KFRI Research Report No. 382 ISSN 0970-8103

ECOLOGY AND BEHAVIOUR OF THE ARBOREAL MAMMALS OF THE NELLIAMPATHY FORESTS

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December 2010

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(Final Report of the Research Project - KFRI 446/2004)

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Project proposal

Project No.	KFRI 446/2004
Title	**Ecology and behaviour of the arboreal mammals of the Nelliampathy forests**
Investigator	Dr. K.K. Ramachandran
Research Fellow	R. Suganthasakthivel
Objectives	1. To assess the distribution of arboreal mammals in Nelliampathy forests 2. To study the population structure of the arboreal mammals 3. To study the food habits of the arboreal mammals and 4. To study the behaviour of arboreal mammals
Duration	April 2004 - February 2009
Funding Agency	KFRI Plan Grants

Contents

Acknowledgements

We thank the Kerala Forests and Wildlife Department for necessary permissions for the field work. The field support and accommodation were provided by the Kerala Forest Development Corporation at Nelliampathies. We thank the Divisional Managers, Assistant Managers and Field Officers - Mr. Raghu, Mr. Sreenivasan, Mrs. Janaki Narayanan and all staff at Pakuthipalam and Pothumala KFDC for their kind and generous hospitality. . We thank with great respect the field assistance rendered by the native residents Mr. Devendran, Mr. Baalu, Mr. Ravi, Mr. Chinnan, Mr. Thaman and Mr. Chandran without which the field work would not have been possible.

At KFRI, we thank Dr. Vijayakumaran Nair of GIS Department for the support provided with the satellite image analysis and GIS, Mr. Subash Kuriakose for taking phographs and video of lion-tailed macaque troops in Nelliampathy, Mr. V.S. Ramachandran, Mr. Sunil and Mr. S. Babu for being with us in the field, on and off.

Also thanks and acknowledgements are due to the former Programme Coordinator, Forest Ecology and Biodiversity Conservation Division and the present Registrar, Dr. C. Renuka for her support and help. Thanks are also due to Dr. Swarupanandan, Former Head, Ecology Department and the former directors Dr. J. K. Sharma, Dr. R. Gnanaharan for showing keen interest in the study and the present director Dr. K.V. Sankaran for his encouragement and support during the final stages. Finally we thank the three reviewers Dr. E. A. Jayson, Dr. K.V. Bhat and Dr. Mammen Chundamannil who had critically gone through the manuscript and suggested modifications.

The drivers at KFRI - Mr. Madhavan, Mr. Chandran, Mr. Vijayan, Mr. Rajendran, Mr. Paul, Mr. Girijavallabhan, Mr. Jiji and Mr. Sahul Hameed helped us with the trips to Nelliampathies and back. Fond remembrances are due to them, for driving us through all difficult roads in Nelliampathies.

Abstract

A study of arboreal mammals in Nelliampathy forests was conducted between 2004 and 2008 to assess their distribution, population structure, food habits and behavior. The study was restricted to the forest ranges of Nelliampathy and Kollengode of Nenmara Forest Division. Sweep surveys were used to record the distribution of all available species whereas line transect methods were used to assess the abundance and density of major arboreal mammals *viz.*, lion-tailed macaque, Nilgiri langur and Malabar giant squirrel. The food habits and other behavioural observations were made using focal group follows aided with GPS. Ecological Niche Modelling was done in GIS to find out the potential habitat available for major arboreal mammals.

Eleven arboreal mammals were recorded from the evergreen forests of Nelliampathies through sweep surveys. They include five primates, five rodents, and one mustelid (small carnivore). Important sightings include the rare and endemic species such as the Nilgiri marten, Malabar spiny tree mouse and Malabar slender loris. A total of 59 transect surveys were done covering a distance of 705 kilometers. The Nilgiri langur was the most sighted group (n=254), followed by Malabar giant squirrel (n=194), lion-tailed macaques (n=63) and bonnet macaques (n=19). The abundance and population density of the first three species was calculated using line transect distance estimation. A total of 13 lion-tailed macaque troops with 200 individuals and 23 Nilgiri langur troops with 150 individuals were recorded and mapped in the evergreen forests of Nelliampathies. Population structure was studied for nine lion-tailed macaque and 16 Nilgiri langur troops. The food and feeding behavior of these two species were studied and niche breadth and overlap indices were calculated.

The GIS based habitat suitability analysis showed that the plateau region is the most ideal habitat for these arboreal animals with potential evergreen forests. However, remote sensing satellite image analysis of present forest cover revealed a crucial gap in the mosaic of vegetation in the plateau region due to disruptions by tea and coffee plantations. A corridor in the Karapara region is identified and a follow up study is proposed.

1. Introduction

The beginning of this century saw one of the primate species declared extinct in the tropical Africa (Oates *et al.*, 2000). With only five percent of the tropical rainforests in the world having legal protection from exploitation, as many as 95% of the primate species in the world occurs in tropical region (Mittermeier and Cheney, 1987). Habitat loss followed by fragmentation and degradation due to deforestation, logging and hunting has threatened about 50% of the total primate species in the world in the last thirty years (Chapman and Peres, 2001).

The forest degradation and land use change has been variously estimated for the Western Ghats in the modern times. The conversion of forests into monoculture plantations such as coffee, cardamom and teak opened up extensive uninhabited forests to the north and south of the Palghat gap in the southern Western Ghats. It has been speculated that during the period of 1905 to 1973 sixty percent of the original forest cover was lost i.e., over 100 km^2 per year (Nair, 1988). Another study by remote sensing techniques estimated a loss of about 25.6% forest cover and the reduction of dense forest cover by 33.2% for the last 22 years in the southern part of Western Ghats (Jha *et al.,* 2000).

Arboreality in the mammals is a relative term determined by the use of trees and shrubs to the forest floor for daily activities such as foraging, travel, nesting and denning etc., (Carey, 1996). Predominantly three groups of mammals (primates, rodents and carnivores) in the Southeast Asia are having extreme tree dwelling adaptations. It is the tree living mode and the dependency of canopy for the survival determines an arboreal animal, which is extreme in some groups and partial in other cases.

The mammalian diversity of Indian union is around 390 species distributed in 42 families and 180 genera. Though 15 species of primates, 101 species of rodents and 55 species of carnivores were present in the Indian union, at least two species were declared extinct and above 50% of the existing species were reduced from their original distributional range during the recent times. Of the total of 15 primates, nine species were listed in Schedule I and six species in Schedule II of the Wildlife Protection Act (Agrawal, 1998). Next to the eastern Himalayas, Western Ghats is the second largest abode of endemic mammals. Three primates, two carnivores and two

rodents are endemic to this region. The scenario is grim since about half of the species are threatened to various degrees. About 32 species are marked in the highly endangered category that includes the lion-tailed macaque and small Travancore flying squirrel. A total of 12 species of arboreal mammals were present in the Western Ghats with 7 endemic species of which one is endangered, two near threatened and four vulnerable (Table 1.1 and Plate I).

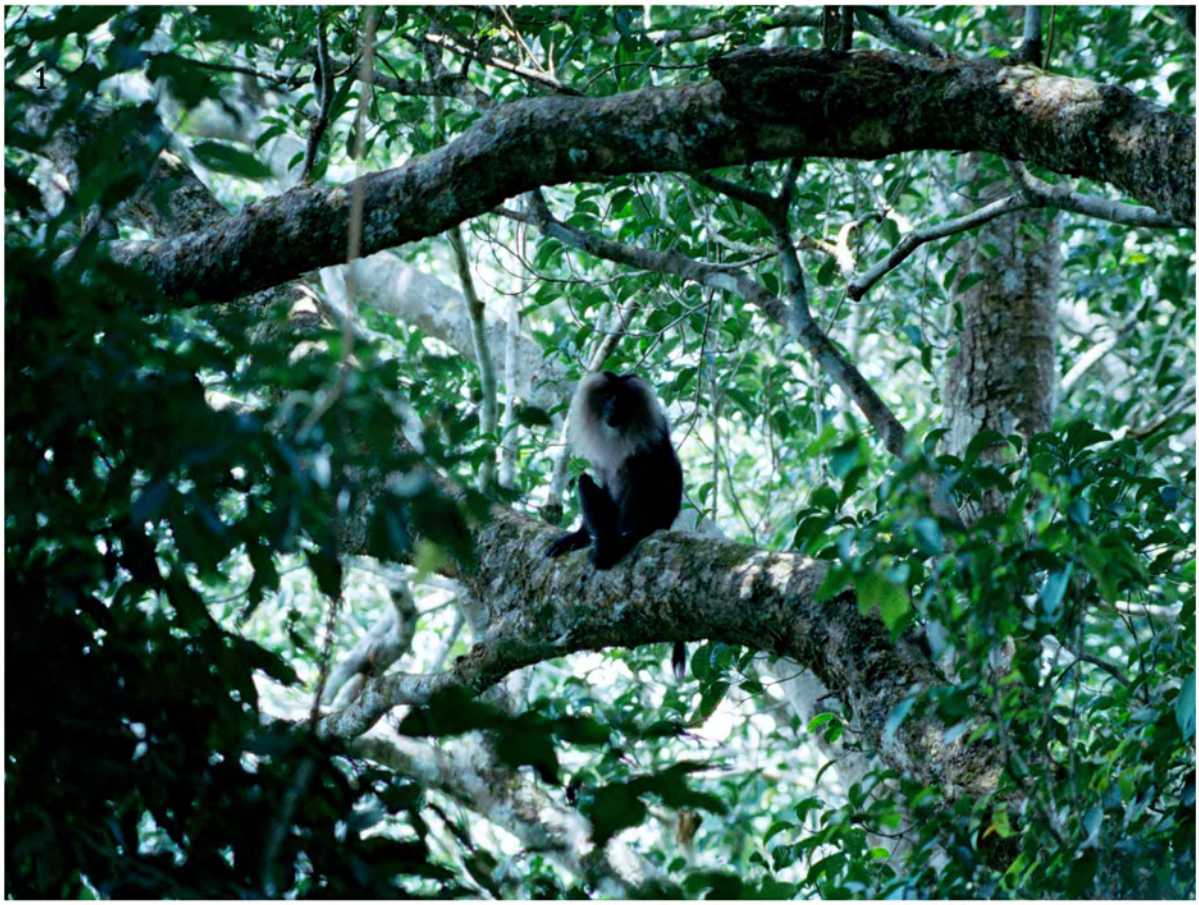
In a country with a total population of over one billion people living in a density of 329 persons per km^2, a refuge of only 5% of the total land area has two third of endemic species. With only 6.8% of the primary vegetation of the original extent remaining, habitat loss and fragmentation resulted in decreasing trends of most of the wild animal populations. Protected areas such as sanctuaries and national parks hosted stages for most of the studies where they constitute only a fraction of the total remaining habitat. For example the state of Kerala has only 21% of the total forested area protected under sanctuaries and national parks. The proportion of the effective forested area to the total geographic area is only between 24 to 28% with the population density of 819 persons per km^2. Given the per capita forest land is very low compared to international standards and the rate of forest depletion is enormous, particularly for this region (Jha *et al.,* 2000; Nair, 1988) biological monitoring programmes are the need of the time as the scientific data is lacking for the management of the present reserves and the potential habitats outside protected areas (Struhsaker, 2002) and hence the need for a study. The present study proposed in this line has the following objectives:

1. To assess the distribution of arboreal mammals in Nelliampathy forests
2. To study the population structure of the arboreal mammals
3. To study the food habits of arboreal mammals and
4. To study the behavior of arboreal mammals.

