

# Distribution and Status of the Nilgiri Langur (*Semnopithecus johnii*) in the Western Ghats, India

Final Technical Report  
2006



**Citation:**

Sunita Ram, and Srinivas, V. (2006) Distribution and Status of the Nilgiri Langur (*Semnopithecus johnii*) in the Western Ghats, India. Final Technical Report. Foundation for Ecological Research, Advocacy, and Learning (FERAL), Pondicherry.

**Cover Photo:** Forest in South Wayanad.

Inset: Nilgiri langur

Gopinath, S. (gopinath@photoessays.net)

**Distribution and Status of the  
Nilgiri Langur (*Semnopithecus johnii*) in  
the Western Ghats, India**

**Final Technical Report  
2006**



**Distribution and Status of the Nilgiri Langur (*Semnopithecus johnii*) in the Western Ghats, India**

**Final Technical Report**

(Project period – January 2005 to December 2006)

**Principal Investigator**

**Ms. Sunita Ram**

Research Fellow

Foundation for Ecological Research, Advocacy and Learning, Pondicherry

Email: [sunitaram@feralindia.org](mailto:sunitaram@feralindia.org)

Research Associate

WCS-India Program

**Co-Principal Investigator**

**Mr. Srinivas, V.**

Research Fellow

Foundation for Ecological Research, Advocacy and Learning, Pondicherry

Email: [srinivasv@feralindia.org](mailto:srinivasv@feralindia.org)

Research Associate

WCS-India Program

**Supported by**

**Foundation for Ecological Research, Advocacy, and Learning**

27, 2<sup>nd</sup> Cross, Vazakulam, Appavou Nagar, Pondicherry – 605011

Tel: 91 - 413 - 2225441, 91 - 413 - 2001329

**Financial Support**

**Wildlife Conservation Society – India Program**

*and*

**Centre for Wildlife Studies**

23, 13<sup>th</sup> Cross, 7<sup>th</sup> Block West, Jayanagar, Bangalore – 560 082, Karnataka, India.

Tel: 91-80-26715364 Fax: 91-80-26715255

# CONTENTS

<b>Executive Summary</b>	<b>1</b>
<b>Acknowledgements</b>	<b>3</b>
<b>Introduction</b>	<b>4</b>
<b>Objectives</b>	<b>5</b>
<b>Description of Study Animal</b>	<b>6</b>
<b>Description of Study Area</b>	<b>8</b>
<b>Methodology</b>	<b>10</b>
<b>Analysis</b>	<b>11</b>
<b>Results</b>	<b>12</b>
<b>Discussion</b>	<b>24</b>
<b>References</b>	<b>28</b>

## Executive Summary

A comprehensive evaluation of the distribution and status of the Nilgiri langur (*Semnopithecus johnii*, Fischer) a vulnerable primate endemic to the Western Ghats of India was last undertaken in the late 1970's. Given an increase in indirect threats and continuation of direct threats, it becomes imperative to reassess their current distribution and status for effective conservation interventions.

This project undertakes to do this by taking a spatial approach. The objectives of the project are to:

1. Study the current distribution and status of the Nilgiri langur in the wild and identify areas occupied by the Nilgiri langur including those that are not already under protection.
2. Evaluate the influence of landscape composition and physiognomy on the distribution and status.
3. Analyse the information obtained on spatial scales and use landscape concepts to suggest conservation strategies.

Data on presence of the Nilgiri langur has been collected from field visits, questionnaire based surveys, and from literature. The data was collected with reference to the grids of the 1:50,000 scale Survey of India maps. Six variables including altitude, Normalized Difference Vegetation Index (NDVI), cvNDVI, LandScan dataset, fragmentation of habitats and latitude have been used to model and predict the distribution of the species. Generalized additive model has been used for this.

Our results show based on habitat suitability the Nilgiri langur is likely to be distributed in an area of about 4584.88 sq km, with a buffer area of 1613.72 sq km in the Western Ghats.

All the predictor variables that were used were included in the final model although the contribution of each towards the prediction varied. The presence of human activity was found to contribute most to the presence/absence of the species with lower impacted areas showing presence. The other major factors that influenced the presence were altitude (with a preference for higher altitudes) and the index of dry and wet forest cover.

The Nilgiri langur seems to be distributed in three distinct landscapes. The Northern region extends from their northernmost extent in the Brahmagiris up to Silent Valley National Park and includes forests in the Wayanad, North and South Nilambur Divisions, and the Mukurthi National Park, and the Nilgiri hills in Tamil Nadu. This is separated by the Palghat gap from the next landscape which includes the Indira Gandhi Wildlife Sanctuary, Parambikulam Wildlife Sanctuary and Nelliampathi hills, Vazhachal, Munnar and the High Ranges and the Palani hills. The southernmost distribution is separated by the region referred to as the cardamom hills. This includes the Periyar Tiger Reserve, Megamalai and forests of the Theni Division, and forests to the south of it including the Agasthyamalai Biosphere Reserve and the forests of the Kanniyakumari Division.

Data on levels of direct and indirect threats to the Nilgiri langur collected during the questionnaire and field surveys was analyzed spatially to determine areas of high impact. It was seen that areas outside the Protected Area network showed high levels of both direct and indirect threats. Also, interestingly the regions of high threat levels were along the state borders indicating a requirement for more cooperative monitoring of forests on the borders.

Based on this analysis, eight high priority areas have been identified for the conservation of the species. Of these the areas within the southern two landscapes support good populations of Nilgiri langur and their status here is more or less stable to increasing indicating that these areas can support the Nilgiri langur in the long-term. It is important to note that these two landscapes have a large portion of the forests under the Protected Area network. The priority areas identified in this study correspond with high priority conservation areas listed in earlier studies in the Western Ghats, thus, indicating the importance of these areas for not only the Nilgiri langur, but other species as well.

## **Acknowledgements**

We are grateful for the support of the following Departments, Organizations and People in undertaking this project.

We thank the Kerala Forest Department for the permission granted to undertake the field work. The cooperation given by the officers and the staff of all the Divisions and Ranges was very encouraging. We thank them all for their support.

Data for Kalakad-Mundanthurai Tiger Reserve and adjoining areas was undertaken during a long term study on the Ecology, behaviour and demography of the Nilgiri langur. We thank the Tamil Nadu Forest Department for granting the necessary permissions.

We thank Wildlife Conservation Society - India program and Centre for Wildlife Studies, Bangalore for the financial support.

Several people accompanied and assisted us during the field work. We thank Gopinath, S. Cherian, S. T. and Ram, S. for their help and company during field visits. We also thank Gopinath, S. for the use of his photographs in this report.

Without the help and co-operation of researchers and other informants we would have been unable to do the questionnaire based surveys. I wish to thank Dr. Ajith, Kumar, Dr. Mewa Singh, H. Kumara, Arumugam, Varma, S., Dr. Ramachandran, Dr. Jayson, students at KFRI, Dr. Veeramani, Mr. Sornappan, Kerala Forest Department and Tamil Nadu Forest Department field staff, tribal watchers and guides in Aralam Wildlife Sanctuary , Neyyar Wildlife Sanctuary , Peppara Wildlife Sanctuary , and Shendurney Wildlife Sanctuary and local field assistants. Several local and tribal assistants have helped us in implementing the field surveys. We thank them all.

Dr. John Oates, Dr. Rauf Ali, Dr. Ullas Karanth, and Mr. Samba Kumar for their advise and encouragement.

We acknowledge the logistic and administrative support received from Foundation for Ecological Research, Advocacy and Learning (FERAL), Pondicherry.

## Introduction

Many species found in the tropics are either endemic or are distributed patchily (Struhsaker 1975, Richards 1996) and in many cases their distribution does not fall within a protected area thus exposing them to risks of extinction (Terborgh 1992). The Nilgiri langur (*Semnopithecus johnii*, Fischer) is a vulnerable (IUCN 2004) primate endemic to the Western Ghats of India. Their geographical distribution is restricted to the southern regions of the Western Ghats between 8°N and 12°N latitude and between 76°E and 77.5°E longitude (Oates 1979). The main threats to this colobine have been identified as habitat reduction and poaching.

The last comprehensive evaluation of the distribution and status of this primate species was in late 70's by Oates (1979). Hohmann and Sunderaraj in 1987 surveyed protected areas in Tamil Nadu including the Kalakad Mundanthurai Tiger Reserve, Srivilliputtur, Anaimalai, and the Nilgiris south division (Hohmann and Sunderraj 1990). Singh has studied the distribution of primates in the Indira Gandhi Wildlife Sanctuary between 1995 and 2000. In the state of Kerala, distribution and population studies have been undertaken by a number of researchers (Balakrishnan and Easa 1986, Jayson 1996, Prasad et al. 1998, Ram and Srinivas 2001, Ramachandran and Joseph 2001, Joseph and Ramachandran 2003). In Karnataka a study has shown the distribution of the Nilgiri langur in the Brahmagiri - Makut areas and points out this is the northern-most extent of the species. (Kumara and Singh 2004). They suggest that the absence of the Nilgiri langur north of the Brahmagiri Ghats is ecological and not a factor of hunting

pressures. This region is considered to be an ecotone, rich in plants from the family Lauraceae and with *Cullenia exarillata* being absent to the North (Pascal 1988).

These past studies mainly report distribution of the species within protected areas. One study (Ram and Srinivas 2001) records sighting of Nilgiri langur outside a protected area in Wayanad and discusses possible conservation value of such areas for the Nilgiri langur. Important populations for the survival of this species may exist outside protected areas and these need to be identified. Habitat loss and alteration seem to augment their vulnerability. Studies (Prasad et al. 1998, Prasad 1998) have shown that in the Western Ghats of Kerala, between 1961 to 1988, there has been a decline of 47% of the evergreen and semi-evergreen habitats, a 11% decline in the degraded/scrub habitats, deciduous forest cover has increased by 7.5% and area under plantations has increased by 6-folds over this period. The once large contiguous rain forests in the Anamalai Hills in Tamil Nadu, a habitat the Nilgiri langur are found in, have been clear felled extensively for tea, coffee, teak and eucalyptus plantations, leaving behind several forest fragments (Umapathy and Kumar 2000).

In addition to the different pressures on habitats, the non-availability of current information for forested areas outside the protected area network, makes it imperative to reevaluate the status and distribution of the Nilgiri langur. Also, a spatial perspective of the current distribution, taking into account the ecological factors and disturbance levels, is an important input for drawing conservation strategies.

## Objectives

Thus the specific objectives of this study are

4. Study the current distribution and status of the Nilgiri langur in the wild and identify areas occupied by the Nilgiri langur including those that are not already under protection.
5. Evaluate the influence of landscape composition and physiognomy on the distribution and status.
6. Analyse the information obtained on spatial scales and use landscape concepts to suggest conservation strategies.



*Nilgiri langur Male (Photo: Gopinath, S. (Gopinath@s@photoessays.com))*

## Description of study animal

The Nilgiri langur (*Semnopithecus johnii*, Fischer 1829) is a threatened species (status: Vulnerable, (IUCN 2004), endemic to the Western Ghats on India. They range as single-males, multi-male, and all-male groups, and as solitary males (Bennett and Davies 1994). Group size is between 3 and 25 averaging at 8 to 9 animals per group (Prater 1971). They are territorial animals with loud and distinct inter-group calls.

Their geographical distribution is restricted to the southern regions of the Western Ghats between 8°N and 12°N latitude and between 76°E and 77.5°E longitude. The last comprehensive study evaluating their distribution and status was in late 70's (Oates 1979).

