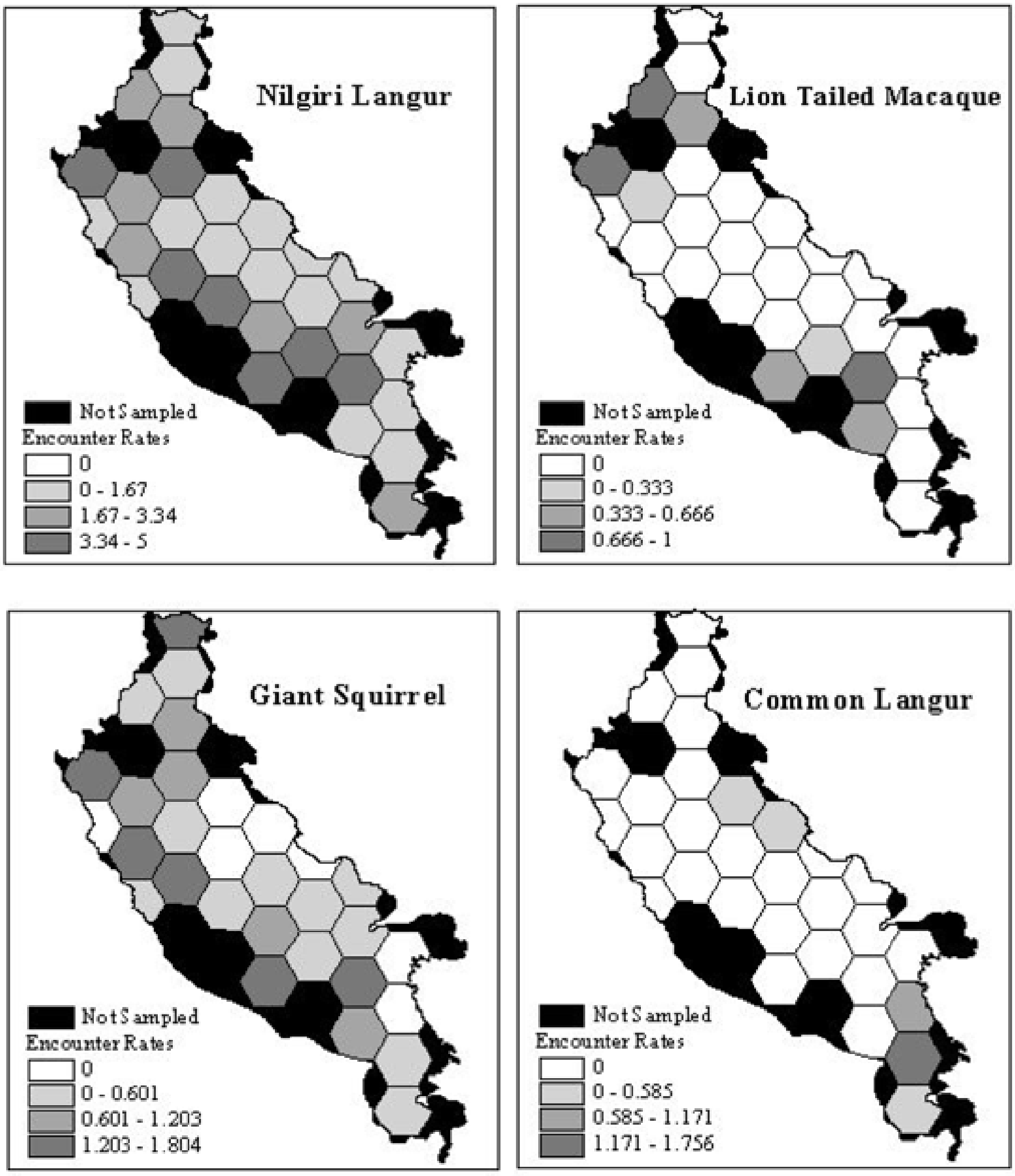
Model 1: 1 group, Detection probabilities are not time specific
Model 2: 1 group, survey specific

Encounter rates: Total encounter rates (from sightings) for species with sufficient data from across the reserve was calculated. These have been given in table 2. It was seen that the Nilgiri langur showed the highest encounter rate. Among ungulates, sambar was encountered more than any other species, and was followed by wild pig. For each hex, sign encounter rates for species with sufficient data were calculated. This is shown in the maps 5a and 5b for each species.

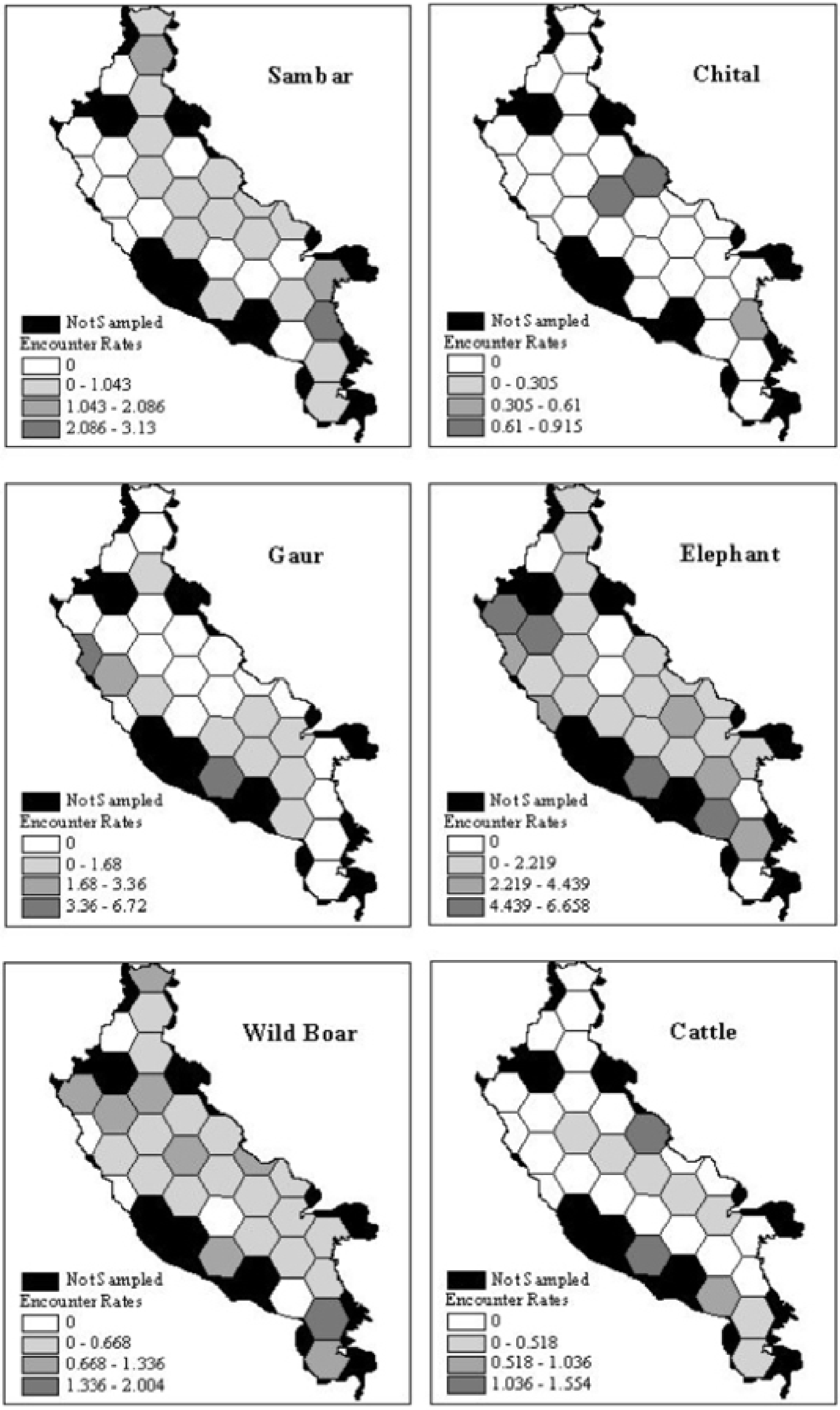
Table 2: Species wise encounter rates

Species	Detection Probability	Encounter rate
Nilgiri langur	0.88	0.318
Giant squirrel	0.72	0.251
Sambar	0.56	0.198
LTM	0.32	0.095
Wild Pig	0.51	0.039
Gaur	0.54	0.037