Table 1.1. List of arboreal mammals reported from the southern Western Ghats south of Palghat Gap

No.	Family	Scientific Name	Common Name	Endemism	Wildlife Protection Act 1972 – Schedule	IUCN	CITES
1	Cercopithecidae	*Macaca silenus* (Linnaeus, 1758)	Lion tailed macaque	Western Ghats	I	EN	A-I
2	Cercopithecidae	*Macaca radiata diluta* (Pocock, 1931)	Pale bellied bonnet macaque	South India	II	LC	A-II
3	Cercopithecidae	*Semnopithecus johnii johnii* (Fischer, 1829)	South Indian leaf-monkey	Western Ghats	I	VU	A-II
4	Cercopithecidae	*Semnopithecus priam priam* (Blyth, 1844)	Coromandel grey langur	South India	II	NT	A-I
5	Lorisidae	*Loris lydekkerianus malabaricus* (Wroughton, 1917)	Malabar slender loris	Western Ghats	I	LC	A-II
6	Mustelidae	*Martes gwatkinsii* (Horsfield, 1851)	Nilgiri Marten	Western Ghats	II	VU	A-III
7	Sciuridae	*Ratufa indica* (Schreber, 1851)	Indian giant squirrel	India	II	VU	A-II
8	Sciuridae	*Funambulus tristriatus* (Waterhouse, 1837)	Jungle-striped squirrel	Western Ghats	II	LC	-
9	Pteromyidae	*Petinomys fuscocapillus* (Blyth, 1847)	Small Travancore flying squirrel	India & Sri Lanka	II	NT	-
10	Pteromyidae	*Petaurista petaurista philippensis* (Elliot, 1839)	Flying squirrel	South Asia	II	LC	-
11	Viverridae	*Paradoxurus jerdonii* (Blanford, 1855)	Jerdon’s brown palm civet	Western Ghats	II	LC	-
12	Muridae	*Platocanthomys lasiurus* (Blyth, 1859)	Malabar spiny tree mouse	Western Ghats	-	VU	-

EN-endangered, NT-near threatened, VU-vulnerable, LC- least concern



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Arboreal Mammals of Southern Western Ghats : 1) Lion-tailed macaque, 2) Nilgiri Langur and 3) Malabar Giant Squirrel

2. Study area – The Nelliampathies

2.1. General Introduction

Nelliampathy hills or Nelliampathies (etymology: *nelli*- Indian gooseberry and *pothiyil*- mountain or hillock) are the hills lying in the southern rim of the Palghat gap (Plates II and III). The forest tracts stretching from the south of the Palghat gap to the Idamalayar-Pooyankutty valley in the south was generally considered as Nelliampathies (Nair, 1988). Except the north and eastern boundaries which are distinct with unique physiography and possessing separate historical narrative, the boundaries of the **s**outh and west are loosely defined. The existing definition overly extends beyond the original realization of the term 'Nelliampathies'.

It was the botanist Fischer who rightly identified Nelliampathy hills as a separate region from 'Anamalais'. Earlier most of the English explorers had not distinguished it from the latter. He states that the 'Anamalais' is separated to the west by the Thekkady river valley and the hills lying to the north west are 'Nelliampathy Hills', justified by the proximity to the west coast receiving high rainfall and the absence of the 'semi arid type of vegetation' (Fischer, 1921).

The inclusion of the forests to the south and west of the Parambikulam basin is inappropriate as these areas possess distinct geographical realities, different political and administrative histories. Moreover, the British government had the policy of assigning the lands to one or other chief lords in order to collect the taxes in an era of state monopolies. The East India Company had just dealt with the mutinies and wanted to settle the scores by taking over the forests and lands of the defeated. Being minority and without effective mechanism for revenue collection, leaving the larger part to the local kings in order to collect more tax (as reviewed in Chundamannil, 1993) was an effective strategy.

Thus until 18th century, though the original inhabitants were the nomadic people of hunter gatherers and slash and burn cultivators, the forests in the North eastern part (Chalakudy and Nelliampathy) of the State of Cochin were believed to be under the administration of small chieftains called *Naduvazhi* and *Nambidi* of Kodasseri and Kollengode of the present Palghat and Trichur districts. In the year 1853, Madras Presidency claimed the entire Parambikulam valley but the case went in favour of the Cochin State. Likewise claims were made by Malabar and Travancore

Palghat Gap From
Seethargundu Ridge

Steep Northern rim

Reservoir in foothills

Palghat Gap seen from Nelliampathis (southern rim)

Evergreen Forest

Evergreen & moist deciduous forests

Tea Plantations

Nelliampathies : Landuses and landscape

over these forests in the end of the 19th century. British eventually leased out a larger portion of the forest tracts in the eastern portion while ascertaining the rights of the Kollengode *Naduvazhi*. Sufficient clause was also made to perpetually renew the lease agreement over years and that was ratified in the year 1887. So there are princely forests, leased forests and state forests during that time each having separate management practices.

Unlike other parts of Travancore, the development in the Nelliampathy plateau was slow due to the lack of communication facilities such as roads. Only by the later half of the 19th century British planters started establishing plantations in the plateau (Varghese, 1970). The first plantations were raised in the lands leased out from the Kollengode ruler in the year 1863. Teak ranked as the chief timber extracted and the major development was restricted to the Parambikulam basin. A tramway was laid in the beginning of the 20th century to facilitate the transportation of logged timber to Chalakudi. The forests were worked intensively and the indiscriminate felling depleted the teak stock in a very short period. It is only after three years from the commissioning of the tramway, acute deficit was felt. Massive amount of logs were needed to sustain the tramway without loss and new areas were opened up to meet the demand. It became economically unviable to keep the tramway and was stopped officially in the year 1951. The leased Thekkady Reserved Forest remained with the South Coimbatore Forest Division of the erstwhile Madras Presidency until the reorganization of states in the year 1956 (Aiyar, 1942; Chandrasekaran *et al.*, 1977; George, 1963; Viswanathan, 1958).

Concessions were given by the Kollengode rulers for extraction and other developmental schemes such as grow-more-food programme in the plateau. Successive world wars and the expansion of the railways accelerated the extraction of timber other than teak. Large scale conversion had taken place in the plateau and mature forests were brought under cardamom and coffee cultivation. Nelliampathy was quickly added as a landmark into the manuals of planters as a prime area that produces stable and reasonable crops all the years unlike in the other parts in Kerala at that time. Owing to a very much stable rainfall and wet conditions Nelliampathies excelled in coffee production in the early 20th century (Langely, 1962).

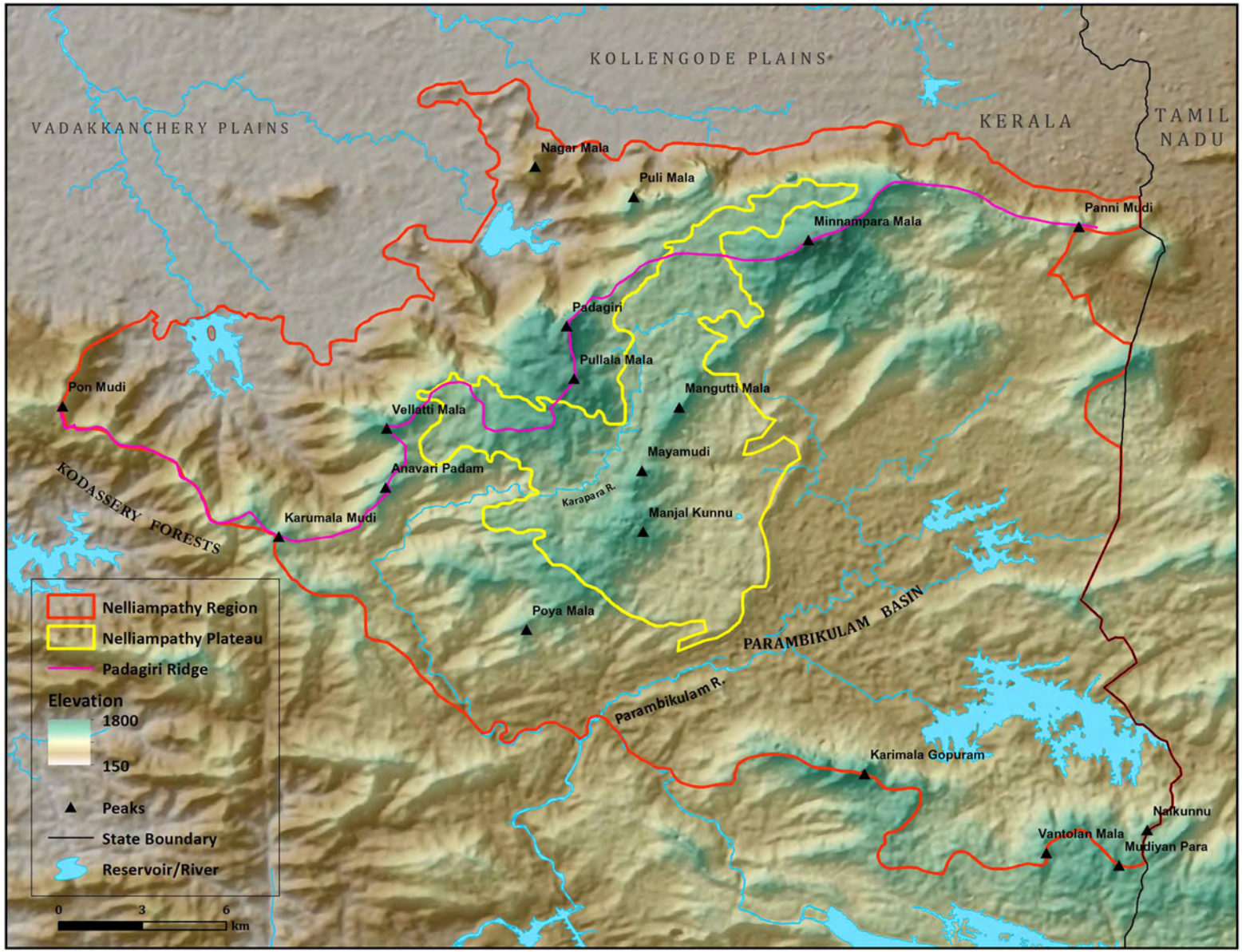
In the year 1971 through an ordinance, and followed by the Kerala Private Forests (Vesting and Assignment) Act the private forests which remained with the

erstwhile chieftains were nationalized. A committee was formed to study the potential of these forests for future preservation and development. Based on its recommendations the forests belonging to the Kollengode Kovilagam were notified as vested forests and taken over by the Government of Kerala (GoK, 1975). Unscientific measures taken in the name of development during the post-independent era of turbulence in Kerala (Chundamannil, 1993) did not spare the landscape.

A series of reservoirs were built in the Parambikulam basin and in the northern fringes. Plantations were expanded and earlier untouched mature patches were subjected to felling and conversion. It is only in the year 1987 after a scientific study, the quantum of destruction was assessed and the practice of selection felling was stopped in the plateau as well as in Kerala (Balasubramanyan, 1987). Thus the forests of Nelliampathies have passed through the ages of state monopolies till the 17^{th} and 18^{th} centuries, colonial expansion in the 19^{th} and first half of the 20^{th} centuries and finally the post-independence development drive in the first two decades of the later half. Cultivation was expanded, new labour was brought in through migration, settlements were spread over and the forests were severely depleted resulting in a mosaic as we observe today (see the map of the section Forests and Land Use). The total human population in the Nelliampathy plateau according to the 1991 census is around ten thousand.