The Nilgiri langur has been described as an evergreen and riverine forest species found typically at higher elevations (2400m elevation in the Nilgiri and Palni Hills: (Poirier 1970, Oates 1978). However in some areas in Mundanthurai they are found at an elevation of 108m (Oates 1978). Also, they are known to use other habitats including deciduous forests (Oates 1978), plantations and cultivated woodlands (Prater 1971) and grasslands between sholas (forests in a mosaic of grassland: (McCann 1933), indicating their adaptability to different habitat types and to more homogeneous and human-influenced areas.

Prior research on the Nilgiri langur includes - feeding ecology and food selection studies undertaken in the Periyar Tiger Reserve (Horwich 1972), Kakachi, Kalakad-Mundanthurai Tiger Reserve (Oates et al. 1980) and Mundanthurai, Kalakad-Mundanthurai Tiger Reserve (Sunderraj 1984, 2000, Ram, 2006). Singh et al. have studied

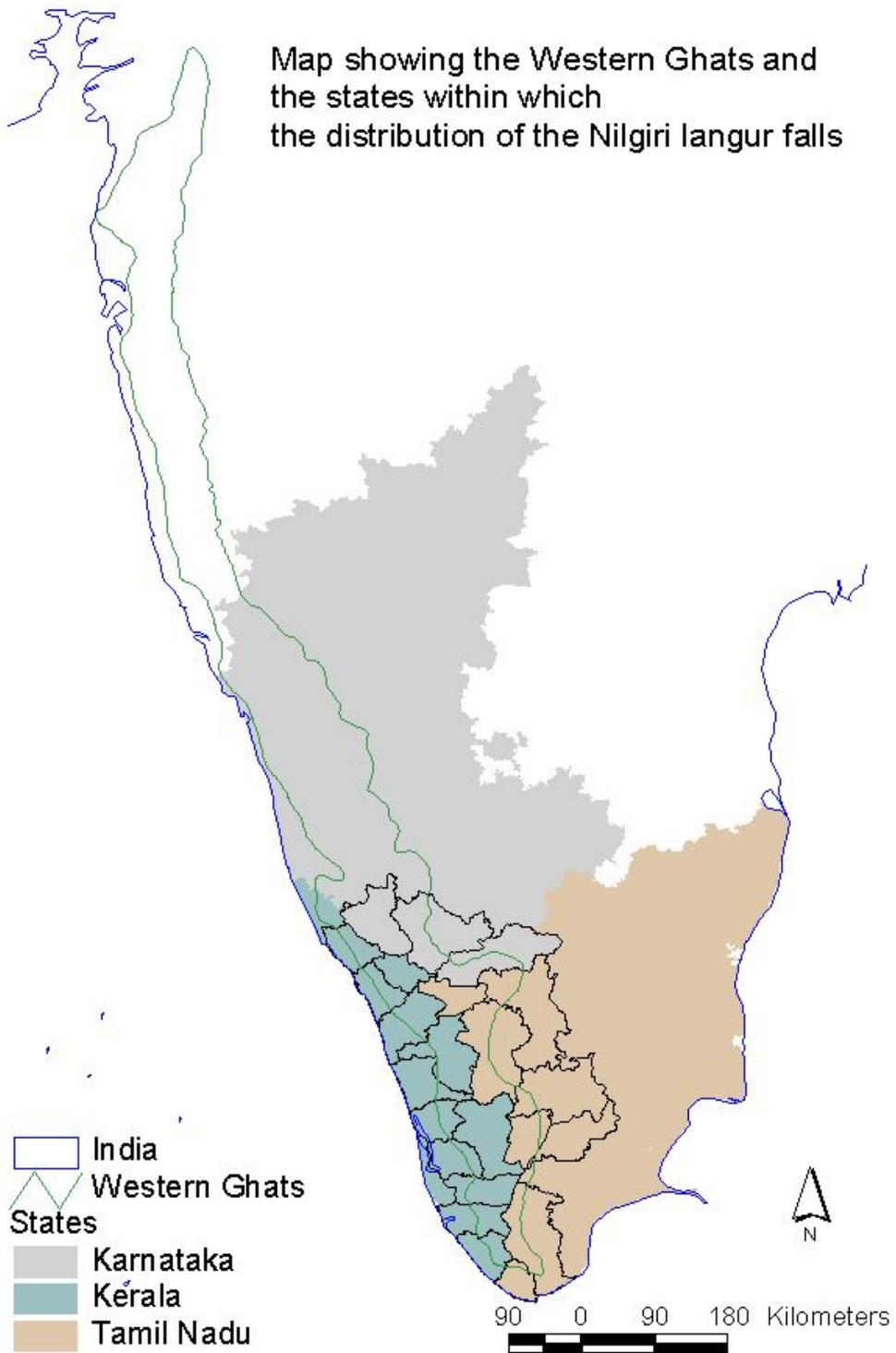
primate associations in the Anamalai Hills and have reported that the Nilgiri langur is a habitat generalist found in almost every habitat type in the Anamalai Hills showing inter-specific associations with *Macaca silenus* in evergreen rain forests at higher elevation (Singh et al. 1997).

Conservation issues: The main threats to this vulnerable colobine species has been identified as habitat loss and degradation and hunting for food and medicine (Kurup 1975, Participants of CBSG CAMP Workshop 2004). Loss of habitat and change in land use patterns have been seen over the entire Western Ghats (Prasad et al. 1998, Prasad 1998, Umopathy and Kumar 2000). The Nilgiri langur has been reported to use habitats outside protected areas thus making them more vulnerable to poaching. Such populations might be important for the survival of the Nilgiri langur and hence need to be identified and conserved.

The Nilgiri langur is legally protected against hunting under the schedule I, part I of the Indian Wildlife (Protection) Act, 1972 (amended up to 2002). Also, they are included in the CITES Appendix II. Other conservation efforts to protect the Nilgiri langur include bringing high biodiversity areas in its range under protection. Although not specifically intended for the conservation of this species, this effort has helped in reducing the poaching pressure on these and other animals in the area to some extent.

This species is threatened in spite of its adaptability to different habitat types and disturbance regimes. Thus understanding the factors affecting their distribution, population and behavior becomes important for its conservation.

Map showing the Western Ghats and the states within which the distribution of the Nilgiri langur falls



## Description of study area

### Western Ghats

The Western Ghats runs along the western edge of the Deccan plateau, separating it from the narrow coastal plain along the Arabian Sea. It runs north south for approximately 1600 km starting from the state of Maharashtra to almost the southern tip of Indian peninsula. The average elevation of the Western Ghats is about 900m, with the Anai Mudi in Kerala as the highest peak at 2595m.

This area forms a very important watershed for peninsular India with more than 40 rivers and streams including the Godavari, Krishna, Kaveri, Tungabhadra, Periyar, Tamarabarani and their tributaries originating from here.

The Western Ghats is a biodiversity rich region and is one of the 25 global hotspots for biodiversity. The variability in the topography and rainfall generates a wide variety of vegetation types ranging from wet evergreen and semi-evergreen forests in the high elevation and western slopes to dry deciduous to scrub in the lower elevation and the eastern slopes. More than 4000 species of flowering plants (nearly 38% of these being endemic), 508 species of birds (4%), 218 species of fishes (53%), 157 species of reptiles (62% endemic), 127 species of mammals (12% endemic) and 121 species of amphibians (68% endemic) are found in the Western Ghats (Nair and Daniel 1986, Daniels 2001, Johnsingh 2001).

This region houses five primate species, the Lion-tailed macaque (*Macaca silenus*), Bonnet macaque (*Macaca radiata*), Nilgiri langur (*Semnopithecus johnii*), Hanuman langur (*Semnopithecus entellus*), and the Slender loris (*Loris tardigradus*). Of these, the Lion-tailed macaque and the Nilgiri langur are threatened.

Although there are several protected areas in this range, it is estimated that only about 7.5% of the Western Ghats is in a pristine condition. The extremely high

human population has resulted in high pressures on the natural resources in this region and has led to habitat loss, degradation and modification. Much of the remaining forest in the Western Ghats today consists of timber plantations or disturbed secondary growth. A study of deforestation and land use change in the southern Western Ghats suggests that there has been a loss of 25.6% in forest cover over a 22 year period (1973 – 1995), with a 19.5% decrease in dense forest, and 33.2% decrease in open forest and a subsequent increase of 26.64% in degraded forests (Jha et al. 2000).

### Kerala :

Kerala covers an area of 38,863 sq km of which about 26% is the total forest area (FSI, 1995 From: (Kerala Forests & Wildlife Department 2004). The forests are legally classified as protected areas (Wildlife Sanctuaries and National Parks (2,395.4 sq km)), Reserved Forests (9,156.98 sq km), and Vested Forests (1,752.93 sq km) with another 214.31 sq km designated as proposed reserve forests. There are 14 protected areas in Kerala, 1 Biological Park and 2 Biosphere Reserves. (Kerala Forests & Wildlife Department 2004).

The forest types found within the state include, Tropical Wet Evergreen and Semi Evergreen forests (3299 sq km), Tropical Moist deciduous forests (4100 sq km), Tropical dry deciduous forest (~100 sq km) Montane subtropical temperate sholas (70 sq km) plantations (1791 sq km) and grasslands (40 sq km) (Kerala Forests & Wildlife Department 2004).

Fauna found in this state includes charismatic and flagship species like the tiger, and elephant and several endangered and threatened species like the lion-tailed macaque, the Nilgiri Tahr and the Nilgiri langur.

Nilgiri langur has historically been present throughout the Western Ghats of Kerala.

The forest census undertaken in 1997 reports the presence of the species in the Agasthyamalai region, Kuttiadi, Meppadi, Nelliampathi, Palghat hills, Periyar, Silent Valley and Wayanad regions. The report also notes that they are absent from the Wayanad plateau. The highest densities are found in the Periyar Tiger Reserve and regions south of PTR roughly up to the Ariyankavu Pass. Silent Valley regions north to Meppadi and Kuttiadi regions.

The region south of Silent Valley and North of Periyar has been reported to have medium densities of Nilgiri langur. This includes the Munnar, Nemmara, Vazhachal, Parambikulam regions. The northernmost and the southernmost extremities of the distribution have been classified as areas with low densities of Nilgiri langur. (Easa et al. 1998).



*Grasslands and Sholas in Kakki. Nilgiri langur is known to occur in these shola forests (Photo: Srinivas, V.)*

## Methodology

All information was collected with reference to the 1:50,000 scale survey of India toposheet. Data was collected from three sources. Primarily, the presence and absence of the species was collected from field visits to different forest areas. Secondly people with knowledge of the forest were interviewed and a questionnaire was filled in to get information both on the presence of the species as well as regarding the habitat. Thirdly, published information has also been collated.

*Field data collection:* Forest areas within the state were visited. During field visits, the location of sighting or calls was noted using a Garmin® 12xl GPS. Information on the habitat type, and if the group was in sight, the number of individuals was noted.



*Sunita with Forest Department personals in North Nilambur Division noting the geographical locations using a GPS (Photo: Gopinath, S.)*

*Questionnaire surveys:* Questionnaire based survey was undertaken to get information regarding presence and absence of the species, threats, status, habitat information including protection level, habitat type, disturbances. This involved interviewing knowledgeable people (including forest officials and field staff, researcher, and locals) based on a set of prepared questions. The questionnaires were filled-in based on these interviews.

Information regarding presence of the species has also been collected from

literature. For this, reports from the Forest Department Kerala Forest Research Institute and information published in journals have been collated.