Map 5a: Hexwise sign encounter rates for arboreal mammals in KMTR



Map 5b: Hexwise sign encounter rates for terrestrial herbivores in KMTR



In the Mundanthurai plateau, a total of 422.60 km of transects was sampled. In each year sampling in Mundanthurai was completed within two weeks, with a minimum of five trained project staff collecting data.

Encounter rates were calculated for herbivores and arboreal mammals sighted (Table 3). Within the plateau, encounter rate for sambar was highest followed by Nilgiri langur. Table 3 also compares the encounter rates with those from earlier studies.

Table 3: Encounter rates from transects walked in the Mundanthurai plateau and comparisons with earlier estimates

	1995[1]	1997-99[2]	2004-05[3]	
			Encounter Rates	Corrected Encounter Rates
Mouse deer	0.11	0.60	0.11	0.20
Sambar deer	0.19	0.34	0.53	0.77
Spotted deer	0.03	0.09	0.02	0.04
Cattle	0.11	0.06	0.06	0.10
Wild pig	0.08	0.02	0.06	0.09
Elephant	NA	NA	0.01	0.01
Giant Squirrel	NA	NA	0.03	0.10
Nilgiri Langur	NA	NA	0.18	0.30
Effort (km)	213.8	129.9	422.60	

1: Viswanathan, 1996; 2: Sankaran, 1998; 3: Present study

Density Estimates: Density Estimates for sambar, chital, mouse deer, Nilgiri langur, giant squirrel, bonnet macaque, wild pig, and cattle have been computed (Table 4). Among terrestrial animals, the Sambar deer had the highest density followed by cattle, and spotted deer in the Mundanturai plateau. Among arboreal mammals, the Nilgiri langur showed the highest population density estimates, and was followed by bonnet macaque and giant squirrel.

The estimated detection probability in the sampled area varied greatly among species between 0.15 to 0.68, clearly showing the need for an estimation method such as distance sampling that could model and estimate these variations.

Photo : Srinivas V.

Gaur

Table 4: Density estimates for animals in the Mundanthurai Plateau

No of transects	11
Distance walked (km)	422.60

Species	No of sightings	Density (Animals/km^2)	Mean cluster size
Giant Squirrel **	12	0.412	1.00
Wild pig *	23	1.634	1.52
Spotted Deer *	13	3.595	5.92
Mouse Deer	42	3.708	1.00
Cattle	32	5.008	4.69
Sambar Deer	175	8.882	1.39
Bonnet Macaque **	27	9.161	9.89
Nilgiri Langur	83	12.018	5.31

** Due to low sample sizes, density estimates for these species has been calculated using the global detection function for all terrestrial species combined.*
*** Due to low sample sizes, density estimates for these species has been calculated using the global detection function for all arboreal species combined.*

Herbivore - Habitat relationships

Tree model analysis was run to determine the variables that influenced the distribution of herbivores in KMTR. For habitat utilization rates, the sign encounter rates for a species has been used. The habitat variables that have been used in the analysis have been summarized in table 5. The summary of the relationship has been shown graphically below. The analysis has been carried out for species where sufficient data points were available. The results reported here are at the hex level.

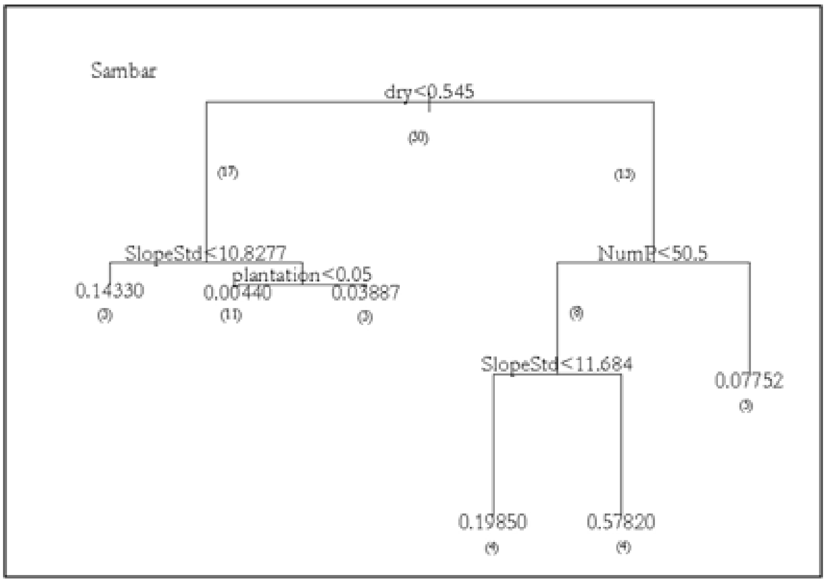
The variables that were used for the analysis were Proportion of area that is Dry Deciduous Forest (Dry), Moist Deciduous Forest (MDF), Wet Evergreen Forest (Wet), Plantations (Plantation), Large Water Bodies (Water); Standard deviation of Slope (Slopestd); Edge Density (ED); Stream Density (StreamDensSum); and Number of Habitat Patches (NumP).

In the graphs below, the values given in parentheses indicates the number of data points that contribute to that particular branch of the tree.

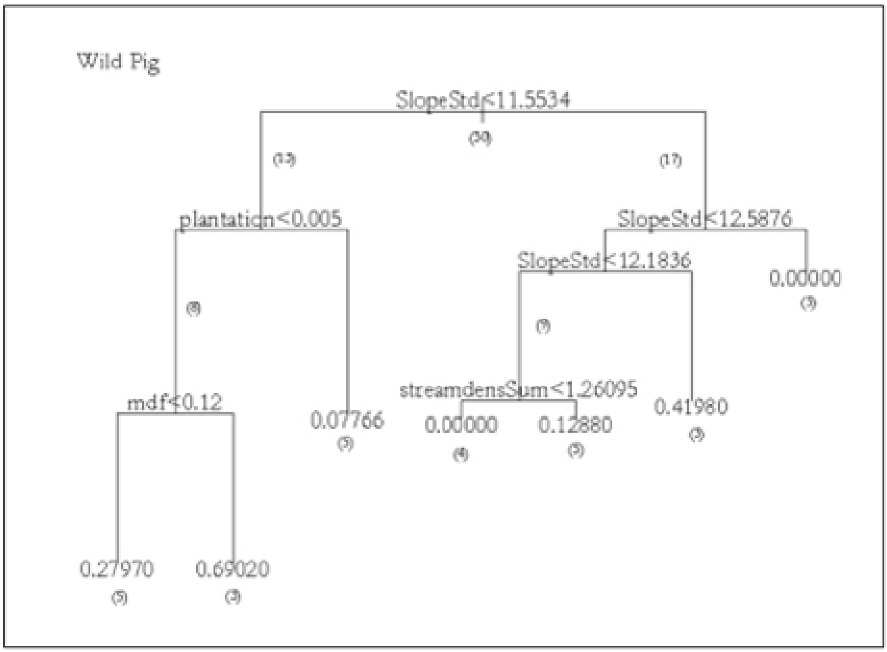
Table 5: Summary of habitat variables used to analyse habitat relationship