2.2 Boundary

Based on the history and taking into consideration of the geomorphologic features, a new boundary is suggested (Plate IV). The tracts stretching between 76° 30’ to 76° 50’ E and 10° 20’ to 10° 35’ N comprising an area of around 736 km^2 is called ‘Nelliampathies’. The main change comes in the delineation of the south and western boundaries. The confluence point of the Karapara and Parambikulam rivers (76° 59’ 22.071” E and 10° 22’ 32.445” N) is taken as the south western limit because of the depression where the uplifted Nelliampathy plateau ends drastically. To its North West and South East are the high ridges separating it from the adjacent areas. Thus the *Karimala Gopuram – Vantolan Mala - Naikunnu* ridge (between 76° 44’ 49.259” to 76° 50’ 19.807” E and 10° 20’ 50.641” to 10° 21’ 56.386” N) seems to fit for the southern reach of a certain king of the plains in the Palghat gap. Because the Sholayar Plateau, Chalakudy Valley and Kodasseri forests south west of the ridge all have



Nelliampathies Redefined

separate administrative histories different from that of Nelliampathies. The geomorphology of these areas is also different from that of the Parambikulam basin and Nelliampathy Plateau. The vegetation composition is distinct as the medium elevation wet evergreen forests of *Cullenia-Mesua-Pallaquim* association is restricted to this region. The western boundary is taken as the ridge that separates the Karapara valley from the Kodasseri and Chalakudi forests. The altitude is very much low here (below 700m) and the low elevation evergreen forests of *Dipterocarpus* were present contrary to the medium elevation wet variants of evergreen found in the plateau. The eastern boundary is taken as the present interstate boundary between the states of Kerala and Tamil Nadu that follows the east-west watershed. So the Nelliampathy, Kollengode and Alathur ranges of Nemmara Division, Parambikulam Wildlife Sanctuary, and a small part of the Vellikulangara Range of the Chalakudy Forest Division is included in the current classification (Plate V). The administrative boundary of the present Nelliampathies falls completely within the present state of Kerala. Though the physical, bioclimatic and land use characterization were done for the entire landscape, the current study on the arboreal mammals of Nelliampathy forests is restricted to the Nelliampathy and Kollengode Forest Ranges of the Nemmara Forest Division with an extent of 313 km^2. The details are given in the Table 2.1.

Table 2.1 Administrative Divisions of Nelliampathy Forests

Sl. No.	Name	Administration	Total area km^2	Area included (km^2)
1.	Nelliampathy Range	Nemmara Division	205.94	171.3
2.	Kollengode Range	Nemmara Division	142.4	142.4
3.	Alathur Range	Nemmara Division	81.68	66.88
4.	Private Plantations	Nemmara Division	69.52	69.52
5.	KFDC Plantations	Nemmara Division	2.91	2.91
6.	Parambikulam Wildlife Sanctuary	Parambikulam Wildlife Division	274.14	274.14
7.	Vellikulangara Range (Part)	Chalakudy Division	108.40	8.61
				735.76

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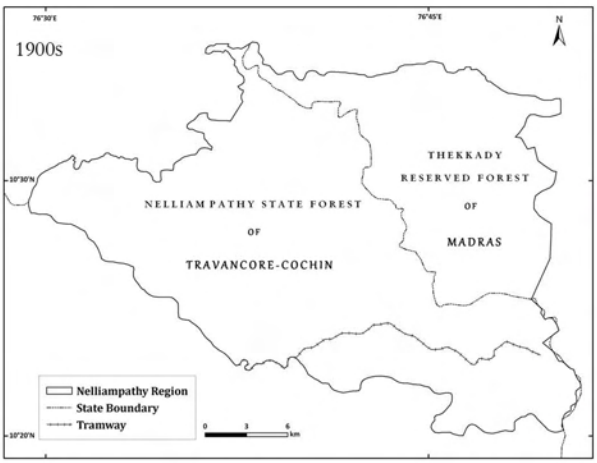

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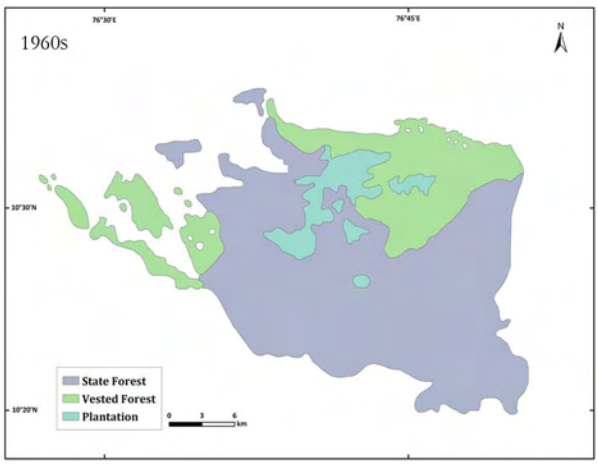

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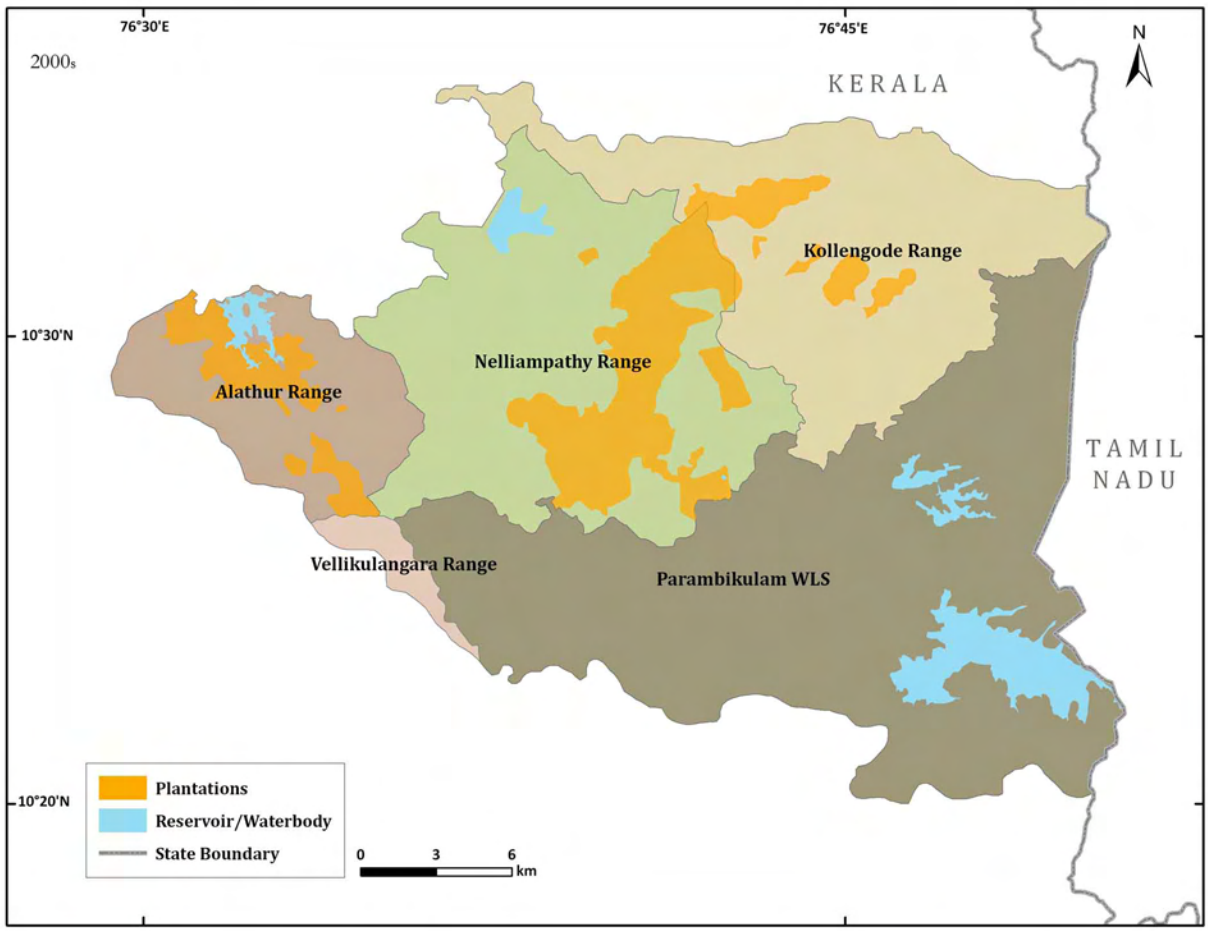


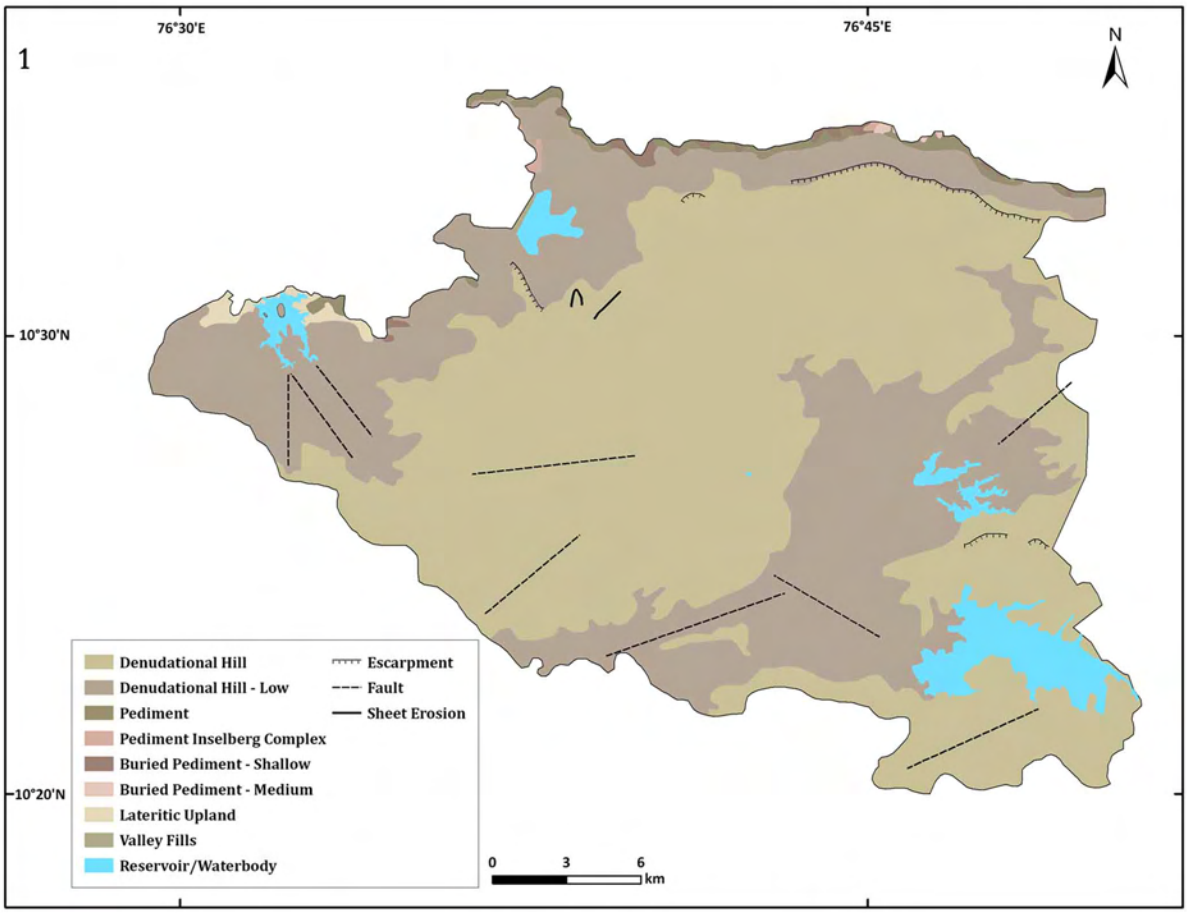
Nelliampathies Through Ages: 1) ca 1916 divided in to Madras Presidency Leased and Nelliampathy State Forests, 2) ca 1976 Reserved forests of the Kerala State and erstwhile Princely forests notified as vested forests (shown green), 3) the contemporary Nelliampathy divided into Nenmara Forest Division, Parambikulam Wildlife Sanctuary and a part of Chalakudi Forest Division