*Sunita interacting with Forest Department Personal and local to fill in the questionnaire based survey in Tirunelli, Kerala (Photo: Gopinath, S.).*

In addition to these, to model and predict the current distribution based on the known presence or absence of the species, six variables that affect the Nilgiri langur have been used. These include: a) elevation, b) Normalized Difference Vegetation Index (NDVI): an index of green biomass, c) cvNDVI: an index of dry and wet cover, d) LandScan data set (Dobson et al. 2000, Bhaduri et al. 2002): a worldwide population database compiled on a 30" X 30" latitude/longitude grid. Census counts (at sub-national level) assigned to each grid cell is based on likelihood coefficients, which are based on proximity to roads, slope, land cover, nighttime lights, and other data sets. The dataset has been log transformed for analysis here, e) fragmentation of habitats, and f) latitude.

*Sampling protocol:* The previously described extent of the species was first used to define the study area. Within each 1:50,000 scale grid a minimum of 10km was sampled. This data was augmented with information collected from questionnaire surveys and literature.

## Analysis

The habitat suitability analysis has been used in predicting distribution of species. This involves using multivariate analysis where several independent variables are used to determine the value of a dependent variable. Multivariate statistics along with GIS form a powerful tool that are increasingly used for modeling in subjects ranging from population viability analysis (PVA) (Akçakaya et al. 1995, Akçakaya and Atwood 1997, Roloff and Haufler 1997) to landscape management for endangered species (Livingston et al. 1990, Sanchez-Zapata and Calvo 1999), ecosystem restoration (Mladenoff et al. 1995, Mladenoff et al. 1997), and alien-invasers expansions (Higgins et al. 1999).

The habitat suitability analysis is based on the following basic steps a) The study area is modeled as a raster map composed of N adjacent cells, b) The dependent variable is in the form of presence/absence data of the species of interest in the sampled locations c) The independent variables that is the ecogeographical variables describe quantitatively some characteristics for each cell, d) A function of the Ecogeographical Variable is then calibrated so as to classify the cells correctly as possible as suitable or unsuitable for the species. The details of the function and its calibration are dependent on the analysis chosen. Based on this function, a habitat suitability map giving the most probable distribution of the species can be obtained.

Presence-Absence data collection is an important part of habitat suitability analysis and the sample must be unbiased to be representative of the whole population. Absence data can lead to some amount of bias as this can be a result of a) true absence that is when the habitat is not favorable for the species, b) historically absent from that particular area for other reasons even though habitat is suitable, and c) non-detection of the species can result in an absence score.

There are several multivariate approaches that can be used in habitat suitability analysis. Of these, the Ecological Niche Factor Analysis (ENFA) (Hirzel et al. 2002) and the Generalized Additive Model (GAM) were explored. ENFA is based on the niche theory and is useful when limited presence data alone is available. GAM has been shown to be a fairly robust approach to model species distribution (Segurado and Araújo 2004). ENFA was undertaken in the program Biomapper (Hirzel et al. 2002) and outputs were validated using the area under the Receiver Operating Characteristic curve values (ROC). GAM was undertaken in Generalized Regression Analysis and Spatial Prediction (GRASP, (Lehmann et al. 2002) program. Choice of models in GAM is based on AIC values and the models have been validated using the ROC values for outputs from this approach. Comparing the validation of the results from the two approaches, the GAM was found to perform better. The distribution of the Nilgiri langur from this approach has been reported here and used for further analysis.

All analysis has been undertaken in Splus (Insightful Corporation 2001b, a) and ArcView 3.1 (Environmental Systems Research Institute 2000).

## Results

### Nilgiri langur presence-absence information:

Map 2 shows areas that were sampled. Sampling was undertaken in two sessions within the state of Kerala - the initial collection was undertaken between February and December 2005. Information from field visits was compiled along with information from questionnaires, published and unpublished literature. Point locations were used in modeling the distribution of the Nilgiri langur.

### Habitat Suitability analysis:

#### *Spatial predictors:*

To predict the distribution of the Nilgiri langur variables were selected based on the ecology of the species. The species tends to occur at higher elevations except in some areas and this was considered an important factor in determining the distribution of the species. Folivores are dependent on vegetation cover – hence the NDVI was used to eliminate areas that were more barren. The cvNDVI classifies areas on the basis of vegetation cover (greenness) through out the year (or in other word, a wet to a dry regime). Fragmentation or how fragmented a landscape is was considered an important factor for presence of Nilgiri langur, and finally the log(landscan) data gives information on how populated an areas is (an index of higher human presence vs. lower human presence).

In addition to these, latitude was also considered as a predictor in the model. The vegetation type in a region is influenced by the latitude. For example, towards the northern part of the range, evergreen forests and shola grasslands occur at much lower elevations than in the southern regions. However, in the southern landscape that includes Periyar and the Kalakad - Mundanthurai Tiger Reserves, the Nilgiri langur also occur at lower elevations in some areas.

#### *Data Exploration:*

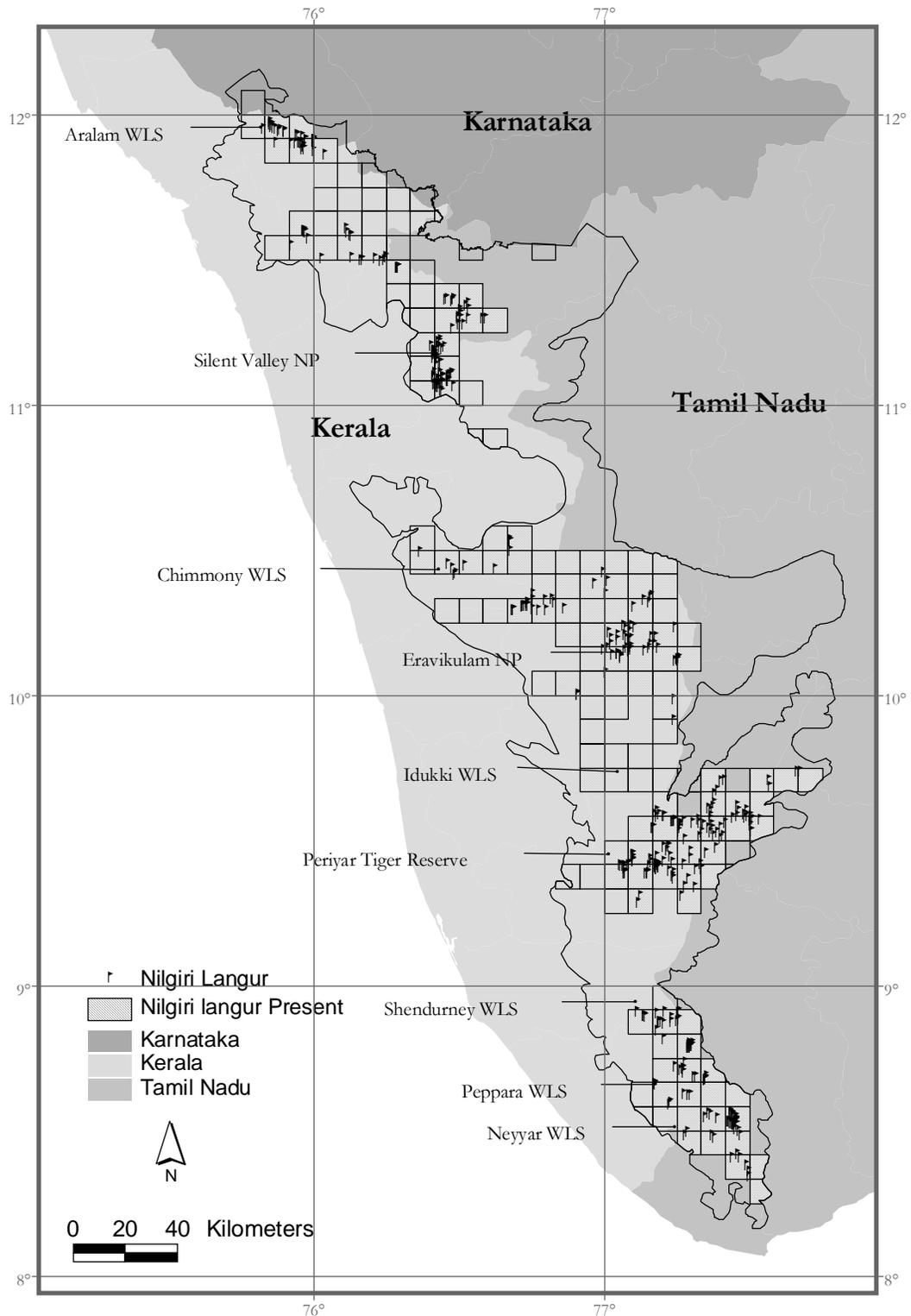
The first step involved was an exploratory analysis of the data. This was undertaken to investigate possible outliers and correlations between the predictors before proceeding with the model selection.

Table 1 gives a summary of the environmental predictor variables used to model Nilgiri langur distribution:

The presence-absence data was mapped to check the spatial distribution of the points and to identify outliers (Figure 1). The locations correspond closely to large forest patches within the Western Ghats and include protected areas, reserved forests and other forested areas. No outliers were identified and all points in the dataset have been used in the modeling.

	Latitude (Decim Deg)	Log (Land Scan)	NDVI	cvNDVI	Fragment	Altitude
<b>Minimum</b>	8.16	0.000	146.0	12.570	0.1600	31.0
<b>Mean</b>		1.449	226.3	26.233	0.5214	844.3
<b>Maximum</b>	12.16	3.860	249.0	54.540	1.0000	2508.0

Table 1: Summary of the predictor variables used in the model.



Map 2: Grids for which presence-absence information is available has been indicated (includes data from field visits, questionnaire survey and literature). Grids are with reference to 1:50,000 scale Survey of India toposheet. The shaded grids and the point locations indicate presence of Nilgiri langur

Presences (#): 461 Absences (\*): 272

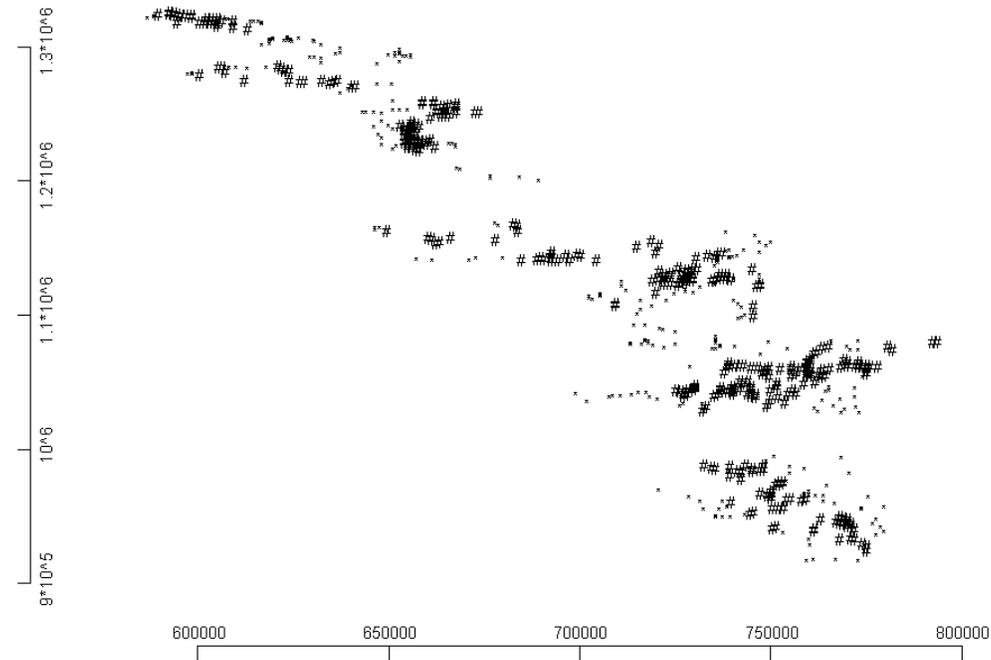


Figure 1: The presence-absence data were mapped as part of the exploratory data analysis using the GRASP module in Splus.