Habitat Variable	Min	Max	Mean	StdDev.	LCLMean	UCLMean	Median
mdf	0.000	0.680	0.148	0.155	0.090	0.206	0.100
dry	0.000	1.000	0.431	0.389	0.285	0.576	0.450
plantation	0.000	0.250	0.037	0.075	0.010	0.065	0.000
wet	0.000	0.980	0.347	0.359	0.213	0.481	0.195
water	0.000	0.540	0.036	0.100	-0.001	0.074	0.005
NumP	13.000	61.000	36.500	13.271	31.545	41.455	34.000
ED	22.180	56.220	43.182	8.191	40.123	46.240	44.120
SlopeStd	9.717	15.294	11.730	1.072	11.330	12.131	11.640
streamdensSum	0.361	1.539	1.179	0.281	1.074	1.284	1.262

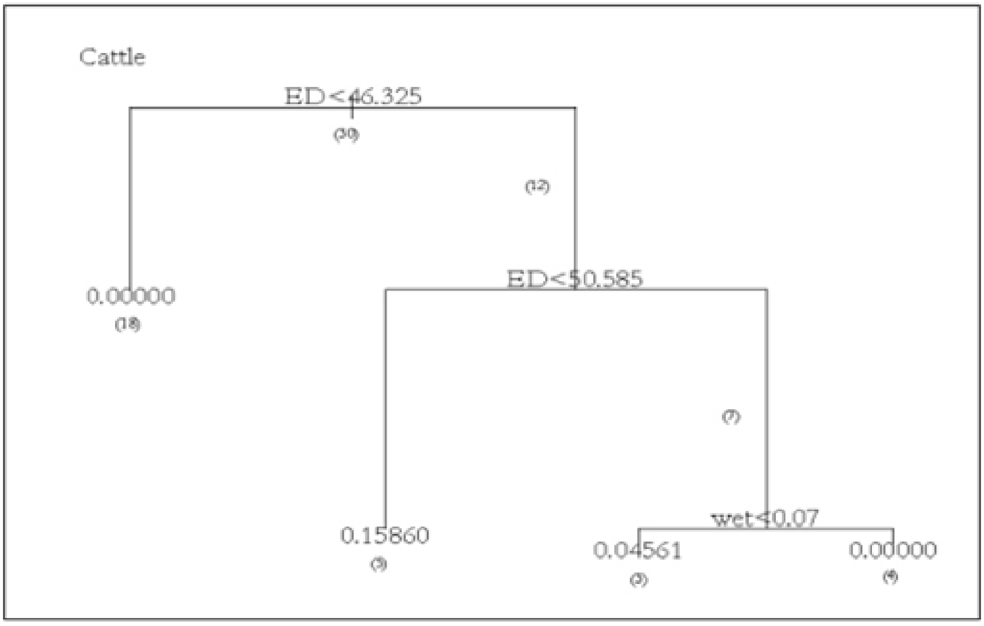
Sambar: Our analysis for sambar shows that when proportion of dry deciduous forests is greater than 0.545 and when number of patches is less than 50.5, and standard deviation of the slope is greater than 11.684, the sign encounter rates is the highest at 0.578. In other words, sambar sign-encounter rates are highest in habitats that are large contiguous patches of dry deciduous forests that are more rugged and undulating.



Wild Pig: For Wild pig, when slope is less than 11.553, plantations are less than 0.005, and proportion of moist deciduous forests is greater than 0.12, encounter rates are highest at 0.69. In other words, the factor mainly influencing their presence is the nature of terrain in the area. The encounter rates were low in areas with very rugged terrain, with high encounter rates for fairly flat land with low proportion of area under plantation and higher moist deciduous forests. But overall, pigs seem to be present across different habitat regimes.

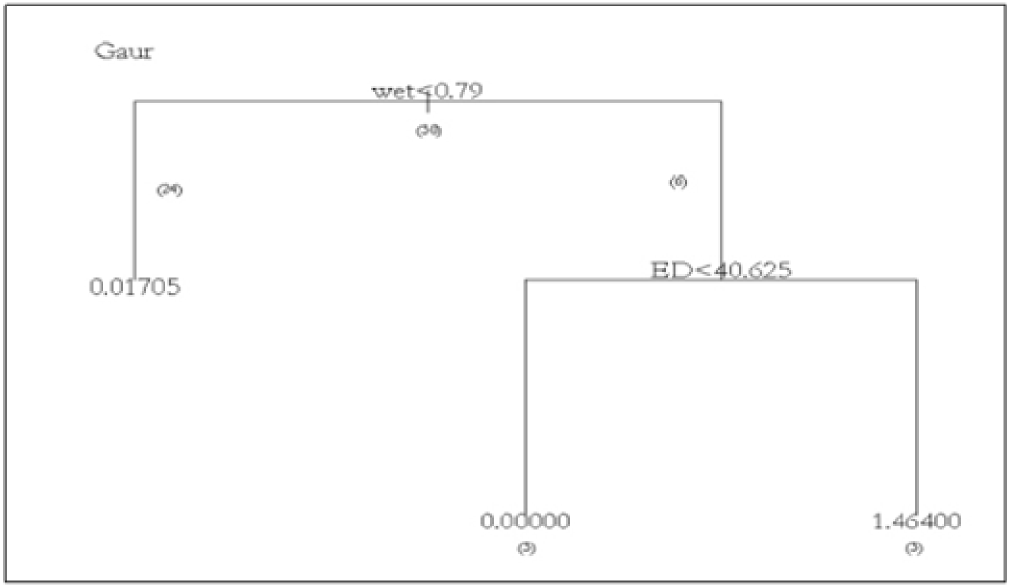


Cattle: This analysis shows that cattle prefer habitats where the edge density is higher and that they do not prefer wet evergreen forests.



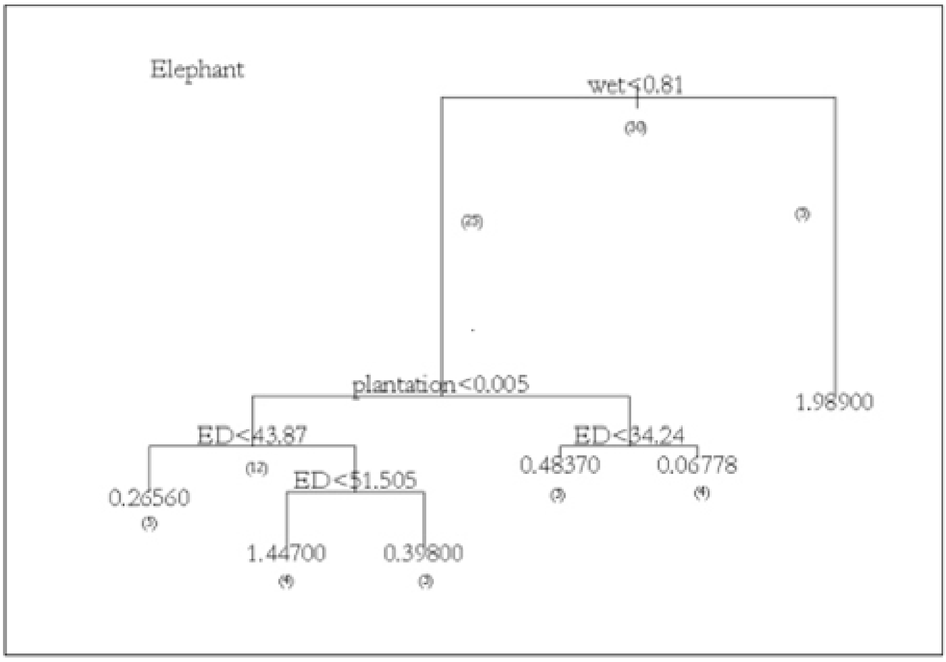
Gaur: The factors that influence gaur population are proportion of wet evergreen forest followed by edge density when proportion of wet evergreen forest is greater than 0.79 in a hex, and the edge density is greater than 40.625 then the encounter rate is 1.464. Most of the data points fell in the proportion of wet evergreen forest < 0.79 category indicating that populations in most hexes was at much lower encounter rates.