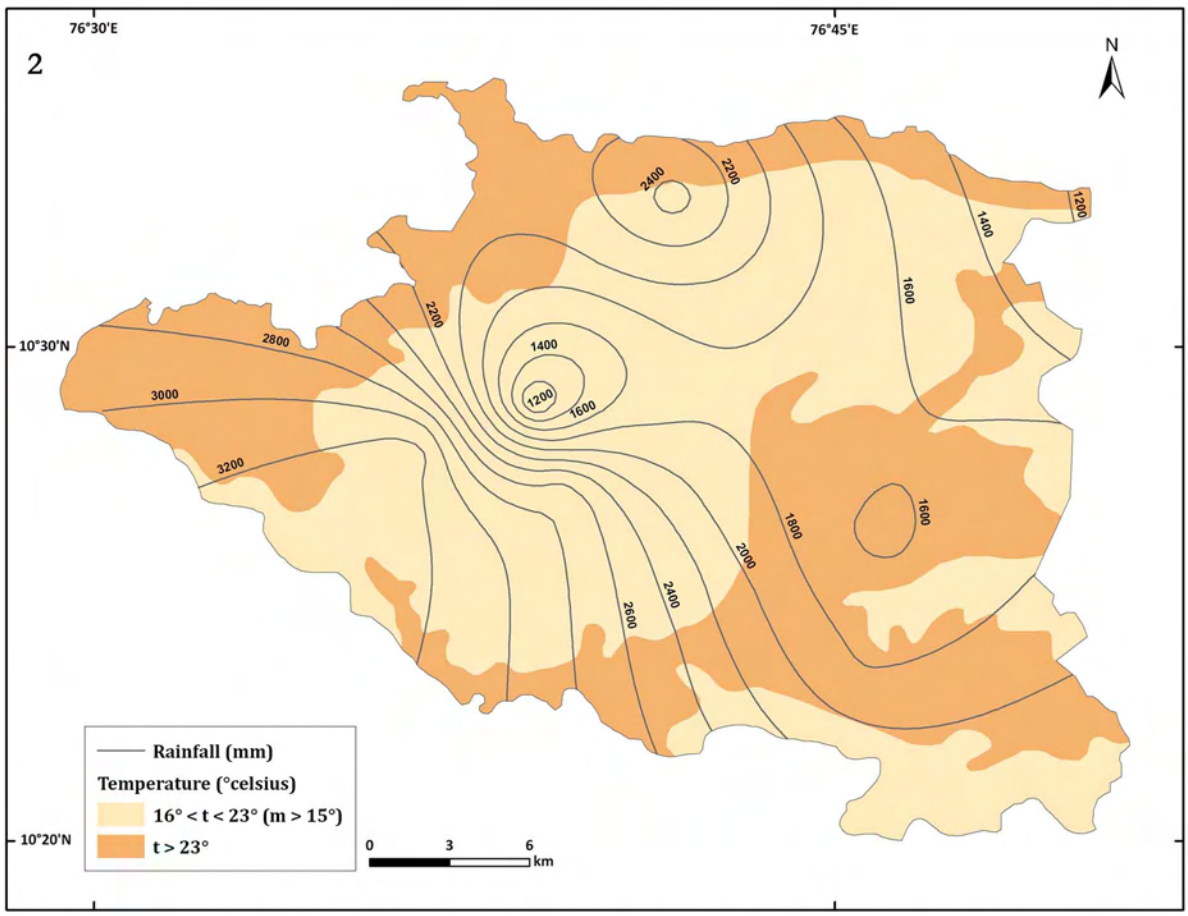
2.3 Geomorphology, Geology and Soils

Nelliampathies form a subset of the major landscape unit 'Anamalais' and the geomorphologic characterization of this landscape is of intermediate and partially dissected surface with strongly dissected relief. The physiography of the Nelliampathies is peculiar in comparison with an uplifted surface shielded by crisscrossing ridges. The main features are the escarpment in the northern rim, the plateau proper in the central portion and the Parambikulam basin to the south of the landscape. The uplifted plateau is found in the central portion of the study area. Three major ridges are seen around the plateau. The first one is the Seethargundu ridge, an escarpment in the east west orientation starting from the Panni Mudi in the eastern corner and running west to end at the Nagar Mala located in the hillocks north of the Pothundy reservoir. It forms the southern rim of the Palghat gap and the slope is steep and sudden to its north. The highest point in the Nelliampathies is Minnampara Mala located at an altitude of 1633m above MSL.

There is a ridge running almost at right angles to the escarpment from Minnampara Mala in the north south direction ending at the Manjal Kunnu and Poya Mala. This ridge divides the uplifted plateau into two halves, the one "Nelliampathy" plateau proper and the tabled land south of the Mangutti Mala. From the Govindamala peak another ridge runs parallel to the earlier one and through the peaks Padagiri and Pullala by forming the north western limit of the plateau. It ends at the Karumala Mudi by forming the watershed limit between the Karapara River and Vandazhi of Mangalam catchment.

The Karapara River originates in the eastern end of the plateau and flows south through the plateau proper. Exiting out from the plateau and turning west, it falls into a deep gorge and turns further south to meet the Parambikulam River. The hydro geomorphology map prepared by the Kerala State Land Use Board for the Palakkad district (KSLUB & NRSA, 1995) was used to extract the geomorphology map of the Nelliampathy region (Plate VI). Hydro geomorphologic classification categorizes Nelliampathies into denudation hills of high and low elevations. Denudation is the process of weathering due to erosion, biochemical and mechanical factors. Scarf is found in the northern rim and the rise of hills in the north and eastern side is abrupt that gives rise to the pediments and associated forms. Fault like linear





Geomorphology, Rainfall and Temperature : 1) Map showing the weathering effects in denudation of hills, escarpment in the northern rim and lineaments spread over. 2) Rainfall isohyetes showing east - west trend and two different temperature regimes (see the text for details)

features called lineaments are identified in nine places mostly along the river courses. Three lineaments of north south orientation are seen in the head ways of the Mangalam reservoir following the courses of Tipillikayam, Kumbancheri and Vattapara rivers origination from the Ponmudi – Anjanapara ridge. The place where the Karapara River takes its course out of the plateau towards the west and south in the southern orientation (between 76° 35’ to 76° 40’ E and 10° 26’ to 10° 27’ N) that falls into a deep gorge is identified as a lineament. The deep valley north of *Poyamala* is another fault of north east – south west orientation falling into the Karapara River. Other lineaments are seen in the deep valleys following the river courses of Parambikulam. The first lineament here is in the south west - north east orientation starts from Parambikulam and ends at Kuriarkutty. The second one is in the east west orientation that starts from Kuriarkutty and ends at Orukomban. The river valley of Tuvayad Ar south of Parambikulam reservoir running east west and the headwaters of Tunakadavu-Peruvaripallam reservoir extending to the east into the Karian Shola-Top slip area in the Valparai plateau are the lineaments seen in the eastern portion of Nelliampathies. Two major rivers drain the landscape *viz*. the tributaries of Bharatha Puzha in the north and north eastern slopes and the Karapara and Parambikulam rivers of the Chalakudy watershed in the south west.

The metamorphic Charnockites are the major rock type with intrusion of granites in the north and north eastern portion of the plateau. Higher level of soil taxonomy shows two types of soil associations in the study area such as Inceptisols and Ultisols. An early stage of soil profile development is represented by Inceptisols and they are further classified in to humic subgroups. They are relatively rich in organic matter. Mature stages are Ultisols and they are also further classified into the suborder of humults. The presence of soil moisture throughout the year by higher rainfall and warmer conditions leads to the development of humults and further into typic subgroups. The soil types found in the study area are of a) Typic Palehumults – Haplohumults, b) Typic Palehumults associated with rocks are very deep, well drained clayey soils with moderate erosion, c) Typic Haplohumults and Oxic Dystrudepts characterized by very deep well drained clayey soils with moderate erosion and gravely loam soils on gentle slopes, d) Oxic Dystrudepts associated with rocks are deep and well drained soils with severe erosion and e) Humic Dystrudepts –

Typic Palehumults are very deep well drained gravely loam soils with moderate erosion (Ramesh *et al.*, 2007a)

2.4 Rainfall and Temperature

Rainfall data were collected from over 27 stations in the study area from different sources. Interpolation was done using Kriging and 200 mm interval isohyets were drawn for the Annual average rainfall (Plate VI). An east west gradient is seen with the rainfall gradually increases while moving to west. The eastern side of the Parambikulam basin is a rain shadow region due to the presence of high ridges and uplifted surfaces of the Nelliampathy plateau and Sholayar that blocks the trade winds. Starting from 1200mm average rainfall in the Sungam area that borders with Tamil Nadu, the gradient gently increases and reaches a maximum of 3200 and above in the Karapara catchment area in the Western portion of the contemporary Nelliampathy range and Alathur forests.

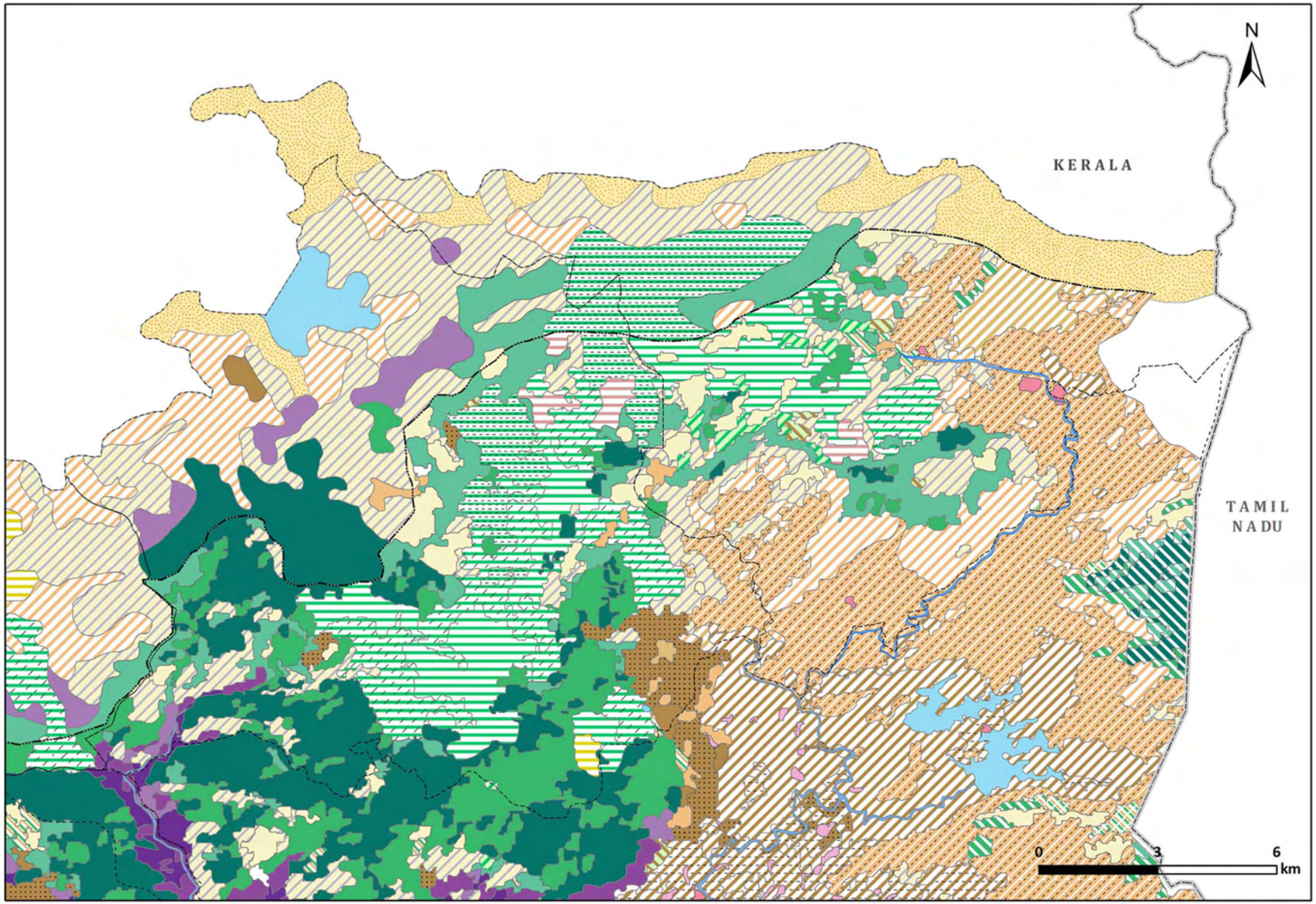
Temperature map is extracted from the bioclimatic maps published for the southern Western Ghats (Pascal, 1982). According to the classification followed in that map, Nelliampathies falls in the *Allepey-Mangalore* thermic and rainfall regimes. The classification is based on the difference between the mean temperatures of the hottest and coldest months. This thermic regime is characterized by the low mean temperature during the peak monsoon season of the month July. Two different temperature gradients are found in the study region. First one fairly matches with the uplifted plateau above 700 m altitude which the mean temperature of the coldest month is above 15° but below 23° Celsius. The second one is the region which has the mean temperature of the coldest month is above 23° Celsius where the denudation hills of the low category found in the northern slopes of the escarpment and Parambikulam basin. The denudation hills of the high category of the hydro geomorphology map exactly coincides with the medium temperature and high rainfall gradients conducive for the process of denudation by weathering.