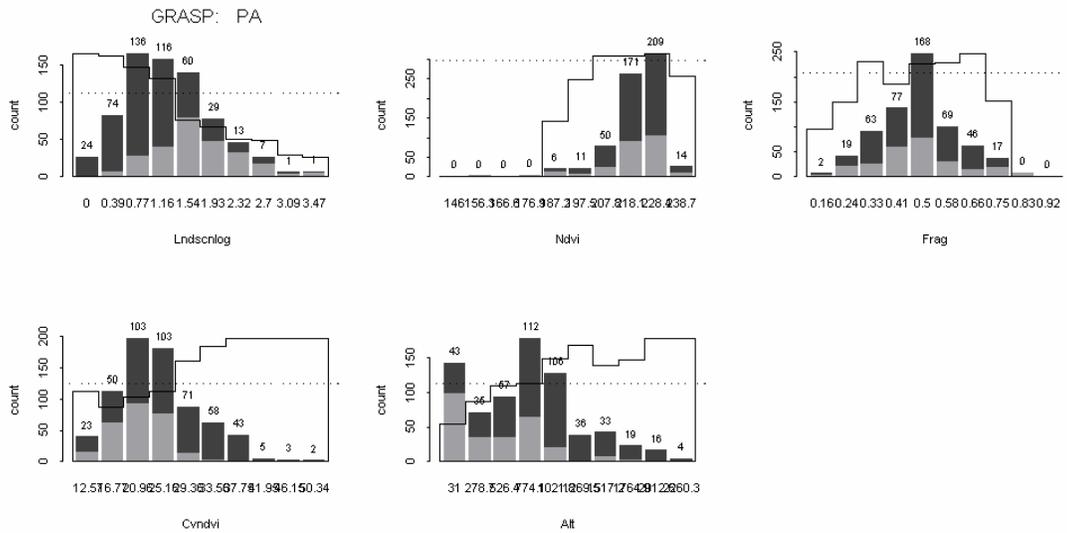


Fig 2: Distribution of the Nilgiri langur across Environmental gradients in the Western Ghats. Entire histogram bars represent the distribution of all points. The darker areas in each bar represent the number of points corresponding to presence (also written on top of bar). The plain line is the ratio between presence and absence points and the dotted line is the overall mean proportion of presence locations.

The environmental space occupied by the species is described using histograms generated in GRASP (Fig 2). The Nilgiri langur seems to be present in areas of low human presence. However, data is normally distributed across different fragmentation levels. Being folivores, their presence is characterized by larger green cover and towards more evergreen/wet regimes. Although the data indicates

presence at all altitudes, number of absence points at higher altitudes and wetter forest types is notable. Similarly at lower altitudes the ratio of between presence and absence points is lower and indicates that the Nilgiri langur does not prefer areas of lower altitude. Scatter plots of response versus predictors (Fig 3) also indicate similar trends.

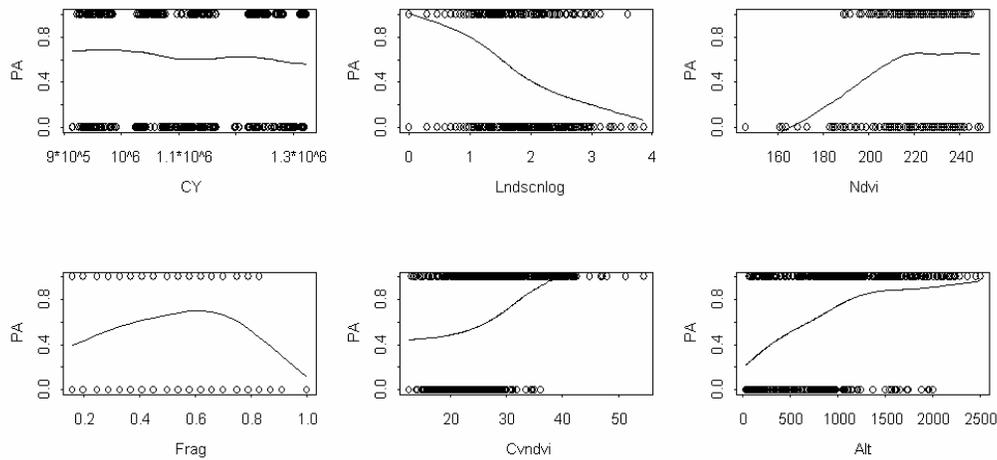


Fig 3 : Plots of response versus predictors. A smooth line is added to the graph.

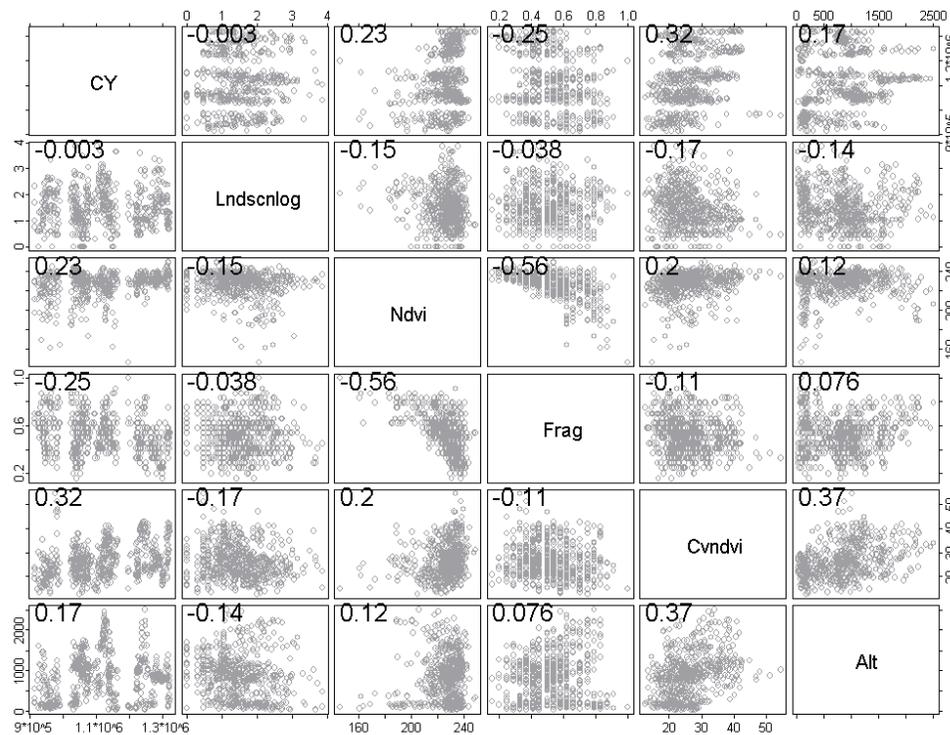


Fig 4: Correlation matrix of the variables used in the modeling shows levels of autocorrelation and the use of redundant data.

Correlation between the predictors was calculated (Fig 4). This allows the identification of correlated predictors, the presence of which can cause errors in calculating additive surfaces (Lehmann et al. 2002). Fragmentation and NDVI were the most correlated (-0.56) but the strength of correlation did not warrant dropping either of the variables from the model.

**Model Selection:**

A binomial model was chosen with a stepwise procedure used to select significant predictors. The starting model included the variable  $\log(\text{LandScan})$  smoothed with 4 degrees of freedom. A forward step was used to add predictors and the significance of adding a variable was based on the Akaike Information Criterion (AIC) value. At each step, the variable for which the model was most significant was added.

The stepwise selection of the predictors for the Nilgiri langur distribution resulted in the following model:

$$\text{Nilgiri langur presence: } (CY, 4) + s(\text{Lndscnlog}, 4) + s(\text{NDVI}, 4) + s(\text{Frag}, 4) + s(\text{CvNDVI}, 4) + s(\text{Alt}, 4)$$

Where  $s$  = spline smoother, and 4 is the degree of freedom for the spline smoother.

It can be seen that all the predictors used were included in the final model.

**Model validation:**

Two methods are used – i) the ROC method of validation and ii) plot of observed response variable versus predicted response variable.

Both the simple validation and cross-validation of the model (Fig 5) gave high ROC values (ROC = 0.928 and ROC = 0.912) indicating a good fit and fairly good model stability. The correlation between observed and predicted values was relatively high ( $r = 0.767$ ) and corresponded to more than half ( $r^2=0.59$ ) the variation explained by the model.

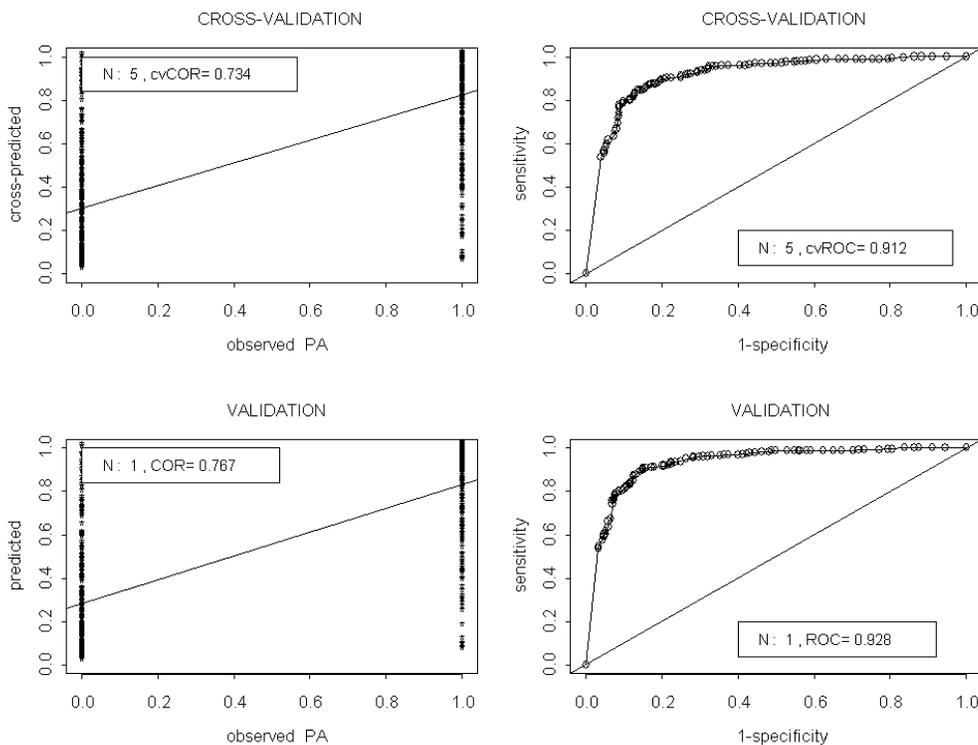


Fig 5: Graphs showing the outputs of the simple validation and the area under the ROC curve.

**Model Interpretation:**

Plots of the regression models; and response curves that results from the model and the overall contribution of the variables to the models has been calculated within GRASP.

The partial and the combined response curves (Figure 6 and Figure 7) show that the Nilgiri langur presence is characterized by a strong negative response to human presence, and latitude and a positive response to altitude.