Interpreting the above results, gaur seems to prefer higher proportions of wet evergreen forests and where edge densities are greater.

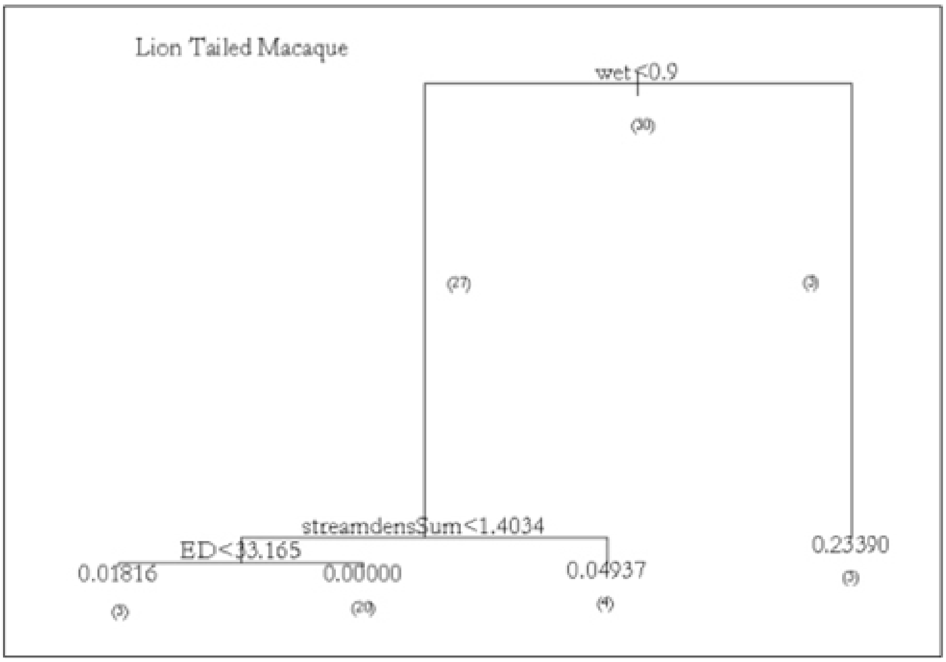


Elephant: The data was unequally split. Proportion of wet evergreen forests being more influential with wet>0.81 showing highest encounter rate. A high encounter rate was seen when hexes showed proportion of wet evergreen forests less than 0.81, with proportion of area under plantations was less than 0.005 and for edge densities between 43.87 and 51.505.

Interpreting the graph, elephants in KMTR use higher proportions of wet evergreen forests. When wet evergreen forest area is lower, they prefer habitats that have very low proportions of plantations (less than 0.5%) with greater edge densities. In areas where the proportion of plantations is higher, they prefer areas of lower edge density.

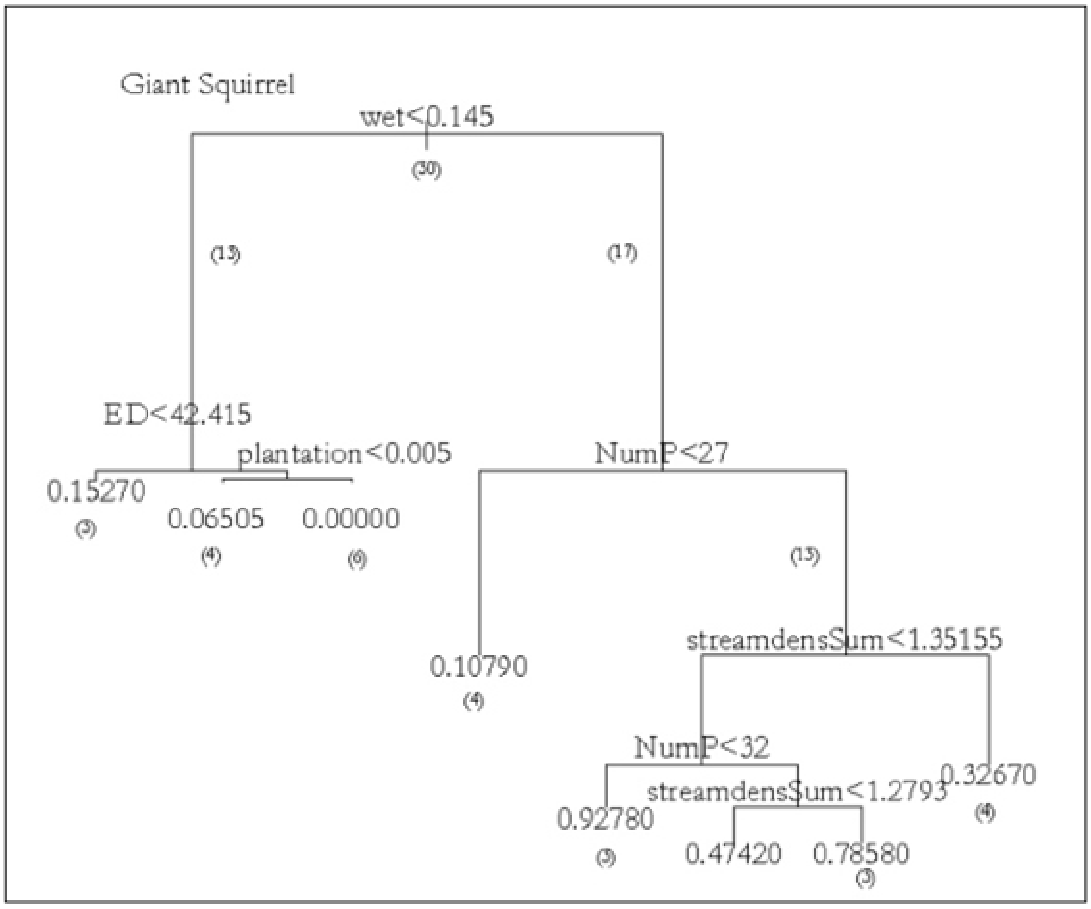


Lion-tailed Macaque: LTM was sighted in 10 hexes. The most important factor is the proportion of wet evergreen forest in an area. The greater the proportion of wet evergreen forests, greater is the encounter rates. At proportions lower than 0.9 they require stream densities greater than 1.403. At lower stream densities, they are present at low densities when edge density is less than 33.165. In other words, LTM are a wet evergreen species. At lower proportions of wet evergreen forests, they tend to be concentrated in areas of high stream densities. At lower stream densities they require areas with low edge densities (which translates to - large contiguous patch of wet evergreen forest or lower fragmentation).