2.5 Forests and Land use

A recent forest type map published by Ramesh *et al.*, 2007 for the western Anamalais landscape unit at the scale of 1:75,000 and the Forest Map of South India (Ramesh *et al.*, 2002) were used to combine the land use map of the region (Plate

VII). The vegetation is broadly divided into four types with respect to the bioclimatic features such as rainfall and temperature. They are the low elevation wet evergreen forests which occurs below 700m elevation with the mean temperature of the coldest month is above 23° C and rainfall over 2000mm. The second type is the medium elevation wet evergreen forests found in between 700 to 1500 m elevation where the mean temperature of the coldest month is between 16° to 23° C with the rainfall exceeding above 2000mm per year. The forests found above 1500 m elevation with the same bioclimatic occurring are the dry fringe evergreen forests of various compositions. Moist deciduous forests occurs in lower elevations (below 700m) where the rainfall is between 1500 to 2000mm. Dense and disturbed forms are classified for the evergreen forms and bamboo mixed woodland and savannah woodland were found in between the moist deciduous forests. As the bioclimatic map suggests (Plate VI), the major medium elevation wet evergreen forests of *Cullenia-Mesua-Pallaquim* is found in the plateau and adjacent regions whereas the low elevation evergreen forest are restricted to the lower elevation of the Karapara River.

Most of the climax wet evergreen forests were converted in to commercial plantations of tea, coffee and cardamom. The north eastern part of the plateau has the tea plantations and the coffee and cardamom plantations are abundant in the south western part where the rainfall is excess and the number of dry months are relatively low (2-4 dry months per year). This is the area where the mosaic of evergreen, coffee and cardamom plantations, disturbed forests and thickets and open areas were found. The forest management history discussed earlier in the introduction showed the different phases in the depletion of the forests of Nelliampathy. The first scientific study on the selection felling practice in the plateau was by Balasubramanyan in the year 1987. The species vital for survival of arboreal mammals such as *Cullenia exarillata* and *Pallaquim ellipticum* constituted over 98.5% of the total felling. Logging damages and the change in the microclimatic conditions were studied in detail. Regeneration and establishment of primary species in the selection felled gaps showed poor regeneration for *Pallaquim* and *Cullenia* and the repeated disturbances levels may be predicted to change the forest structure (Chandrasekara and Ramakrishnan, 1993). Several endemic species earlier recorded from this landscape are becoming rare and facing local extinction (Ramesh *et al.,* 2007b).



Source: Ramesh *et al.*, 2007

Landuse of Nelliampathies (Legend overleaf)

Legend for Landuse Types (Classification based on French Institute of Pondicherry)

The present forest cover map (Ramesh and Gurukkal, 2007) shows that the medium elevation *Cullenia* forests stretching from Karapara to Pulikkal stream has more fragments distributed to the north and south of the Karapara river. The extent of different land cover types of Nelliampathy and Kollengode Forest Ranges is given in the Table 2.2. The cardamom and coffee plantations of various disturbance levels keeps the canopy connectivity in the south western side of the plateau. Increasing disturbance and anthropogenic pressure may permanently fragment and isolate these two patches.

Table 2.2: Extent of different land-cover types in the study area of Nelliampathies

	Land cover	**Area (km^2)[§]**
Evergreen	Low elevation dense	2.68
	Low elevation disturbed	0.50
	Medium elevation dense	51.48
	Medium elevation disturbed	18.58
	Semi evergreen	3.49
	Dry friage	10.13
	Dry fringe	0.32
	Evergreen woodland	1.76
Moist Deciduous	Deciduous dense	2.35
	Savannah woodland	22.93
	Bamboo	13.08
	Bamboo woodland	32.28
	Deciduous reeds	0.60
Plantations	Cardamom	20.85
	Coffee with cardamom	19.20
	Tea	19.13
	Rubber	0.51
	Other	3.69
	Home gardens	0.34
Others	Grassland and rocky outcrops	27.08
	Thickets and open areas	55.99
	Water	1.66
	Total	**308.63**

[§] Ramesh *et al*., 2007

3. Methods

Localized field studies in biology provide valuable information in a hitherto little explored landscape. Systematic surveys recording the distribution, abundance and population structure of animal communities forms the baseline in the understanding of the status of existing populations. Knowledge about the isolated populations and the effects of habitat loss and fragmentation, population regulation through differential survival rates of metapopulations resulting from increasing predator and anthropogenic pressures enables to assess the prioritizing of site specific conservation measures. Since the ultimate goal of ecology is in understanding the species distributions (MacArthur, 1972), the study of the patterns of diversity in "different backgrounds" and from lesser known geographies has the potential in gathering evidences which could verify the existing principles and develop the generalities with accurate logic, the main prerequisite for science.

The first ever information on the wild animals of Nelliampathies starts with the account written by Lieutenant A. P. Kinloch on larger mammals in the year 1923. He has listed about 25 species of which seven were arboreal mammals. The lion-tailed macaque (LTM) was noted as a rare animal compromising smaller groups found only in the evergreen forest while the bonnet macaques (BM) were seen avoiding dense evergreen forests and frequent more in the northern cliffs and southern bamboo forests. The common langur was described as a very rare animal found occasionally in the northern cliffs whereas the Nilgiri langur (NL) was lamented over the "inordinate fond" attached with the flesh for its alleged medicinal purpose by the tribes and local plantation workers. According to the author an otherwise common species famed for its whooping calls declined drastically over a ten years. The other species are the Nilgiri marten, Flying squirrel and Malabar Giant squirrel (MGS) where the record of the first species is the range extension apart from the type localities in Nilgiris and Coorg at that period. The Bombay Natural History Society's mammal survey report for the Nelliampathy plateau (Lindsay, 1926) has some additions to Kinloch with the collection of some species of bats and rats. Apart from that no information on the mammalian fauna is available in the published literature until the state distribution

and status on lion-tailed macaque was published (Easa *et al.*, 1997). Three troops were reported from Nelliampathies with the total number of individuals being only five. In between a troop of lion-tailed macaques in the north-eastern part was known to raid a state owned orange farm in the earlier 1970s (*Pers Comm.*). Since the present objective is aimed at studying the distribution, status and population structure of arboreal mammals a variety of methods were employed and are discussed below.

3.1 Status, distribution and population structure

The distribution and population structure of the arboreal mammals were studied between the fall 2004 to 2007. Only the Nelliampathy and Kollengode ranges and the private plantations found in the plateau are included and thus comprising a total area of 383.22 square kilometers (plantations added with the total administrative areas of both the Forest Ranges). The various methods employed are a) sweep surveys, b) distance sampling by transect surveys, c) group follows with the aid of Global Positioning Systems (GPS) and d) Geographical Information System (GIS) based ecological niche modelling.

3.1.1 Sweep surveys

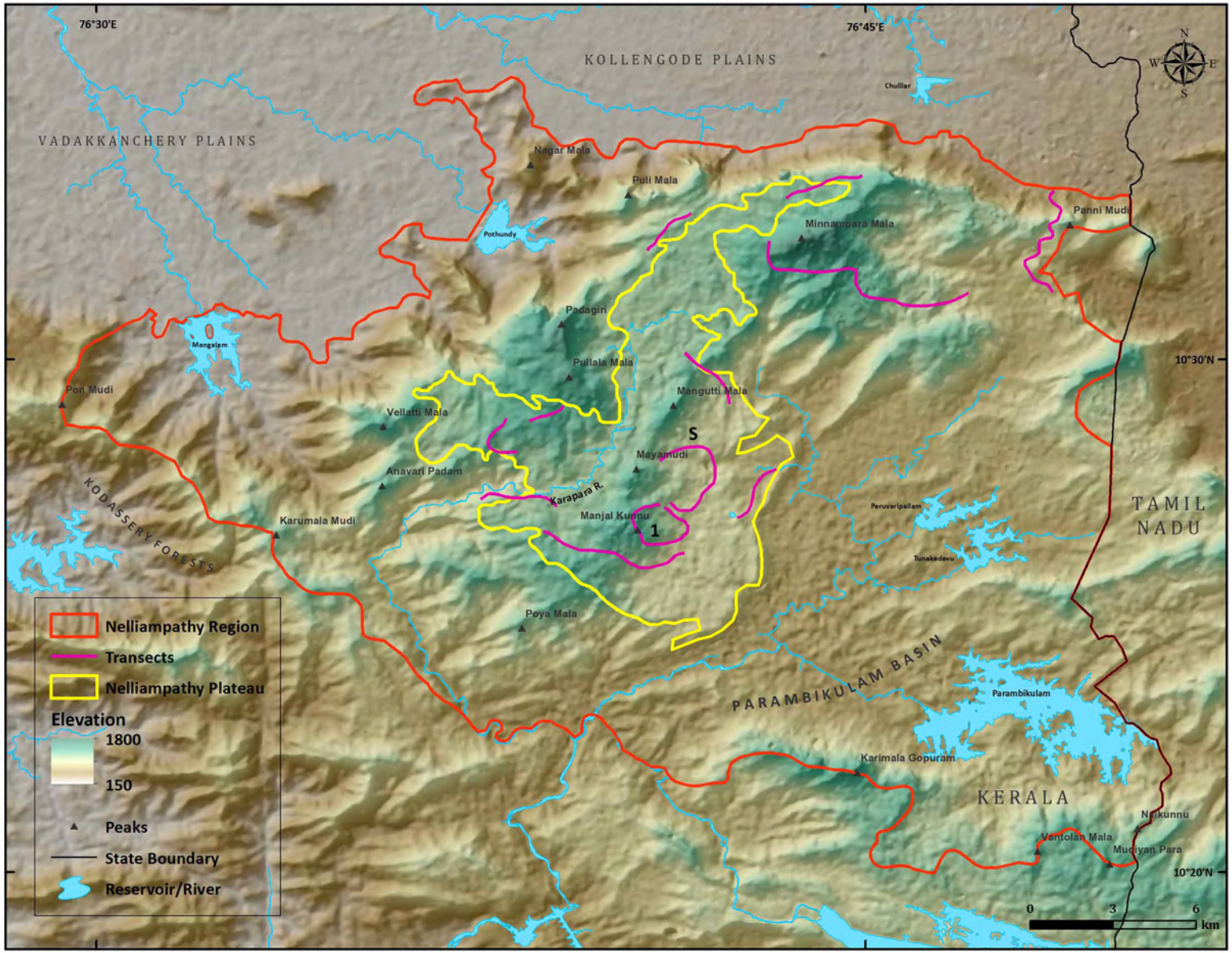
Repeated walk and observation in the same region for a few times in the initial explorative period for few months were taken as sweep surveys. However, to get a total count in a given region (NRC, 1981), sweep survey assumes to scan the whole area by one or multiple observers in a systematic fashion (Whitesides *et al.*, 1988). Though not followed strictly, in this study sweep surveys were applied between the fall 2004 to rise 2005 to get baseline information on the distribution of arboreal mammals and assess the forest types and habitat conditions. GPS was used to record the animal/troop positions. Possible areas were covered using existing trails, forest roads and trek paths. The information generated was later used in laying transects for distance sampling and in selection of troops for group follows for behavior observations and total counts.