Figure 8 shows the contribution of each predictor variable to the model. The left hand panel shows the strength of each of these variables when dropped – the

contribution of Landscan, latitude, altitude and to some extent cvNDVI cannot be explained by the other variables when dropped. These are important predictors. The right hand panel shows the contribution of the each variable when used alone – the principal contribution were ranked as Landscanlog, altitude, cvNDVI, NDVI, fragmentation, and latitude.

It is clear from this that although latitude as an independent variable was not important, the response explained by it in the model could not be sufficiently explained by the other factors when it was dropped.

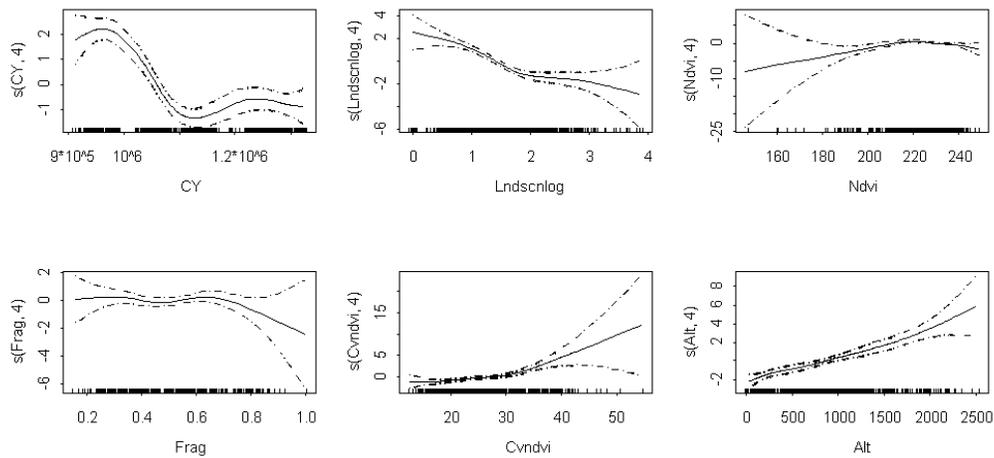


Fig 6: Partial response curves.

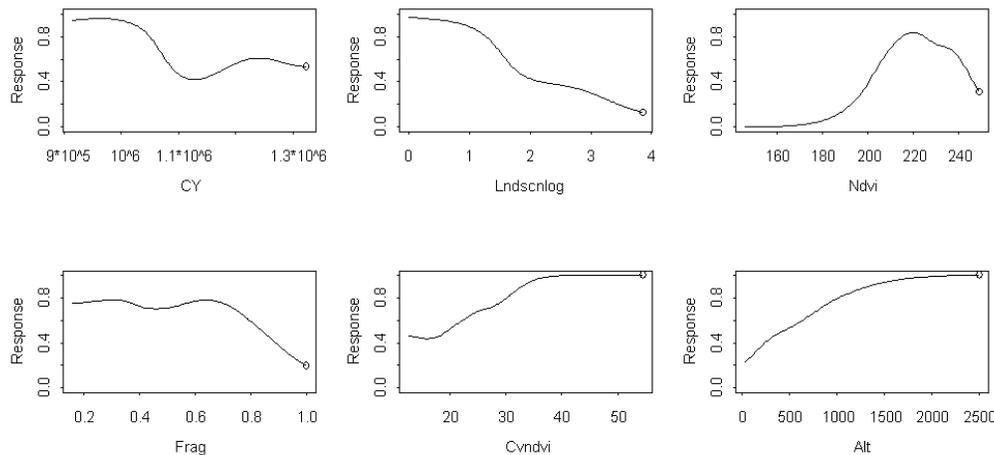


Fig 7: Combined Response curves

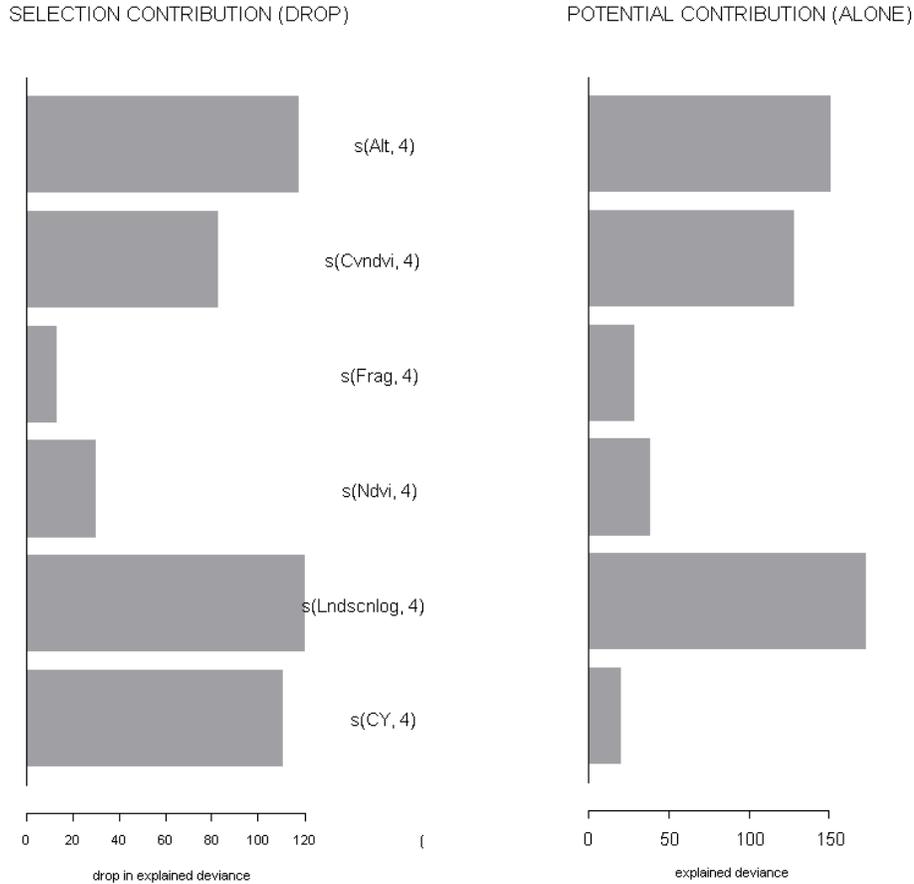


Fig 8: The contribution of each predictor variable to the model is shown. The left hand panel shows the strength of each of the variables when dropped – the contribution of Landscan, latitude, altitude and to some extent cvndvi cannot be explained by the other variables when dropped and hence are important predictors. The right hand panel shows the contribution of the each variable when used alone – the principal contribution were ranked as Landscan, altitude, cvndvi, ndvi, frag, and latitude.

A Correlation and Regression Tree (CART) analysis was also undertaken. It shows that the Nilgiri langur distribution is primarily influenced by only three of the six factors used in the analysis - LandScan, Altitude and NDVI (See Figure 9). The likelihood of presence of Nilgiri langur is maximum when presence of human habitation and presence is low (less than average). For values of LandScanlog less than 1.615, altitude determines the probability of presence. At altitudes less than 825m, Nilgiri langur is absent. At altitudes greater than this and

for Landscan values less than 1.385, Nilgiri langur is present. For Landscan values between 1.385 and 1.615, the probability of presence is maximum.

On the other hand, at higher values of LandScanlog (>1.615), NDVI acts as an important factor. For values of LandScan log between 1.675 and 1.885 and for NDVI values less than 224.5 (around average for the study region) there is a low probability of finding Nilgiri langur.

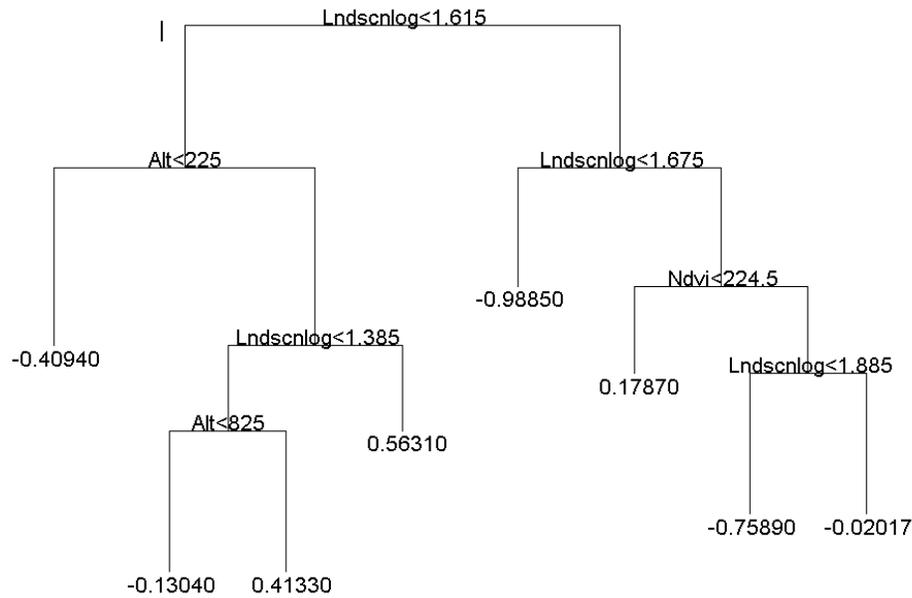


Fig: 9: TREE analysis: Shows the importance of the three variables used - Landsat, Altitude and NDVI in determining the presence of the species.

### Spatial predictions:

The predictions have been made within GRASP in Splus and this has been taken into ArcView for further analysis. The map below gives the predicted distribution of the Nilgiri langur. The areas in green are areas where Nilgiri langur is most likely to be present. Based on this, the Nilgiri langur is distributed in an area of about 4584.88 sq km, with a buffer area of 1613.72 sq km.

Our study shows that this species, previously distributed south of the Brahmagiri hills is currently distributed in three distinct landscape units in the Western Ghats. The Northern unit includes the Brahmagiri Wildlife Sanctuary in Karnataka, the areas under the North and South Wayanad Forest Divisions, the Nilgiris including Mukurthi WLS and adjoining areas, the Amarambalam area and other forests within the North Nilambur Division and the South Nilambur Division, south up to Silent Valley National Park.

The second unit includes the Indira Gandhi Wildlife Sanctuary, Chimmomy and the Forest areas in Vazhachal, Nemmara, Parambikulam Wildlife Sanctuary, Eravikulam Wildlife Sanctuary, Munnar Division and the Palani Hills/Forests around Kodaikanal.

The southern most unit is distributed from Periyar Tiger Reserve includes the forests in the Theni Division, Srivilliputtur Wildlife Sanctuary, and southwards including the forests of Ranni, Konni and the Achankoil, Ariyankavu regions and ends with the forests in the Kanniyakumari and Trivandrum divisions, and the .Agasthyamalai Biosphere reserve which includes the Shendurney Wildlife Sanctuary, Neyyar WLS, Peppara Wildlife Sanctuary, Agastyavanam Reserve and the Kalakad - Mundanthurai Tiger Reserve.

Southern region: In this region, the Nilgiri langur is found within the following Protected Areas: Periyar Tiger Reserve, Srivilliputtur Grizzled Giant Squirrel Sanctuary, Shendurney Wildlife Sanctuary, Peppara WLS, Neyyar WLS, and the

Kalakad – Mundanthurai Tiger Reserve. Within the PA, KMTR (approx 510 sq km) followed by PTR (about 245 sq km) seem to have the most areas where Nilgiri langur is found.