Giant Squirrel: Proportion of wet evergreen forests seem to be important for Giant squirrel populations. In areas with greater proportions of wet evergreen forests (>0.145) the number of patches and stream densities play an important role. At stream densities lower than 1.352 they seem to show high encounter rates as well as the most data points. They are at low densities or absent in areas with lower proportion of wet evergreen forest, with edge densities greater than 42.415 and proportion of plantations greater than 0.005.

Interpreting these results, the giant squirrel is found nearly everywhere. At lower proportions of wet evergreen forests, they prefer lower edge densities. And at higher proportions of wet evergreen forests they prefer less patchy areas. When number of patches is higher, they tend to be seen more in areas with comparatively fewer streams (the cut-off limit is towards the maximum stream density seen in KMTR).



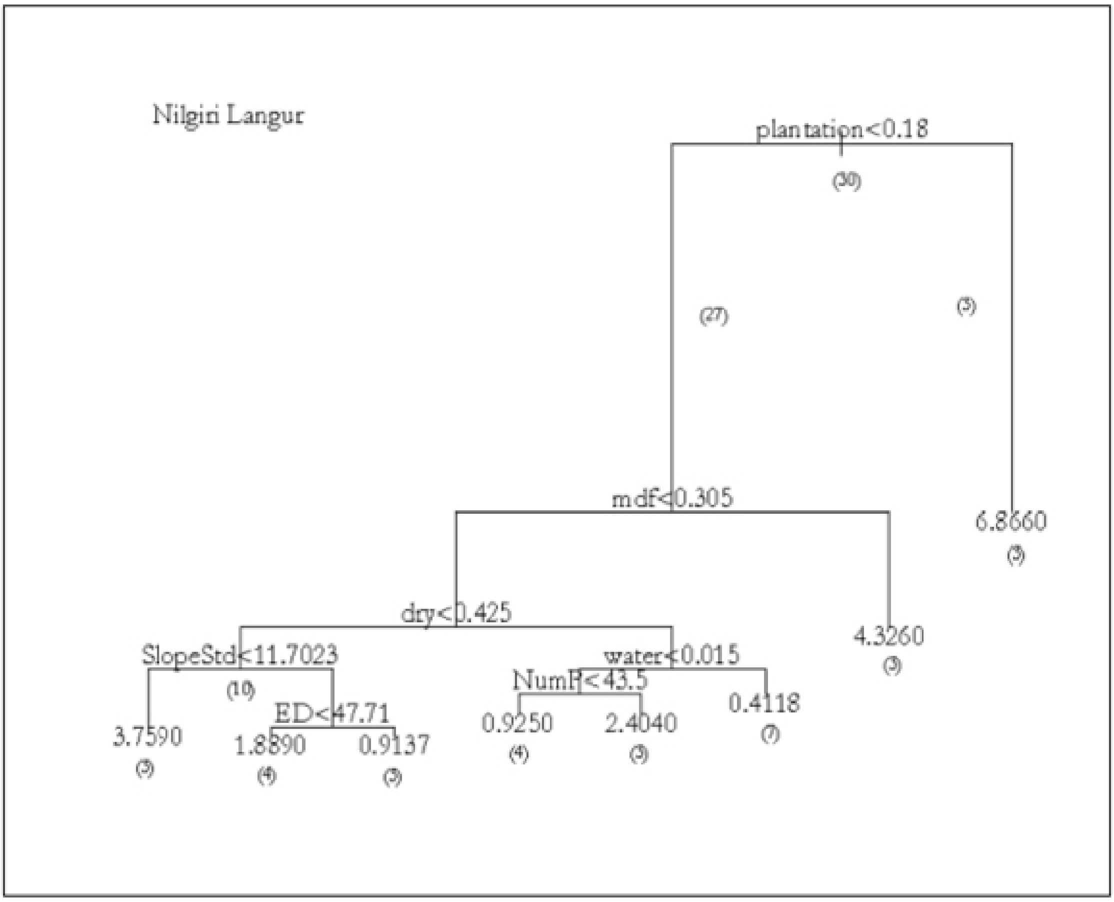
BBTC Tea Estates

Nilgiri Langur: For the Nilgiri langur, it is interesting to note that the primary factor and the maximum encounter rates are seen in hexes where plantations occupy large proportions. However these reflect data from just three hexes. These hexes include the Kodayar, Kakkachi and Kudiravatti areas. Although these hexes include a high proportion of plantations (which is predominantly tea, but also includes coffee, cardamom, and eucalyptus), they also include high proportions of wet evergreen and moist deciduous forests and low to no areas under dry deciduous forest. Also, the tracks that were sampled in these hexes were mostly outside the plantation area. Given this, when these data points were excluded from the analysis, it was seen that the Nilgiri langur preferred areas with high proportion of moist deciduous forests. When mdf was lower than 30% of the area, encounter rates were higher in hexes with greater proportion of wet evergreen forests.

For areas with lower proportion of plantations, extent of moist deciduous forests is an important determinant. At lower proportions of mdf (<0.305), the proportion of dry deciduous forest plays an important role. When proportion of dry deciduous forests is less (<0.425), the slope and edge density play an important role in determining encounter rates.

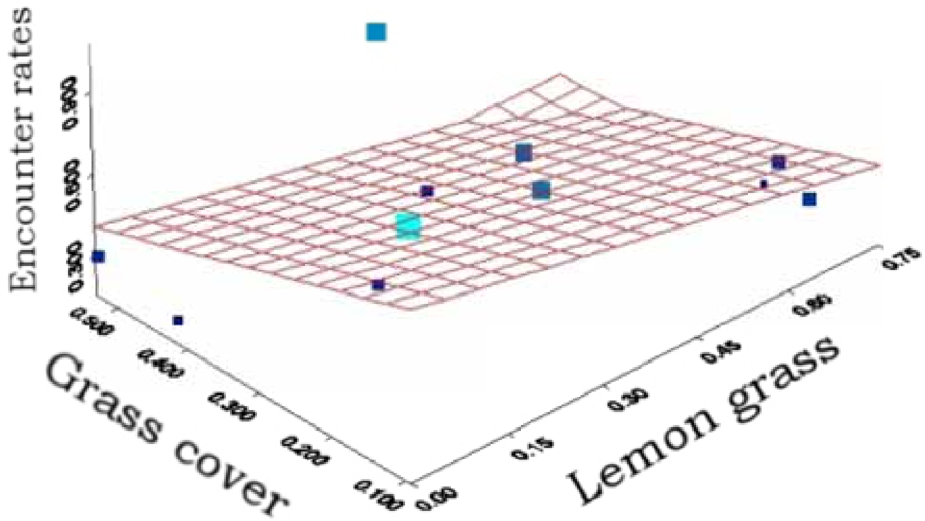
When proportion of dry deciduous forests is greater than 0.425, then area under large water bodies and the number of patches is important.

Thus, it is clear from our analysis that the Nilgiri langur requires moist deciduous areas, with less proportion of dry deciduous forests and average ruggedness.



To understand how availability of forage (grass cover) and dominance of lemon grass affects encounters of herbivores on the plateau, data from the most abundant herbivore species was analysed. For each transect we calculated the proportion of data points under grass cover (from field data, see methods for details) to arrive at the availability of forage. Dominance of lemon grass for each transect was determined as the proportion of sampling plots where lemon grass was the dominant species. Results indicate the sambar encounter rates are the least along transects in areas dominated by lemon grass and decreased as the proportion of grass cover increased suggesting that they preferred forest interiors with shrubs as compared to open grassland patches (Fig 1).

Figure 1: Sambar encounter rates decreases in areas dominated by lemon grass



Lemon Grass is the predominant grass species found in the lower reaches in KMTR

Photo : Srinivas V.