3.1.2 Distance sampling by transect surveys

Two dimensional line-transect is the widely used method in quantifying the population density of living animals (Buckland *et al.*, 2001). Natural resource

management requires precise knowledge about the distribution and abundance of flora and fauna. Because of the mobile characteristic of the fauna, it is tricky to get accurate estimates of the population in the given space over time. Several methods have been tried so far and the efficiency depends on the robustness of the method and the estimation procedures (Buckland *et al.,* 2001). The method tried here is the distance sampling of arboreal animals through transects surveys. Four important implications lies behind the quantification of wild animals as the counting forms the baseline data which is to be monitored over years, the identifications of species rich areas for conservation, comparing the changes through time and space and allows to track the changes in the trends of populations over years (Plumptre and Cox, 2006). Supposedly the efficient method in estimating the density and abundance of forested species, line transect method is commonly applied for tree living animals in the tropical forests (Defler and Pintor, 1987; Skorupa, 1987; Whitesides *et al*., 1988; Umapathy and Kumar, 2000) and because of the accurate estimates it give, there is an increase with application of this methodology in the recent years for arboreal animals especially the primate species of the Africa and South America (De Thoisy, 2000; Fashing and Cords, 2000; Chiarello and De Mello, 2001; Martins, 2005; Palacios and Peres 2005; Plumptre and Cox, 2006; Marshall *et al*., 2008; Waltert *et al.,* 2008). There was no systematic study available on the distance sampling application with transect surveys for the arboreal mammals in India. It is the first time in this study that a series of transects were laid and censuses were taken repeatedly (pseudo replications) to obtain the density estimation of arboreal mammals in the study area at Nelliampathy Forests.

Fifteen transects were selected and laid (Table 3.1) in the middle of year 2005 based on the sweep surveys and all of them were mapped (Plate VIII). Transects were curvilinear and care was taken to avoid following stream courses, ridges, roads and placed in a fashion of sectioning through the gradient wherever it was possible.



Transects: Location of the transects in Nelliampathies with two pseudoreplicates 1 and s

Table 3.1 Transect surveys - sampling effort

Sl. No.	Transect ID	Length (km)	Samples (N)	Total length (km)
1	1	12	28	336
2	S	12	16	192
3	2	9	1	9
4	3	22	1	22
5	4	12	1	12
6	5	20	1	20
7	6	10	1	10
8	7	9	2	18
9	KP	4	1	4
10	MANJ1	16	1	16
11	MANJA	12	1	12
12	RP	12	1	12
13	S2	12	3	36
14	T1	6	1	6
15	K1	6	1	6
Total		**174**	**60**	**711**

All transects were laid in the evergreen forests. Transect lengths varied from 4 to 22 km and two transects, with the identity 1 and S were selected for pseudo replication. Repeated censuses were done for 28 and 16 times respectively. Surveys were done in the forenoon and the radial distances of the sighted animals and the angle sighted were measured visually. The total length of transects covered during the 2005 to 2007 was 711 kilometers.

There are three assumptions in transects surveys. They are

a) g(0)=1, the probability of detecting an individual or a group in the line is equal to one i.e., no animals were missed in the line

b) objects were detected at their initial positions and

c) distances were measured accurately and animals were counted correctly.

All the above analyses were done in Microsoft Excel and DISTANCE 5 softwares. The total geographic area of the Nelliampathy and Kollengode ranges as defined earlier was included in the original computations and no attempt was done at estimating the total number of arboreal mammals present in the entire study site.

3.1.3 GPS aided group follows

The troops of diurnal primate species were monitored over two years and their respective sleeping sites were marked and a continuous record was maintained. Feeding, ranging and other behaviour observations were done for the lion-tailed macaque in the Pakuthipalam area. The troop movement routes were tracked with GPS. Total counts were done for the troops of lion-tailed macaque and Nilgiri langur. Age sex categories were followed from Poirier (1969) for Nilgiri langur and Joseph and Ramachandran (2003) for lion-tailed macaque with the following modifications. The adult females are further classified into single and cradling individuals. All the cradling infants are categorized separately. The sub adults of lion-tailed macaques are further classified into males and females.

3.1.4 GIS based ecological niche modeling

The study of niche differentiation and the use of spatially explicit distribution models advance the understanding of the distribution of animals in space. The complexity of the real world necessitates development of models towards the understanding of the ecological realism in a dynamic landscape when the distribution and abundance of a species is unknown or ubiquitous. Several rare and endangered species remains elusive and the quantified information is scanty. Pseudo replications are costlier in areas where the logistics are near impossible. Habitat models are the replicas of original phenomena explicit in space to face this uncertainty. Biodiversity loss and species extinctions have forced the natural resource management to find alternative, cost effective and robust methodologies to understand the functional ecosystems and landscapes by a variety of means.

The improvement of the Geographical Information Systems (GIS) and the integration of the mathematical computing into the GIS platforms enabled the opening of new frontiers in spatial statistics. Multivariate statistics can now be applied with a spatial context in linking the species and its habitat. The general principle behind the

habitat suitability models is in visualizing the probable distributional space. The dependant variable is the information about the occurrence of the species in question and the independent variables are the digital maps explaining the eco-geographical characteristics of the defined space. A function is established between the two and expressed in the conventional form dependent on the nature of the statistical analysis. For a detailed review of habitat suitability models see Guisan and Zimmermann (2000). The potentiality of creating a common working framework which enables the interaction and enhances the integration while planning and allocation of conservation efforts between the land managers and wildlife biologists/ecologists through a visual media is the main dogma of the spatially explicit models (Turner *et al.,* 1995).

The distribution ecology of most of the arboreal mammals in the Western Ghats is less studied or unknown. For example, the lion-tailed macaque *Macaca silenus* is one of the most endangered primates of India endemic to the southern Western Ghats. The total population in the wild is estimated to be less than 4000 individuals distributed in the states of Kerala, Tamil Nadu and Karnataka. Being habitat specialists, they are much restricted to the moist forests and it is believed that the population consists of less than 50 subpopulations isolated to the eight major rainforest patches in the Western Ghats (Molur, *et al.,* 2003). Though detailed studies are available on the ecology and behaviour of this species (Green and Minkowski, 1977; Karanth, 1985; Kumar *et al.,* 1995; Kurup, 1978; Ramachandran and Joseph, 2001; Singh *et al.*, 1997a, b, 2000, 2002; Sugiyama, 1968) overall information on the distribution at the landscape level is either not available or scanty. The scenario in Kerala is interesting as in the modern times developmental activities like commercial plantations of tea and coffee, hydro-electric dams has resulted in the habitat loss and fragmentation of the once contiguous forests which directly affected the meta-population dynamics of the lion-tailed macaques. The effect of the fragmentation is crucial to the survival of the LTMs and very few studies exist (Krishnamurthy and Kiester, 1998; Umapathy and Kumar, 2000).

3.1.4.1 Theoretical background: ENFA

Ecological Niche Factor Analysis (ENFA) is a model that computes the habitat suitability maps through a multivariate approach without the absence data. It is based on the factorial analysis that compares the distribution of the localities of the

focal species observed to the reference set describing the multidimensional space of ecological variables in the area of interest (Hirzel *et al.,* 2002a).

It is the extension of the Hutchinson's concept of the ecological niche as a hyper volume in the multi dimensional space of ecological variables within which a species can maintain a viable population. For example if there are two environmental variables x_1 and x_2 which has the values $x_1^{'}$, $x_1^{''}$ and $x_2^{'}$, $x_2^{''}$ limiting factors for permitting a species S_1 to survive. N_1 is defined as the limiting factors of x till x_n in which every point in the environment permits the species S_1 to exist indefinitely, which is the fundamental niche (N_1). The fundamental niche is an abstraction of the ecological niche and the variables x_n can be both physical and biological. So it is the set of points in an abstract n-dimensional space (Hutchinson, 1957).

In Ecological Niche Factor Analysis, the independent variables are the spatially defined eco-geographical variables (EGVs) that quantitatively describe the ecological features. The distribution of the EGVs for the whole study area is the global distribution (G_s) and the distribution for the localities where there is the proof for the species presence is the species distribution (S_s) (Fig. 1).

There are two key measurements that quantify the fundamental niche of the focal species. They are the marginality and specialization. Under the concept of Hutchinson's fundamental niche a species is expected to be non-randomly distributed in relation to all habitat variables. That is a species with an optimum value for a particular variable, for example temperature, is expected to occur within its optimal range. So the species niche is the subset of the global environment. The distribution of species locations along the habitat variables may differ from the entire study area (i.e. the set of EGVs differs from the global set) in terms of the mean (marginality) and variance (specialization).

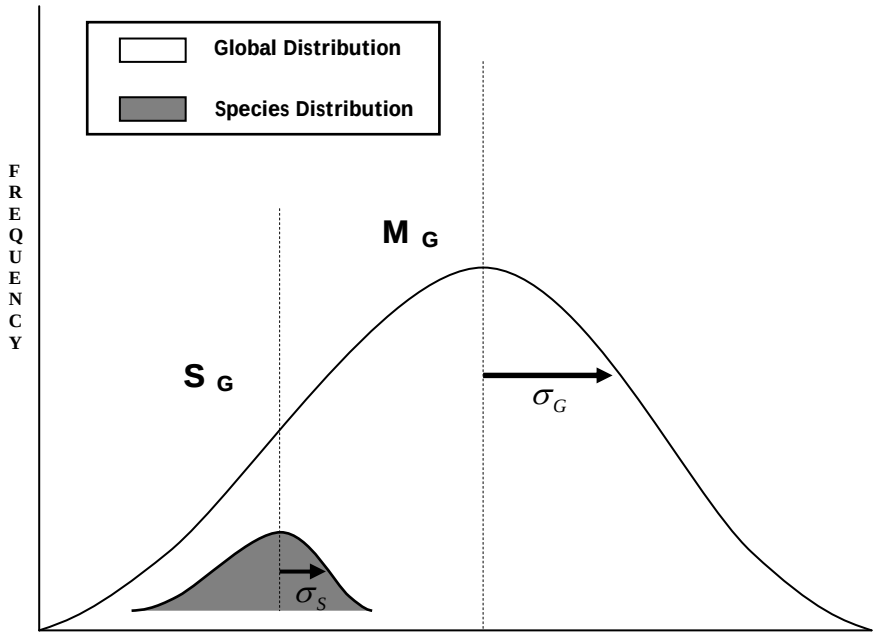


Fig. 1 Global and species distributions

So the ecological niche referred here is the subset of cells in the eco-geographical space where the species in question has a probability to occur. The multivariate niche can be quantified on any of the axes by an index of the marginality and specialization. It is because the ecological factors are not independent and exhibits spatial autocorrelation, factor analysis is employed to transform the *V* correlated variables to uncorrelated factors. These factors explain the amount of variance though the subsequent analysis may restrict to the important factors.

e) Implementation

Ecological Niche Factor Analysis (ENFA) is implemented in the software Biomapper (http://www2.uni.ch/biomapper) developed at the University of Laussane, Switzerland (Hirzel *et al.*, 2002a). Biomapper works in the GIS-environment of *Idrisi* using the same file structure with an extension of *.rst* raster files. The basic input is the dependent variable in the form of a Boolean map with presence information in the defined space. It can be refined through the collection of the geographic coordinates from the published distribution accounts, field studies, databases, and geo-referencing of museum specimens. In this study the distributional records of the four arboreal mammals – Malabar giant squirrel, lion-tailed macaque, Nilgiri langur and Nilgiri

marten were obtained from various field methodologies such as sweep and transect surveys, group follows and opportunistic sightings. For the two primate species the epicenter of the troop home ranges or the sleeping sites were taken as the presence point instead of taking all the available distributional points. This may restrict the modeling algorithm in generalization and overfitting by filtering the available presence points and reduce the spatial autocorrelation to some extend. The habitat suitability model built in this case represents the available potential habitat for the troops instead of individual animals. So the lion-tailed macaque has thirteen and Nilgiri langur has twenty three presence points overall in corresponding to the totally recorded thirteen and twenty three troops respectively. Malabar giant squirrels have a total of sixty six spatially unique presence points and Nilgiri martens have only four. The other independent variables are the derived ecological variables in the form of digital eco-geographical maps. The part of the Kollengode and Nelliampathy ranges of the Nelliampathies was chosen as the reference area and modelled. Topographical data, land cover, hydrography, bio-climate and other variables were derived from the various sources (Table 3.2) and are organized in GIS in the preparation of the eco-geographical raster maps. Then the analysis was performed and the suitability map has been produced and cross validated with in built validation procedures using the continuous Boyce index (Boyce *et al*., 2002).