Outside of this, the distribution of Nilgiri langur south of Periyar and North of the Agasthyamalai Biosphere Reserve is of particular importance. There is a gap in this stretch, which falls within the Punalur division and the southern part of the Achankoil Division. This region corresponds to the Ariyankavu pass and the forest type includes secondary moist deciduous forests, with smaller areas under disturbed wet evergreen to semi evergreen forests. Other land use includes plantations of tea, teak and other miscellaneous plantations.

Forest Divisions in this area which are of high conservation value are Ranni, Achankoil, Thenmala and Thiruvananthapuram Divisions in Kerala and Tirunelveli Division in Tamil Nadu.

The middle portion of its distribution includes some of the highest areas in the Western Ghats, in the Munnar and the Kodaikanal regions. These areas are characterized by high altitude grasslands interspersed with sholas.

Within this region, main areas where the Nilgiri langur is found in outside Protected Area is in Munnar and Palanis. Over the years the habitats in this region have been converted into plantations. In the Palanis including the region around Kodaikanal, plantations of coffee, Eucalyptus, wattle, and orchards are common. The vegetation found here is described as a mosaic of savannah, disturbed forest, thicket, plantation and orchards, with dense evergreen montane formation at elevations above 1800m.

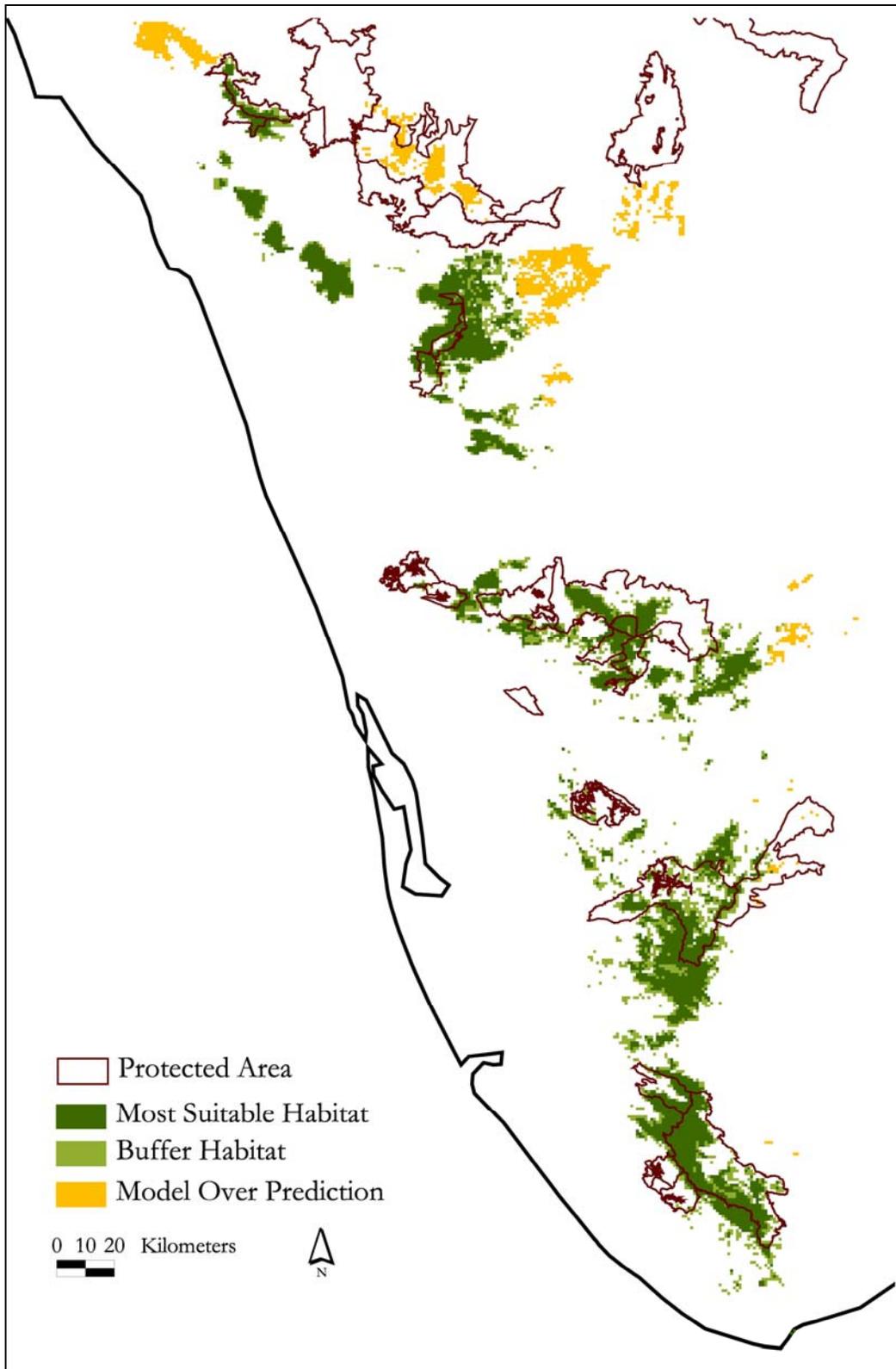
Towards the west of the Palani hills is the Munnar landscape dominated by vast holdings of tea plantations interspersed with few shola patches.

However, there is contiguous patch of forest within the PA network in this region. This includes the Indira Gandhi Wildlife Sanctuary, Grass Hills NP, Peechi, Chimmmony, Eravikulam, Chinnar, and Parambikulam which afford protection and excellent habitat for the Nilgiri langur. Contiguous to these Protected Areas are areas which have good populations of Nilgiri langur. These areas include, Valparai in Tamil Nadu, Vazhachal Forest Division and the Nelliampathi area which falls within the purview of the Nemmara Forest Division and the Parambikulam WLS in Kerala

In the Northern landscape, the Nilgiri langur is found from North of Olavakkod and is separated by a distance of at least 35 km from the populations in the south. The main protected areas where the Nilgiri langur is found are Silent Valley National Park, Mukurthi National Park, Nilgiri Biosphere Reserve, Aralam WLS in Kerala, and Brahmagiri WLS in Karnataka. The forests outside this where Nilgiri langur are found in the Nilgiri, Nilambur south (New Amarambalam), Nilambur North, along the Western slopes in South Wayanad and North Wayanad divisions, and in the areas adjoining Aralam WLS and Tirunelli in North Wayanad Division, adjoining the Brahmagiri WLS.

The landscape in the northern part is highly modified and with majority of the area under coffee plantation and to a lesser extent tea and other miscellaneous plantations.

In the recent past, some forest areas especially in Kerala have been given the status of a Wildlife Sanctuary or National Park. As the demarcation for these was not available, these areas have been included in the above lists under the Forest Divisions.



Map 3: Predicted distribution of the Nilgiri langur based on Habitat Suitability Modeling. The core or the most suitable habitats (dark green) have been buffered by a region of less suitable habitats (light green) where the Nilgiri langur could also exist. Places where the model has over predicted the distribution is also shown (yellow).

### Threat Analysis:

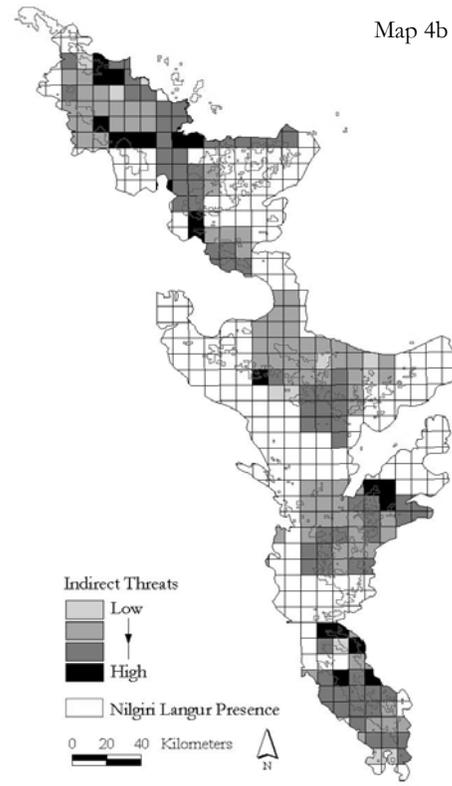
Both direct threats (poaching) and indirect threats (including habitat modification and habitat loss) are causes for the Nilgiri langur being a threatened species.

**Direct Threats:** From our questionnaire surveys, areas that have high poaching pressure both for the Nilgiri langur and for other animals were studied. Map 4a shows this for the areas sampled.

It is notable that most of the grids with high direct threats are those which are not under the Protected Area network or are along the boundaries of a Protected Area.

identify areas within the distribution of the species where indirect threats are high, we overlaid information on human activities that tend to contribute to habitat modification and loss, collected from the questionnaire surveys. The information collected included levels of Minor Forest Product collection, fire, tourism, pilgrim, and human population within each grid. A disturbance index was obtained which was scaled to 100.

Map 4b gives the disturbance across the distributional range of the Nilgiri langur. The patterns seen with respect to Protected Areas are similar to that seen for direct threats.

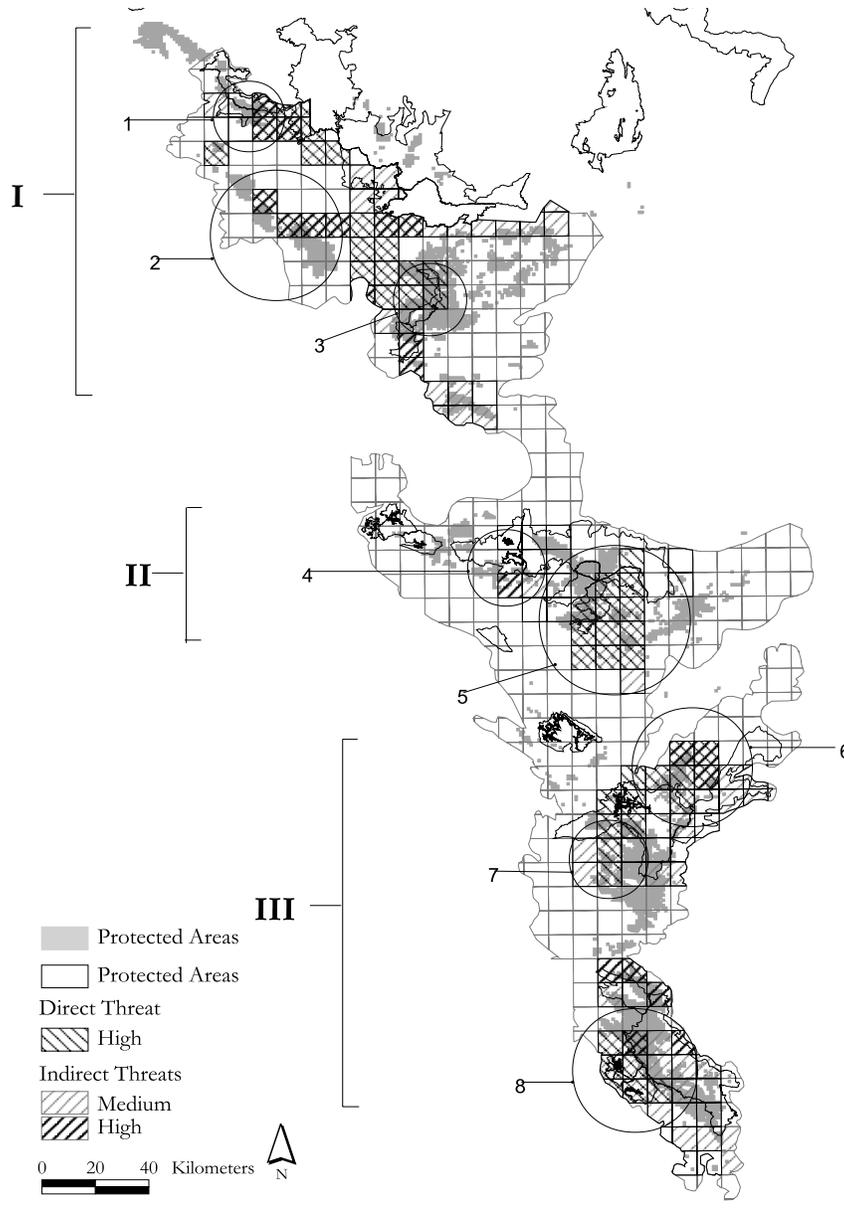


**Indirect threats:** Habitat loss and modification is the foremost indirect threat. The results show that the Nilgiri langur prefers a wet regime and areas with higher green cover at higher altitudes. Also, there is a strong preference for areas that are least influenced by humans. To

By overlaying threats over the Nilgiri langur distribution map, areas that need conservation intervention have been identified (Map 5). Based on this eight areas have been identified where the Nilgiri langur is found and threats are

high. Of these other than areas 2 and 7, the rest are areas along the state boundaries. Also, these mostly correspond to areas that are not under the Protected Area network. A more intensive

survey looking at threats will probably refine these general regions to problematic locations and help in identifying specific problems that need to be dealt with to reduce the threat factor.