Discussion

Results from the patch occupancy rates indicate that while few species are widely distributed within the reserve around 60% of the species were encountered in less than 50% of the sampling girds. Species that are widely distributed include sambar, giant squirrel, elephant, wild pig and Nilgiri langur, in that order, with Nilgiri langur being present in all the sampling grids. Species like bonnet macaque, chital, common langur and lion tailed macaque where highly restricted (<35% of the sampled grids) in their distribution while the rest of the species were moderately distributed. When one compares the naive occupancy estimates with the estimated occupancy estimates all species recorded an increase in the number of actual grids that they occupied. This percentage change was largest for mouse deer (179%) while it was the least (20%) for Nilgiri langur and giant squirrel suggesting that species with least change were more easily detected than those with large percentage this has can further be confirmed by examining the detection probabilities. The estimated occupancy rates for KMTR cannot be compared with other sites or across years as this is the first ever estimates obtained for any species in country. If these surveys are repeated in the same site each year a comparison will estimate changes in occupancy rates indicating range expansion or contraction. This would reflect if populations are increasing or decreasing. Further this study establishes rigorous sampling protocols and the identification of covariates for monitoring efforts that focus on site occupancy.

Further, one needs to be sure of what these estimates indicate. In the case of wide ranging landscape species like elephants, the values indicate habitat utilisation rates rather than occupancy rates. To arrive at occupancy rates for such species the size of the sampling unit (grid) needs to be larger than the home range of the species.

These estimates can further be refined using site level and sampling level covariate information. Other than arriving at precise estimates with the use of covariates one can actually estimate site level occupancy rates. This would be useful to monitor changes within the reserve. While incorporating covariates in modeling it is also possible to establish factors that affect occupancy rates (MacKenzie and Bailey, 2004). This will further throw light on parameters that affect species occurrence within the park.

Based on the estimated occupancy rates and encounter rates with incorporated detection probability, sambar and wild pig are the most abundant ungulates in the reserve followed by cattle, gaur and chital. Among the arboreal mammals that contribute to prey of carnivores, Nilgiri langur topped the list followed by giant squirrel and lion tailed macaque.

For the Mundanthurai plateau, when encounter rates of herbivores is compared to previous studies (Table 3), with the exception of sambar, other species show either no significant change or show a decrease. Based on these encounter rates, it would be erroneous to conclude that sambar populations have doubled in the past 10 years in the Mundanthurai plateau. The same trend is reflected when one examines the density estimates from different studies on the plateau. The reason for this observed increase is largely due to increase in spatial coverage of transects. The 1995 study (Viswanathan, 1996) reports a sambar density of 4.6 animals per sq km, the 1997-99 study (Sankaran, 1998) reports densities of 2.6 (forest interior) - 7.8 (road side) animals per sq km and this study reports 8.9 animals per sq km. Transects used for the 1995 study were largely restricted to areas around the Mundanthurai guest house. Similarly the results for the 1997-99 study is also restricted to a small part of the plateau. On the other hand, estimates from this study are obtained by uniformly sampling the entire plateau, thus covering larger areas.

Our estimates reflect actual ground situation, as compared to the other two studies where smaller areas have been sampled and inferences have been drawn for the entire plateau. Thus arriving at any meaningful population trends from studies with very different sampling design is not possible. The estimates from the current study can be used as a benchmark, and carrying out surveys using the same transects annually will be useful to determine population trends across the plateau. Thus this study clearly establishes the need to implement proper design based surveys and valid methods like line transects to effectively monitor population trends and their responses to various management changes.

Density estimates obtained from Mundanthurai are very low when compared to estimates derived using line transects in other sites in India (Karanth *et al.*, 2004). Although there are other sites with similarly low densities, the key element missing from the Mundanthurai plateau is the presence of large bodied prey species like the gaur which are found in other low density sites like Melghat, Pench and Tadoba. Due to low densities of prey and predators the Agastyamalai complex is not among the high priority sites for tiger conservation (Wikramanayake *et al.*, 1998). Another study on the status of elephants in Southern India (AERCC, 1998) also lists this area as non priority area for elephant conservation. Given that KMTR is the largest protected area in the Agastyamalai complex with 56 percent of forest under dry - moist deciduous patches, it can potentially house higher prey populations that can support all 3 carnivores found in the landscape.

Results from previous studies and this study show that large parts of the Mundanthurai Plateau are under Lemon grass (*Cymbopogon flexousus*) communities and are these areas are frequently affected by fires. "They are also the most herbivore unfriendly: grazed only when immature or immediately-following fires, but avoided when mature. Consequently, large areas of the Mundanthurai plateau are generally unfit for herbivore use on average. As a result, the carrying capacity of herbivores on the plateau is much lower than it could potentially be, which in turn translates to lower predator carrying capacities." (Sankaran, 1998). Results from this study indicate that encounter rates along transects is low when the ground cover is sparsely vegetated by grasses and the least when the grasses are dominated by lemongrass, thus strengthening results from previous studies.

The Mundanthurai Plateau, have been extensively modified by humans in the past and at present disturbances from human enclaves continue to operate. These disturbances have obviously caused the system to change from its original state. Efforts have been made to minimise the pressures from outside the park, but much needs to be done to address pressures from within the reserve. Both the reports from the Tiger Task Force (Narain *et al.*, 2005) and National Forest Commission (Kripal *et al.*, 2006) clearly highlight this problem in several of our parks and mention that efforts need to be made to prioritise settlements and take actions to prevent further habitat modifications. "Removal of the "disturbance" does not necessarily imply that the system will revert to its original "state"; it could also switch to an alternate "stable" state that is different from the original" (Sankaran, 1998). Restoring habitats is possible only with a pro-active management strategy based on sound ecological research rather than a "let it alone" policy. However, primary research, long term monitoring, employing both experimental and survey techniques, is necessary before the final choice of adaptive management strategy can be arrived at. Such strategies can double the prey populations in about 10 years.

In KMTR no single evidence of tigers was observed in the lower reaches during the course of this study. This is coupled by the fact that two other predators, namely leopards and dholes, operate within the park. Under such circumstances it is well documented that large sympatric carnivores are able to co-exist (Johnsingh, 1993; Karanth and Sunquist, 1995) as they prey on species with different body sizes - tigers prey on large animals (> 175 kg body weight), leopards on medium sized prey (>30 kg), and wild dogs include both small body weight (<30 kg) as well as medium sized animals in their diet. Field examination of predator scats confirms these observations. When one looks at the distribution of large bodied prey species, it is evident that they are restricted to higher elevation areas with wet evergreen and moist deciduous forests within the park.

A previous study that examined diets of carnivores in the plateau reports that there was no evidence of tigers on the plateau and that the proportion of large ungulates in the Mundanthurai leopard diet was markedly low, indicating the non-availability of these prey species (Ramakrishnan, 1999). During the course of this study we encountered 294 scats of which only two were tiger scats. Of the scats that were encountered on the Mundanthurai plateau, field-examination indicates that chital and sambar formed the main part of leopard diet. In the previous study chital and sambar formed only 33% of the diet of this carnivore. If scats encountered in the current study includes higher percentages of chital and sambar, this would indicate that the prey base in the Mundanthurai plateau is improving since 1999. Further microscopic examination of hair specimens collected from these scats needs to be undertaken before arriving at conclusions.

Results from the habitat herbivore relationship analysis show that the forest type primarily affects the encounter rates of all species (with the exception of wild pig and cattle). This is followed by the other landscape features.