Post processing is done by altitudinal zone wise classification of modelled surfaces to explore the extent of the predicted areas and the level of predictions in different intervals. It was calculated by clipping the predicted data into three distinct categories a) low elevation zone (from the average foothill elevation till 800m MSL), b) medium elevation zone (800m to 1400m above MSL) and high elevation zone (above 1400m MSL). Corresponding attribute values for each category for the four species were compared. Similar reclassifications were done for the Plateau Major versus Plateau Minor representing the Nelliampathy plateau and rest of the down slopes, and according to the forest types of the southern Western Ghats based on the maps published by the French Institute of Pondicherry (Ramesh *et al.*, 2002 and 2007) and the results were compared.

Table 3.2 Types and sources of data used in modelling

Data type	Eco-geographic variable	Source
Topography		
Elevation and related variables	Dem- low, medium and high elevations, Slope & Aspect	SRTM 90m Digital Elevation data – Update Version 4. CGIAR Consortium for Spatial Information http://srtm.csi.cgiar.org/
Climate	Annual average rainfall	Interpolated surface from field collection of rainfall data from plantations, government farms and weather stations
Remote Sensing		
Land-use/land-cover	Vegetation type map	French Institute of India's forest type maps for Western Anamalais and Coimbatore-Trichur region http://www.ifpindia.org/cartoweb3/htdocs/southIndia_map_5.php
Soil	Soil type map	FAO/UNESCO Digital Soil Map of the World and derived soil properties http://www.fao.org/ag/agl/lwdms.stm
Derived eco-geographic variables	Distances to road, habitation, river and Fractal dimension of vegetation	Survey of India topographic sheets

3.1.5 Methods followed for behavior observations

Continuous *ad libitum* sampling (Altmann, 1974) was employed in gathering information on the food and feeding behavior of the lion-tailed macaques (LTM) and Nilgiri langurs (NL). The troops of the two species were followed together and separately wherever possible in the intensive study area from dawn to dusk. Other opportunistic observations were also noted. The information gathered were the plant species eaten, the part consumed, the amount of time spent on each resource and the individual of the species during each observation. All the plants were identified up to the species level and the identity of the plant species were confirmed later in the lab through the collection of plant parts (leaves, fruits, seeds and flowers). The abundance

of the major food species in the study area were taken from previous studies (Balasubrananian, 1987, Chandrasekara, 1991; Ramachandran, 2009) for comparison.

3.1.5.1 Diet diversity and overlap analysis

Niche breadth was calculated using Levin's measure (Krebs, 1989) in estimating the diet diversity of the two species. Five resource parts were recognized viz. fruit, flower, leaf, seed and other (includes animal matter). Levin's index estimates the niche breadth by measuring the uniformity of the distribution of individuals among the resource states. The formula is

$$B = 1/EP_j^2$$

which can be written as

$$B = Y^2/EN^2_j$$

where B is the Levin's measure of niche breadth, P_j is the proportion of individuals found in or using resource state *j*, or fraction of items in the diet that are of food category *j* (estimated by N_j/Y & $E\ P_j = 1.0$), N_j is the number of individuals found in or using resource state *j* and Y is the total number of animals sampled ($E\ N_j$).

Niche overlap between the two species was calculated using Morisita's measure which is an index of similarity which can be used as a measure of overlap as well. It is calculated from the formula

$$C = \frac{2\sum P_{ij}\ P_{ik}}{\sum^n P_{ij}\left[\left(n_{ij}-1\right)/\left(N_j-1\right)\right] + \sum^n P_{ik}\left[\left(n_{ik}-1\right)/\left(N_k-1\right)\right]}$$

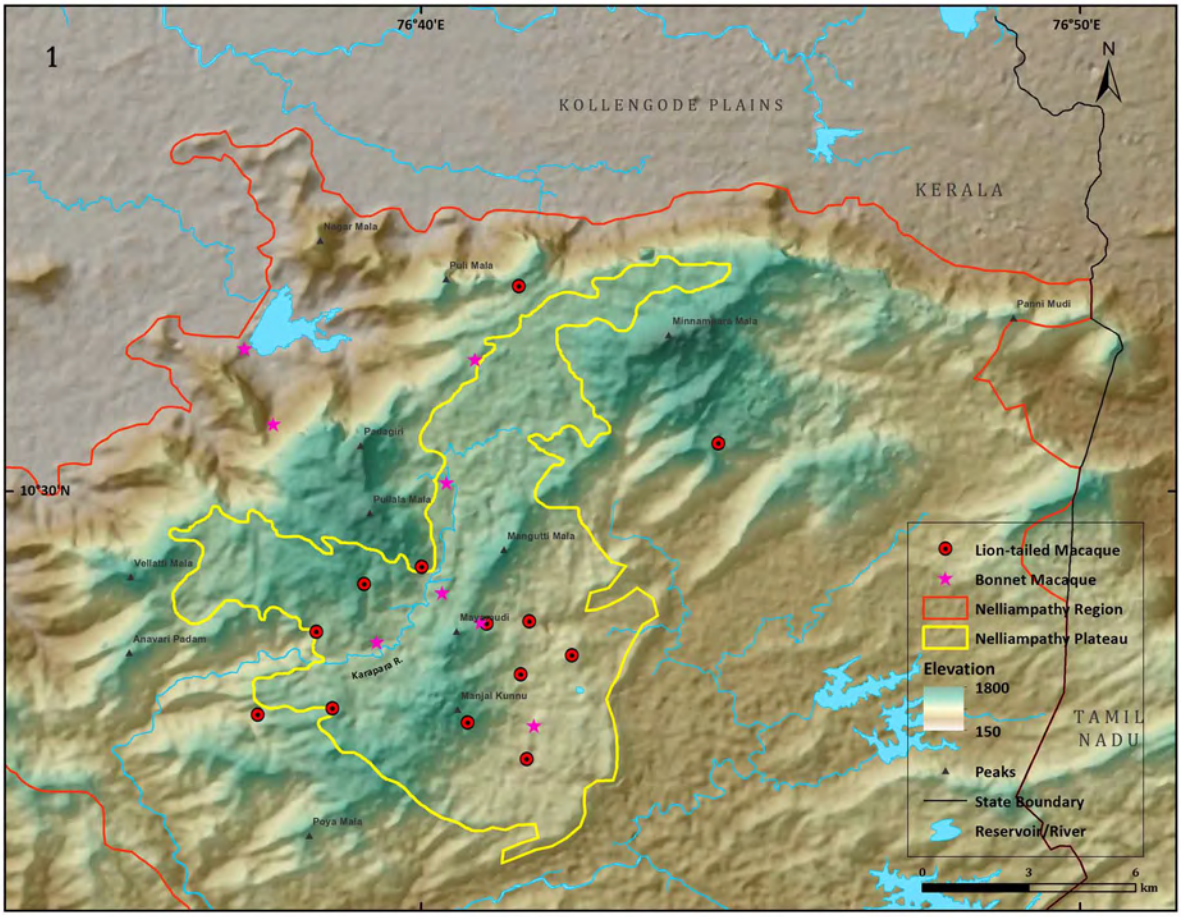
where C is the Morisita's index of niche overlap between species *j* and *k*, P_{ij} is proportion resource *i* is of the total resource used by species *j*, P_{ik} is proportion resource *i* is of the total resources used by species *k*, n_{ij} is the number of individuals of species *j* that use resource category *I*, n_{ik} is the number of individuals of species *k* that use resource category *I* and N_j & N_k are the total number of individuals of each species in sample.

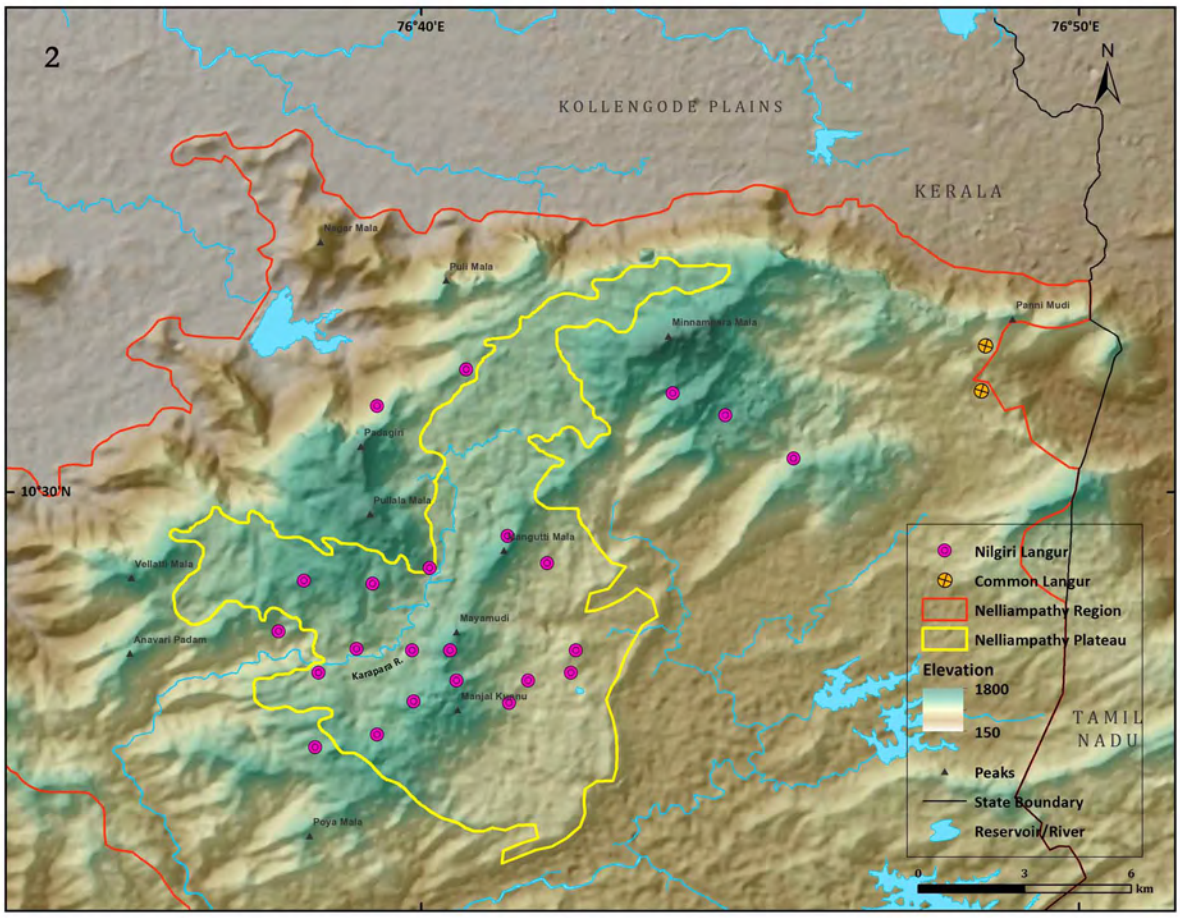
Only one observer was present in the data collection and the study period was between the fall of 2004 and 2007.