<sup>A</sup>Map 5: Areas where conservation interventions is required. I, II, and III indicate landscape regions where the Nilgiri langur is found in. 1: Tirunelli (N. Wayanad FD), Brahmagiri WLS, 2: South and parts of North Wayanad FD, 3: Nilambur south FD, Nilgiri south FD, and Mukurthi NP, 4: Vazhachal FD, 5: Munnar FD, 6: Megamalai, 7: Ranni FD, 8: Trivandrum FD and areas on the Kerala-Tamil Nadu border in the Agasthyamalai Biosphere reserve.

A: Only areas of high levels of threat are considered here. Areas adjoining these high pressure areas where Nilgiri langur is present and threat level is moderate or information was unavailable have not been considered. Monitoring and population studies over long periods will help in identifying other conservation areas for the Nilgiri langur..

## Discussion

### *Extent of Distribution:*

The Nilgiri langur has been reported to occur south of 12°N and between 76 and 77.5° E (Oates 1979) the northern most specimens collected by G. C. Shortridge from Srimangala and Kutta, Karnataka in 1912-1913 (Oates, 1979). The current field information suggests that the Nilgiri langur is probably restricted to the forest regions south of 12° N in the Western Ghats, which corresponds to forests on the southern slopes of the Brahmagiri Wildlife Sanctuary. Their extent on the West was recorded at Aralam Wildlife Sanctuary at 75.827°E and 11.954° N during the current field surveys. Their Easternmost extent as obtained from questionnaire surveys was 77.67° E. However, this has not been verified in the field. The Easternmost extent for which field record is available is in KMTR at about 77.5° E which corresponds to the previously defined extent of this species. Thus there is a confirmed but marginal change in the extent of the Nilgiri langur on the western side. Presence is probably a result of its being adjoining to the Brahmagiris Wildlife Sanctuary and Tirunelli area and also the location of the sighting falls within a Protected Area where the levels of poaching is considerably less as compared to non-Protected Areas.

### *Threats*

The threats to the Nilgiri langur are two-fold - direct and indirect.

*Direct Threat:* The Nilgiri langur is poached for its flesh, blood and organs which are traditionally thought to have medicinal value especially for lung ailments. The species is afforded protection under Schedule I, Part I, of the Indian Wildlife Protection Act, 1972 (amended up to 2002). In spite, there is ample evidence that this species continues to be poached (see photo).

Our questionnaire survey indicates that within Protected Areas poaching incidences are low and have reduced over time. This is an indication that a much stricter enforcement of the Wildlife Protection Act, 1975 is effective in addressing this issue and there is a requirement to bring areas outside the Protected Area network that are important for the conservation of this primate species into the formal protection of the system.



*Nilgiri langur meat seized by the Kerala Forest Department. This incident was recorded during the current field surveys. (Photo: Srinivas, V).*

Kurup, (Kurup 1975) notes that the Nilgiri langur can establish itself in most portions of its original habitat where human persecution is not acute. Hence efforts towards this will be a positive step towards the conservation of this species.

In general, poaching of larger mammals like the Tiger and Elephant get prioritized and reported. Smaller animals like primates, birds or amphibians are often ignored as loss of smaller (lesser) biomass. There is an urgent requirement in creating awareness of the status of these smaller species both amongst the field staff within the Forest Department as well as the general public as an effort towards increased vigilance and positive support for any conservation action.

*Indirect threats:* Threats in the form of habitat loss and modifications affect not only the Nilgiri langur but other animals as well. This leads to loss of preferred habitats, smaller population sizes, a higher

exposure to poaching, and stochastic events like floods and disease outbreak. Also, with an increase in fragmentation there is a definite risk in isolating populations that will ultimately face problems of inbreeding.

The common contributors to habitat loss and modification in this region are developments projects including dams and hydro-electric projects, conversion into plantations, timber and fuel wood collection and Minor Forest Produce collection.



*Tea plantations in Munnar have fragmented the landscape making it difficult for animals to move between the isolated shola forest patches. Photo: S. Ram*

In addition to habitat modification and loss, there is an additional threat to arboreal mammals from the high tension wires that run from the site of hydro-electric projects and settlements. There has been several incidences where Nilgiri langur and less often bonnet macaques getting electrocuted.

Our analysis shows that the most important factor determining the current distribution of the Nilgiri langur is the presence of human influence which has a negative impact. In the present scenario, natural factors like altitude and vegetation cover contribute less in determining the distribution of the Nilgiri langur.

Oates, 1979 points out that in forest areas that have not been greatly damaged and poaching incidences are low, the Nilgiri langur is a relatively abundant animal.

### ***Status and Priority areas for conservation***

In this section, the focus is on the three major landscapes identified in the results section. The status of the species and comparisons with areas of conservation prioritization in the Western Ghats that has been identified by others (Das et al. 2006) has been discussed.

Landscape I: This is the northern most extent of the species. Given that the majority of the area is already converted to plantations, it is important to preserve the remaining forest in this region. Oates, (1979), notes that the Nilgiri langur is probably in “a very precarious position or even extinct” in the Brahmagiri and their status is uncertain in the Wayanad plateau. There are records showing their presence in the southern part of the Brahmagiri Wildlife Sanctuary along the border with Kerala. Although our modeling shows presence of Nilgiri langur to south of  $12\frac{1}{2}^{\circ}$  N, field records shows that currently the Northern extent of the species is probably only  $12^{\circ}$  N. This could be due to various reasons including heavy hunting pressure in Coorg (as noted by Oates, in 1979) and loss of habitat. Our modeling exercise over predicts the distribution in some places (see map 3). This could be due to the predictor variables like altitude and NDVI used in the model. Incorporating detection probabilities could help in refining the distribution map.

The areas that this study identifies as priority areas correspond to Reserve Forests of high conservation priority identified in Das et al 2006. These include, New Amarambalam Reserve Forest, Forest areas between Coonoor and Mukurthi Wildlife Sanctuary, Evergreen forests between Nilambur Forest Division and Brahmagiri Wildlife Sanctuary in the Wayanad and Kozhikode Forest Division of Kerala. This area also has large plantations of coffee. Cardamom and coffee plantations afford some levels of contiguity between forest

patches and if direct threats in such areas are kept in check, there is a good chance of the Nilgiri langur populations increasing in these areas.

Landscape II: The shola patches in Munnar continue to have Nilgiri langur, but these islands in the middle of plantations are areas where direct threats are potentially high and long term survival of the species is in doubt. However the Vazhachal Forest Division in Kerala and Valparai in Tamil Nadu have good populations of the Nilgiri langur and if protected from poaching and habitat modification, will continue to support good populations. Oates (1979) reports that numbers were increasing in the remaining forest patches and where poaching was not acute. This seems to be the scenario even today and given the large contiguous areas under protection this region is important for the long term survival of the Nilgiri langur. This landscape also includes the Palani hills, which in the previous status report had an estimated number of 150 – 500 animals. Although, current numbers is not known, the probability of long term survival of any existing population will depend on the levels of protection that can be afforded here. Given that the population within the Anaimalai – Parambikulam - Eravikulam complex is increasing, this region should not become a sink for the animals for lack of protection.

The high conservation areas in this landscape identified in Das et al (2006) includes the areas west of Eravikulam, and South Western side of the Palanis and the Munnar region.

Landscape III: A corridor at the Ariyankavu pass to bridge the gap between the Agasthyamalai Biosphere reserve and the forests in Ranni Division and the Periyar Tiger Reserve will make this the largest contiguous forest patch and given the high density of Nilgiri langur will be the most important for their long term survival. A corridor will be

beneficial for not only the Nilgiri langur, but also larger mammals like Elephants.

Oates (1979) has also identified the Agasthyamalai region as an area that would support populations of long-term viability. However, he notes that there is no detailed information for the forests south of Periyar but poaching pressure is high here. Forests in Ranni especially adjoining the Periyar Tiger Reserve and Gavi, currently support a good population of the species and the area should be marked for better protection and where possible should be brought under the Protected Area network.

In addition, in the areas North of Periyar Tiger Reserve it is interesting to note that there are several areas outside the Protected Area network and forest divisions where Nilgiri langur is found. This includes areas adjoining the Periyar Tiger Reserve, Srivilliputtur Wildlife Sanctuary, and the Theni Forest Division. The land use in this area includes tea and cardamom plantation and the forest type includes medium and high elevation disturbed evergreen to semi evergreen forests and secondary moist deciduous forests. This area along with the forests in the Theni division should focus on bringing down the levels of both direct and indirect threats like land use and habitat modifications. The human-wildlife conflicts in this region are known to be high. This area has been the focus of some recent conservation dialogues relating to inter-state corridors (Kerala Forests & Wildlife Department 2004, PA Update 2006). Such corridors will be beneficial not only for larger mammals like the elephant, but also will help in the protection of Nilgiri langur populations.

This region also corresponds to a large part of the irreplaceable sites and Reserve Forests of high conservation value identified by Das et al 2006. This includes, the Kuttalam - Puliara Reserve Forests and the Kulattupuzha – Thenmala range, and the Ranni and Konni forests.

North of Periyar Tiger Reserve several smaller areas are shown in our model to have Nilgiri langur populations. These were however not detected during our field surveys, which could be due to low detection probability. The main habitat type in this area is tea and Eucalyptus plantations except one patch of medium elevation disturbed to evergreen forest type of approximately 120 sq km which lies Northwest of Kumily and south of Kanchiar. Given its proximity to the Idukki Wildlife Sanctuary further surveys in this forest region need to be undertaken and if necessary brought under the Forest Department.

This project has helped in demarcating the current distribution of the Nilgiri langur. It has used spatial analysis to determine areas of high conservation value. Such inputs are especially important for management initiatives like inter-state corridors that are currently being discussed (Kerala Forests & Wildlife Department 2006).