For sambar, the proportion of area under dry deciduous forest is an important factor for higher utilization rates. Such kinds of habitat are found along the eastern side of the reserve. This part of the park is however prone to high levels of disturbance including fuel wood collection, settlements, fire and grazing pressures, and is within the tourism zone of the reserve. Gaur on the other hand requires greater proportion of wet evergreen forest type with areas of large edge density. This is typically seen in the shola-grassland systems found at higher elevations towards the western boundary of the reserve around Kodayar and Kannikatti.

Among arboreal mammals, there is a clear demarcation of vegetation requirements. The endangered lion-tailed macaque prefers areas of high proportion of wet evergreen forest and high stream densities. The Nilgiri langur population is determined by higher proportions of moist deciduous and wet evergreen forests, and lower proportions of dry deciduous forests. On the other hand, the common langur is seen only in the drier areas towards the eastern boundary of the reserve. The giant squirrel although are primarily affected by proportions of wet evergreen forests, they are fairly evenly distributed across the different habitat types. The distribution of these species corresponds to reports from other areas in the Western Ghats (Singh *et al.*, 1997).

For a fine-scaled understanding of the relationship between the habitat variables and herbivores, the analysis needs to be carried out for each line that was sampled.

Accomplishments

a. Research Accomplishments

Population estimates for herbivores have been determined for the Tiger Reserve. Substantial effort has gone into sampling the entire reserve using valid methods based on a spatially explicit survey design. Moreover, this study estimates patch occupancy rates for herbivores, which is the first such report for any species within the country.

This study fills in the lacuna in our understanding of the factors that drive population dynamics.

This study has established methodological protocols for KMTR and population estimates that can be used as benchmarks for long term monitoring.

Outcomes from this project have already resulted in two papers that have been presented at symposia - one at a National Level symposia and the other at an International Symposia (see appendix 2 for abstracts of these). In addition, work on another 4 potential scientific publications is in progress.

b. Training Materials

One of the objectives of the project is to prepare training material. Training manuals in English (see resource CD) and in Tamil (see enclosed) have been prepared. The manual gives in detail the different sampling methodologies the basic theory behind it, and details on data collection, and equipments required for undertaking the methods. These manuals have been prepared after interactions with the Forest Department officials as well as the training program participants.

c. Local Capacity Building

The other objective of this project is to build local capacities to monitor wildlife populations.

Training was undertaken at two levels. The first was to train the field assistants who have been drawn from the local tribal community residing within the reserve. Some of these assistants had previous experience working on earlier projects in the reserve. The assistants were trained in data collection procedure and field sampling techniques. This included identification of scats and pellets, vocalization method used for sampling loud calling primates, line transect sampling, use of equipments including compass and range finder. They have also been trained in the use of a GPS for marking locations, tracking paths and for navigation, in addition to being trained in map reading. As part of their training they have been instructed and given hands on experience in different data collection methods for vegetation studies.

The second level of training was for the Forest Department field staff, students and volunteers. Two training programs were undertaken at this level. The first was held in 2002 in the Kalakad range and the second was held in 2005 in the Mundanthurai range. A total of 27 persons have been trained during these programs. The training program covered data collection and analysis for population density estimation using line transects, index surveys including encounter rates, and vocalization. Other sampling methods including the camera trap method were demonstrated. Participants in these training programs were taught to read a compass, calculate distances using an optical range finder, navigate, mark locations and track paths using a GPS in addition to map reading. They were also instructed on how to use these equipments for the different sampling methods. The participants were given hands on experience in data collection, compilation of data and basic analysis.

d. Mapping

The base map (see attached and the resource CD) was updated by undertaking surveys where current road and trails network, and some important locations were recorded using a GPS. On the request of the Forest Department staff, base maps showing the range and the beat boundaries have been prepared in Tamil. This is the first ever large-format map to be produced in a local language. This is aimed as a handy tool for the field staff.

Photo : Sunita Ram

Abandoned cardamom plantations at Sengaltheri

Photo : Srinivas V.

At higher elevations grass species other than lemon grass are seen

Photo : Srinivas V.

Sunita instructing the Field Assistants on sampling methods

Photo : Srinivas V.

Forest Department staff being trained in the use of the compass

Photo : Srinivas V.

Dilip undertaking a map reading and planning exercise with field assistants

Photo : Gopinath S.

Participants at the Mundanthurai training program being trained in the use of the range finder and compass

Photo : Gopinath S.

Photo : Gopinath S.

Srinivas training participants in the use of GPS

Photo : Gopinath S.

Instructors (Srinivas and Dilip) with the participants of the training program held at Mundanthurai

Photo : Gopinath S.

During the training program other methods like camera trapping were demonstrated

Photo : FERAL

Leopard photographed by the camera trap in Mundanthurai

Dissemination of results and publication plan

As highlighted in this report, the current project has resulted in several important outcomes. For the effective use of the information and knowledge that has been acquired through the course of this project, dissemination of these is a priority. Listed below are the publications including scientific and popular articles, booklets and posters that are being planned along with the mode of dissemination.

a. Handbooks and Manuals:

1. List of plants found in the Mundanthurai plateau along with the local names: handbook to be prepared along with the Kani field assistants.

2. Training material prepared as part of the project. This is being made available for free download from the FERAL website (http://feralindia.org).

b. Scientific Papers:

Published:

Srinivas, V. and Sunita Ram (2003) Use of vocalization for estimating population of Nilgiri langur in Kalakad Mundanthurai Tiger Reserve. Proceedings of 28th Conference on Ethological Society of India, Mundanthurai, Tirunelveli district, Tamil Nadu. pp.53-55.

Srinivas, V., P. Dilip Venugopal, and Sunita Ram (2006) Site occupancy and encounter rates of Malabar Giant Squirrel (*Ratufa indica*, Erxleben) in the Kalakad Mundanthurai Tiger Reserve, Tamil Nadu, India. Presented at the 4th International Tree Squirrel Colloquium and the 1st International Flying Squirrel Colloquium, Periyar Tiger Reserve, India.

In Preparation:

Vegetation of the Mundanthurai plateau (in collaboration with Dr. N. Parthasarathy, Pondicherry University).

Herbivore density estimates in the habitat mosaics of the Kalakad Mundanthurai Tiger Reserve.

Vocalization as a tool for determining density estimates of loud calling primate species.

Sighting of the *Calotes andamanensis* in Sengaltheri, Kalakad Mundanthurai Tiger Reserve. - a short communication submitted to the Journal of the Bombay Natural History Society)

Appendix 1

Classification and Regression Tree Models

(Source: Insightful Corporation, 2001, Garrard, 2002):

Tree-based modeling is an exploratory technique for uncovering structure in data and is used for

- devising prediction rules that can be rapidly and repeatedly evaluated
- screening variables
- assessing the adequacy of linear models
- summarizing large multivariate data sets

Classification tree models are useful when the response variable is made up of several distinct, unordered classes. They are nonparametric, can use several types of independent variables, and are not significantly affected by outliers (Verblya 1987). Regression trees have the same advantages, although they are used to predict numerical values instead of classifications. Classification trees could be used to predict habitat types, while regression trees could be used to predict abundances.

In both the classification and regression problems, there is a set of classification or predictor variables (x), and a single-response variable (y).

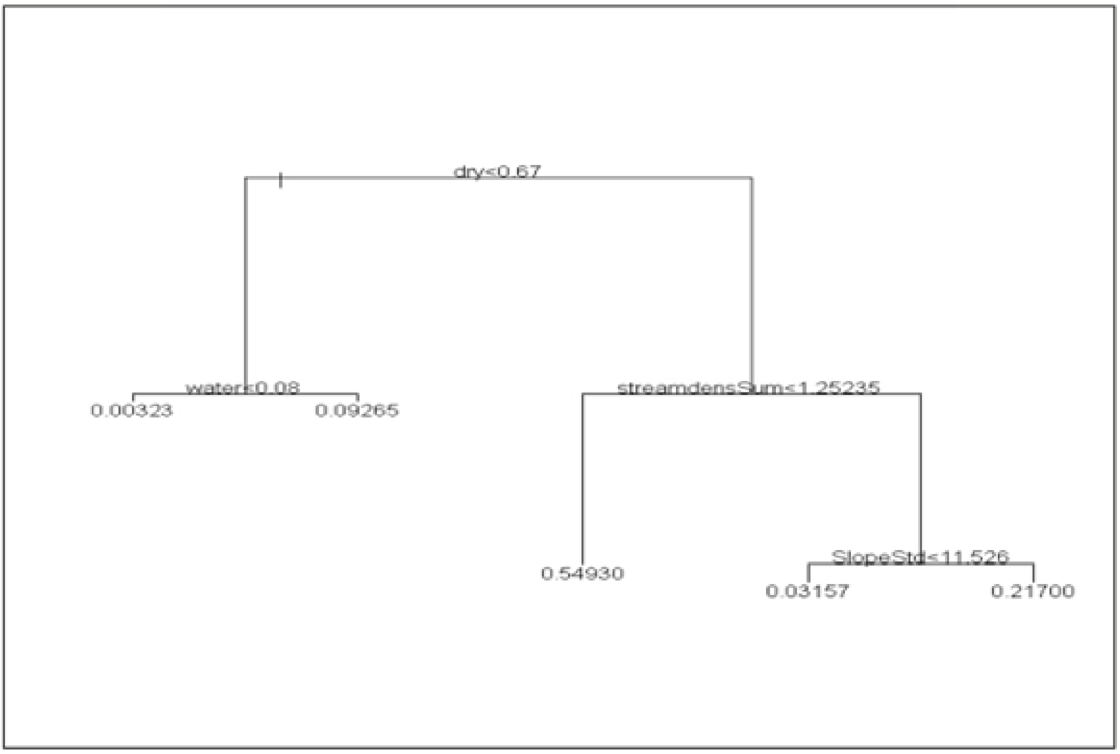
A classification or regression tree is the collection of many rules based on which the data is displayed in the form of a binary tree. The rules are determined by a procedure known as recursive partitioning. Tree-based models provide an alternative to linear and additive models for regression problems, and to linear and additive logistic models for classification problems. Compared to linear and additive models, tree-based models have the following advantages:

- Easier to interpret when the predictors are a mix of numeric variables and factors.
- Invariant to monotone re-expressions of predictor variables.
- Missing values are treated more satisfactorily.
- Non-additive behavior are captured better.
- Allow more general interactions between predictor variables.
- Can model factor response variables with more than two levels.

Generally, tree models are over-fitted to begin with and then they are reduced in size later. There are several methods for choosing a final tree size, and tree size might also depend on the intent of the model. The goal is to reduce the tree size so that it is neither fitted precisely to the specific data set it was grown on, nor is so general as to render its predictions meaningless. There are two methods used to reduce tree size: pruning and shrinking.

Interpreting the tree: Out of a suite of variables, only few that are more important to determine the value of the response variable are taken. At each level, the data points are classified based on some rule. For example, the result output for encounter rates from direct sighting of Sambar is shown graphically below.

The variables that are used in the final construction of the tree are a) proportion of forest cover under dry deciduous, Stream Density, slope, and proportion of area covered by large water bodies. For values of variable "dry" less than 0.67 the variable "water" is the next most useful variable to classify the dataset. Thus, for variable "water" less than 0.08, the expected encounter rate is 0.00323 and , for "water" more than 0.08, the expected encounter rate is 0.09265. Similarly, For values of variable "dry" greater than 0.67, 'stream density' influences the encounter rate. For values of "streamdensSum" < 1.25235, the encounter rate is 0.54930, and for values > 1.25235, standard deviation of slope determines the encounter rate.



In addition to the information available in the graph, a text output tells you what variables were used in the analysis, what were the parameters that were specified for the analysis, and a list of the variables that were used in tree construction. It also details how the data was split across the different terminal points.

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Appendix 2

Abstracts of published papers

Citation:

Srinivas, V. and Ram, S (2003) Use of vocalization for estimating population of Nilgiri Langur in Kalakad-Mundanthurai Tiger Reserve. Proceedings of 28th Conference on Ethological Society of India Feb 7 and 8 at Mundanthurai, Tirunelveli district, Tamilnadu. pp.53-55.

USE OF VOCALIZATION FOR ESTIMATIING POPULATION DENSITIES OF NILGIRI LANGUR IN KALAKAD-MUNDANTHURAI TIGER RESERVE

Srinivas, V[1]. and Sunita Ram[1,2]

Behaviour has classically been used as a refining tool for sampling animal populations. However in the case of animals that give loud calls on a regular basis, it is possible to use their vocalization behaviour to estimate their abundances and densities at which they occur. We have used vocalization behaviour of the Nilgiri langur, a threatened primate species endemic to the Western Ghats of India, for estimating its densties. This study, conducted in Sengaltheri, Kalakad-Mundanthurai Tiger Reserve, estimates a troop density of 0.82 troops / km^2. The paper outlines the methods and highlights the scope for further development of methods that rely on vocalization.

Keywords: monitoring, Sengaltheri, *Trachypithecus johnii*, speech recognition, sampling techniques.

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Citation:

Srinivas, V., Venugopal, D. P., and Ram, S. (2006) Site occupancy and encounter rates of Malabar Giant Squirrel (*Ratufa indica*, Erxleben) in the Kalakad-Mundanthurai Tiger Reserve, Tamil Nadu, India. Fourth International Tree Squirrel Colloquium and the First International Flying Squirrel Colloquium. Mar 22 and 23 at Periyar Tiger Reserve, India.

SITE OCCUPANCY AND ENCOUNTER RATES OF MALABAR GIANT SQUIRREL (*Ratufa indica*, Erxleben) IN THE KALAKAD-MUNDANTHURAI TIGER RESERVE, TAMIL NADU, INDIA

Srinivas, V[1,2], Dilip Venugopal, P.[1] and Sunita Ram[1,3]

Monitoring species across large landscapes, to accurately estimate species abundance, requires considerable amount of effort and resources. To circumvent this problem it has been suggested that the sites occupied by the species, determined using presence / absence surveys can be used as a surrogate. However one of the key problems with such surveys is the non-detection of target species, non-detection does not necessarily translate to true absence of the species. It could also mean that the species was present but was not detected during the surveys. This can be overcome by adopting appropriate field and analytical methods. In this paper we present the occupancy rates for unstudied populations of Malabar giant squirrel (*Ratufa indica*) within the Kalakad Mundanthurai Tiger Reserve (KMTR), Tamil Nadu. A total of 486 km of trail and paths were sampled in which 91 direct sightings and 89 calls of giant squirrels were recorded during the study period. We estimate high occupancy rates for Malabar giant squirrel, 0.86, within KMTR. We also find that occupancy rates are low in areas with high percent of degraded dry deciduous forests and scrub. These areas are also associated with high levels of human disturbance. We illustrate how such methods can be used to study and monitor other species of squirrels with limited distribution and those that are found in severely fragmented habitats. Other than providing methodological and insights into occupancy surveys the study also illustrates the potential use of these models in meta-population studies.

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