Our threat analysis shows that threat levels in several areas along state borders is high. As an effort to protect not only the Nilgiri langur, but also other species, an increased cooperation between the southern states will help in curbing the threats along the state borders. It is encouraging that in the recent past efforts

are being made by the Forest Ministers of the southern states to work in tandem to protect the forests and wildlife (PA Update 2006)

### ***Future Research***

The next logical step in the conservation effort for the Nilgiri langur is to collect baseline information on populations. This will be the basis for long term monitoring. Standardized and appropriate methods that are easily repeatable need to be identified and used. One of the constraints of such an effort is the large area to be monitored. There are several approaches that can be employed. These include – a) using presence-absence surveys to determine patch occupancy (Royle and Nichols 2003); and b) using vocalization as a method to determine population sizes (Brockelman and Ali 1987, Srinivas and Ram 2003). In both these methods, the scale at which the study is undertaken will have to be determined keeping in mind the biology of the species and sufficient spatial and temporal replicates will be required. Such an effort will not only give quantitative data to identify areas of high conservation value for the Nilgiri langur, but will help in monitoring populations over time and in evaluating any efforts taken for the protection of the species and other wildlife in general.

## References

- Akcakaya, H. R., and J. L. Atwood. 1997. A habitat-based metapopulation model of the California Gnatcatcher. *Conservation Biology* 11:422 - 434.
- Akcakaya, H. R., M. A. McCarthy, and J. L. Pearce. 1995. Linking landscape data with population viability analysis: management options for the helmeted honeyeater *Lichenostomus melanops cassidix*. *Biological Conservation* 73:169 - 176.
- Balakrishnan, M., and P. S. Easa. 1986. Habitat preferences of the larger mammals in the Parambikulam Wildlife Sanctuary, Kerala, India. Pages 191-200 *in* *Biological Conservation*.
- Bennett, E. L., and A. G. Davies. 1994. The ecology of Asian colobines. Pages 129 - 171 *in* A. G. Davies and J. F. Oates, editors. *Colobine monkeys: their ecology, behaviour and evolution*. Cambridge University Press, Cambridge.
- Bhaduri, B., E. Bright, P. Coleman, and J. Dobson. 2002. LandScan: Locating People is What Matters. *Geoinformatics* 5:34 - 37.
- Brockelman, W. Y., and R. Ali. 1987. Methods of surveying and sampling forest primate populations. Pages 23 - 62 *in* C. W. Marsh and R. A. Mittermeier, editors. *Primate conservation in the tropical forests*. Alan R. Liss, New York.
- Daniels, R. J. R. 2001. National biodiversity strategy and action plan: Western Ghats Eco-region. Report submitted to Ministry of Environment and Forests, Government of India.
- Das, A., J. Krishnaswamy, K. S. Bawa, M. C. Kiran, V. Srinivas, N. Samba Kumar, and K. U. Karanth. 2006. Prioritisation of conservation areas in Western Ghats, India. *Biological Conservation*. 133:16 - 31.
- Dobson, J. E., E. A. Bright, P. R. Coleman, R. C. Durfee, and B. A. Worley. 2000. LandScan: A Global Population Database for Estimating Populations at Risk. *Photogrammetric Engineering and Remote Sensing* 66:849 - 857.
- Easa, P. S., K. Jayaraman, and Kerala Forest Department staff. 1998. Population estimation of major mammals in the forests of Kerala - 1997. Kerala Forest Department and Kerala Forest Research Institute.
- Environmental Systems Research Institute, I. 2000. ArcView GIS. *in*. <http://www.esri.com>.
- Higgins, S. I., D. M. Richardson, M. C. Richard, and T. H. Trinder-Smith. 1999. Predicting the landscape-scale distribution of alien plants and their threat to plant diversity. *Conservation Biology* 13:303 - 313.
- Hirzel, A., J. Hausser, D. Chessel, and N. Perrin. 2002. Ecological-Niche Factor Analysis: How to compute habitat-suitability maps without absence data? *Ecology* 83:2027-2036.
- Hohmann, G., and F. W. Sunderraj. 1990. Survey of Nilgiri langurs and lion-tailed macaques in Tamil Nadu, South India. Pages 49-53 *in* *Primate Conservation*.
- Horwich, R. H. 1972. Home range and food habits of the Nilgiri langur, *Presbytis johnii*. *Journal of the Bombay Natural History Society* 69:255-267.
- Insightful Corporation. 2001a. S-Plus 6 for windows Guide to Statistics, Volume 1. Insightful Corporation, Seattle, Washington.
- Insightful Corporation. 2001b. S-PLUS 6 for Windows Guide to Statistics, Volume 2. Insightful Corporation, Seattle, Washington.
- IUCN. 2004. 2004 IUCN Red List of Threatened Species. *in*.
- Jayson, E. A. 1996. Rare and endangered mammals of Kerala. Kerala Forest Research Institute, Peechi, India.
- Jha, C. S., C. B. S. Dutt, and K. S. Bawa. 2000. Deforestation and landuse change in the Western Ghats, India. *Current Science* 79.:231-238.

- Johnsingh, A. J. T. 2001. The Kalakad–Mundanthurai Tiger Reserve: A global heritage of biological diversity. *Current Science* 80:378 - 389.
- Joseph, G. K., and K. K. Ramachandran. 2003. Distribution and demography of the Nilgiri langur (*Trachypithecus johnii*) in Silent Valley National Park and adjacent areas, Kerala, India. *Primate Conservation* 19:78-82.
- Kerala Forests & Wildlife Department. 2004. Official website of the Kerala Forests and Wildlife Department, Government of Kerala. *in*.
- Kerala Forests & Wildlife Department. 2006. Conference of Forest Ministers Southern States - Agenda. *in*.
- Kumara, H. N., and M. Singh. 2004. Distribution and Abundance of Primates in Rain Forests of the Western Ghats, Karnataka, India and the Conservation of *Macaca silenus*. *International Journal of Primatology* 25:1001-1018.
- Kurup, G. U. 1975. Status of the Nilgiri langur, *Presbytis johnii* in the Anamalai, Cardamon and Nilgiri hills of the Western Ghats, India. Pages 21-29 *in* Journal of the Bombay Natural History Society.
- Lehmann, A., J. M. Overton, and J. R. Leathwick. 2002. GRASP: generalized regression analysis and spatial prediction. *Ecological Modelling* 157:189-207.
- Livingston, S. A., C. S. Todd, W. B. Krohn, and R. B. Owen. 1990. Habitat models for nesting bald eagles in Maine. *Journal of Wildlife Management* 54:644–657.
- McCann, C. 1933. Observations on some of the Indian langurs. *Journal of the Bombay Natural History Society* 35:618-628.
- Mladenoff, D. J., R. C. Haight, T. A. Sickley, and A. P. Wydeven. 1997. Causes and implications of species restoration in altered ecosystems: a spatial landscape projection of wolf population recovery. *BioScience* 47:21 - 31.
- Mladenoff, D. J., T. A. Sickley, R. G. Haight, and A. P. Wydevens. 1995. A regional landscape analysis and prediction of favorable Gray Wolf habitat in the northern Great lakes region. *Conservation Biology* 9:279 - 294.
- Nair, N. C., and P. Daniel. 1986. The floristic diversity of the Western Ghats and its conservation: a review. *Proceedings of the Indian Academy of Science Animal Science/Plant Science*:127-163.
- Oates, J. F. 1978. The status of the south Indian black leaf-monkey (*Presbytis johnii*) in the Palni Hills. *Journal of the Bombay Natural History Society* 75:1-12.
- Oates, J. F. 1979. Comments on the geographical distribution and status of south Indian black leaf monkey. *Mammalia* 43:486-491.
- Oates, J. F., P. G. Waterman, and G. M. Choo. 1980. Food selection by the south Indian leaf-monkey, *Presbytis johnii*, in relation to leaf chemistry. *Oecologia* 45:45-56.
- PA Update. 2006. *in* Protected Area Update December 2006 (No. 64).
- Participants of CBSG CAMP Workshop. 2004. Status of South Asian Primates 2004: *Semnopithecus johnii*. *in*. 2004 IUCN Red List of Threatened Species.
- Pascal, J. P. 1988. Wet Evergreen Forests of the Western Ghats of India. Institut Francais De Pondicherry, Pondicherry, India.
- Poirier, F. E. 1970. The Nilgiri langur (*Presbytis johnii*) of South India. Pages 251-383 *in* L. A. Rosenblum, editor. *Primate Behavior: Developments in field and laboratory research*. Academic Press, New York.
- Prasad, N. S., L. Vijayan, S. Balachandran, V. S. Ramachandran, and C. P. A. Verghese. 1998. Conservation planning for the Western Ghats of Kerala: I. A GIS approach for location of biodiversity hot spots. *Current Science* 75:211-219.
- Prasad, S. N. 1998. Conservation planning for the Western Ghats of Kerala: II. Assessment of habitat loss and degradation. *Current Science* 75:228-235.

- Prater, S. H. 1971. The book of Indian animals, Third edition. Bombay Natural History Society, Bombay.
- Ram, S., and V. Srinivas. 2001. Comments on the current geographical distribution of Nilgiri Langur (*Trachypithecus johnii*, Fischer) in Kerala, India. *Asian Primates* 7:17-18.
- Ramachandran, K. K., and G. K. Joseph. 2001. Distribution and demography of diurnal primates in Silent Valley National Park and adjacent areas, Kerala, India. *Journal of the Bombay Natural History Society* 98:191-196.
- Richards, P. 1996. Fighting for the rain forest: war, youth and resources in Sierra Leone. Heinemann, Portsmouth, N.H.
- Roloff, G. J., and J. B. Haufler. 1997. Establishing population viability planning objectives based on habitat potentials. *Wildlife Society Journal* 25:895 - 904.
- Royle, A. J., and J. D. Nichols. 2003. Estimating abundance from repeated presence-absence data or point counts. *Ecology* 84:777 - 790.
- Sanchez-Zapata, J. A., and J. F. Calvo. 1999. Raptor distribution in relation to landscape composition in semi-arid Mediterranean habitats. *Journal of Applied Ecology* 36:254 - 262.
- Segurado, P., and M. B. Araújo. 2004. An evaluation of methods for modelling species distributions. *Journal of Biogeography* 31:1555 - 1568.
- Singh, M., H. N. Kumara, M. A. Kumar, and L. D'Souza. 1997. Inter- and intra-specific associations of non-human primates in Anaimalai Hills, south India. *Mammalia* 61:17 - 28.
- Srinivas, V., and S. Ram. 2003. Use of vocalization for estimating population of Nilgiri langur in Kalakad-Mundanthurai Tiger Reserve. Pages 53 - 55 in *Proceedings of 28th Conference on Ethological Society of India, Mundanthurai, Tirunelveli district, Tamilnadu*. pp.53-55.
- Struhsaker, T. T. 1975. The red colobus monkey. University of Chicago press, Chicago.
- Sunderraj, S. F. W. 1984. Foraging ecology and ranging pattern of Nilgiri langur, *Presbytis johnii*. Unpublished MS thesis. Bharathidasan University, India.
- Sunderraj, S. F. W. 2000. The Ecology of the endangered Nilgiri langur (*Presbytis johnii*) on Mundanthurai plateau, Kalakad-Mundanthurai Tiger Reserve, Tamil Nadu, South India. Ph.D. Saurashtra University, Dehradun.
- Terborgh, J. 1992. Maintenance of diversity in tropical forests. *Biotropica* 24:283-292.
- Umaphathy, G., and A. Kumar. 2000. The occurrence of arboreal mammals in the rain forest fragments in the Anaimalai Hills, south India. *Biological Conservation* 92:311 - 319.