4. Results and Discussion

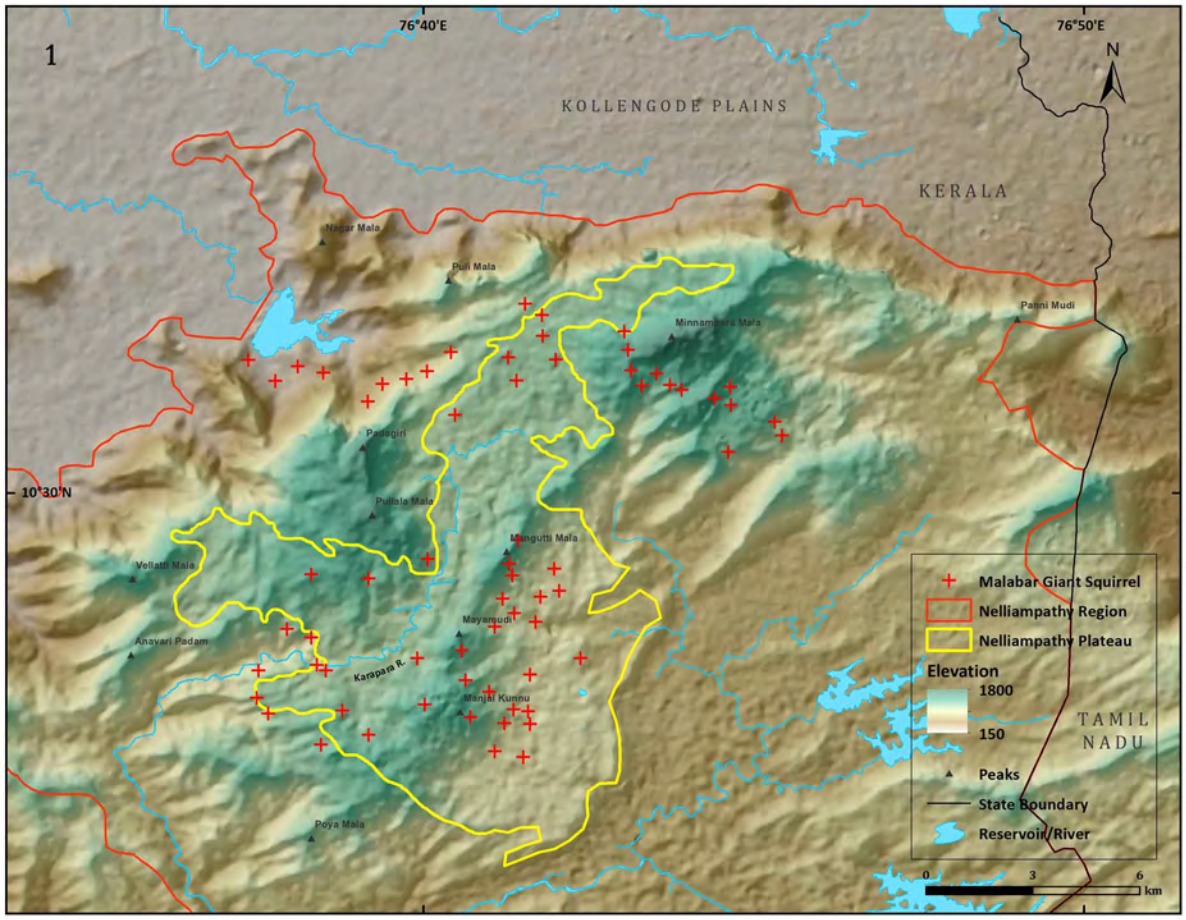
A total of eleven arboreal mammals were recorded from the evergreen forests of the Nelliampathies (Table 4.1) by the sweep surveys, line transects and GPS aided group follow methodologies. There are two additions to the overall arboreal mammalian fauna of the Nelliampathies. The Malabar slender loris *Loris lydekkerianus malabaricus* and the Malabar spiny tree mouse *Platocanthomys lasiurus* were recorded for the first time in the evergreen forests of the plateau. The rare and endemic Nilgiri marten *Martes gwatkinsii* was sighted from four different localities. Next to the type specimens from Nilgiris and Coorg, the third known distribution locality of Nilgiri marten south of Palghat gap until the middle of the last century is from Nelliampathies (Kinloch, 1923). Thirteen troops of lion-tailed macaques and twenty three troops of Nilgiri langurs were recorded and mapped in the evergreen forests of Nelliampathies (Plate IX). Bonnet macaques are often found in the plantations and in the fringes of the evergreen forests as habituated troops and seldom they were seen deep inside the forest. Throughout the study period only one, comparatively shy troop of bonnet macaques was seen in the evergreen forests of Manjalkunnu-Pulickal stretch. The Malabar giant squirrel *Ratufa indica* and the jungle striped squirrel *Funambulus tristriatus wroughtonii* were sighted almost throughout the plateau. The dusky striped squirrel *Funambulus sublineatus sublineatus* was recorded from only one locality in the evergreen forests of Manjalkunnu–Pulickal area. All the troop locations and individual sightings were mapped (Plates IX and X)

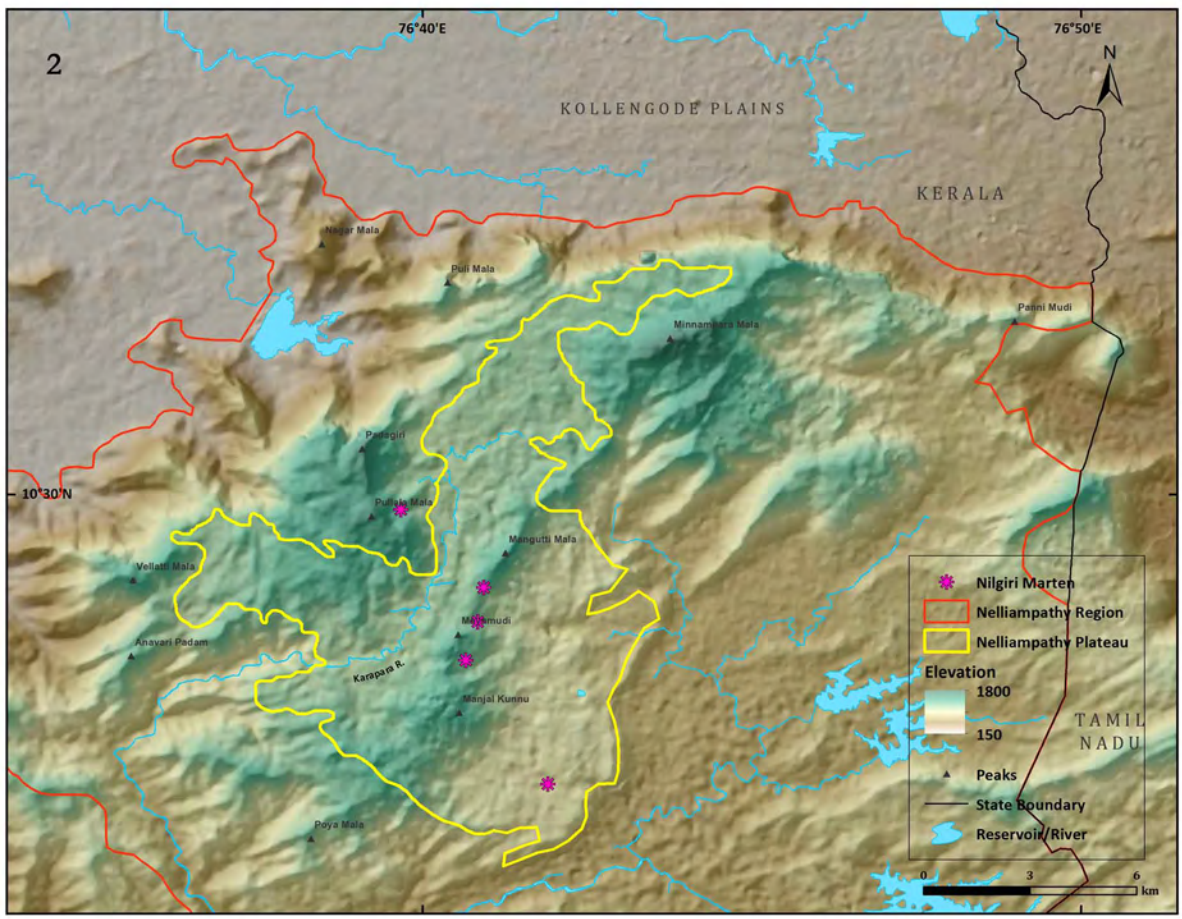
However, the common langur or the Coromandel grey langur *Semnopithecus priam priam* was not recorded in the plateau during the study period from 2004 to 2007. Earlier it was recorded from only one locality in the northern slopes of the Nelliampathy rim. Noted as a “decidedly rare, a very occasional troop” of few individuals roughly found in tens, the common langurs are last seen in the first two decades of the last century (Kinloch, 1923). It was seldom spotted in the evergreen forests and the local tribes were reported eating the meat of this species though not valuing it as of the Nilgiri langur. In the present study two small common langur troops were seen in the Mudivai area of Kollengode range. The total number of





Distribution of primates in Nelliampathy plateau: Troop locations of 1) Lion-tailed macaques and Bonnet macaques and 2) Nilgiri langurs and Common langurs.





Distribution of other arboreal mammals : 1) Malabar Giant Squirrel and 2) Nilgiri Marten

Table 4.1 List of the arboreal mammals of Nelliampathies

No.	Family	Scientific Name	Common Name	Endemism	Previous Studies[§]	Present Study
1	Cercopithecidae	*Macaca silenus* (Linnaeus, 1758)	Lion tailed macaque	Western Ghats	+	+
2	Cercopithecidae	*Macaca radiata diluta* (Pocock, 1931)	Pale bellied bonnet macaque	South India	+	+
3	Cercopithecidae	*Semnopithecus johnii johnii* (Fischer, 1829)	South Indian leaf-monkey	Western Ghats	+	+
4	Cercopithecidae	*Semnopithecus priam priam* (Blyth, 1844)	Coromandel grey langur	South India	+	+
5	Lorisidae	*Loris lydekkerianus malabaricus* (Wroughton, 1917)	Malabar slender loris	Western Ghats	-	+
6	Mustelidae	*Martes gwatkinsii* (Horsfield, 1851)	Nilgiri Marten	Western Ghats	+	+
7	Sciuridae	*Ratufa indica indica* (Schreber, 1851)	Indian giant squirrel	India	+	+
8	Sciuridae	*Funambulus tristriatus wroughtoni* (Ryley, 1913)	Jungle striped squirrel	Western Ghats	+	+
9	Sciuridae	*Funambulus sublineatus sublineatus* (Waterhouse, 1838)	Dusky striped squirrel	South India & Sri Lanka	+	+
10	Pteromyidae	*Petaurista petaurista philippensis* (Elliot, 1839)	Large brown flying squirrel	South Asia	+	+
11	Muridae	*Platocanthomys lasiurus* (Blyth, 1859)	Malabar spiny tree mouse	Western Ghats	-	+

[§]Kinloch, 1923 and Lindsay, 1926; + Recorded, - Not recorded

animals sighted was 3 and 2 respectively. The vegetation is of bamboo mixed woodland – moist and dry deciduous types.

The rapid and sweep surveys throughout the Nelliampathies, systematic line transect surveys in the evergreen forests covering a cumulative distance of 705 kilometers and the group follow observations of more than 300 hours in the evergreen forests of the plateau failed to sight the common langurs. From this, it is possible to state that the common langur may be absent entirely in the plateau region of the Nelliampathies where the vegetation biotope is predominantly evergreen. However, the secluded distribution recorded by Lieutenant Kinloch came as an important observation following the taxonomic revision of Asian primates and subsequent splitting of the subspecies of common langurs (Brandon-Jones *et al.,* 2004). This particular subspecies *Semnopithecus priam* is known to inhabit the drier tracts of the Western Ghats and portions of Eastern Ghats. The other subspecies S*emnopithecus hypoleucos* and *Semnopithecus thersites* were wet zone counterparts present only in the north and south of Palghat gap on the western side of the Western Ghats. So the isolated population present in the northern fringe may be of an extension of the dry faunal elements of the deciduous woodland and drier savannah from the eastern side, i.e., the Anamalais of Tamil Nadu.

In the eastern part of the Anamalais of Indira Gandhi Wildlife Sanctuary, the common langur is known to occur in the deciduous, riparian forests and scrub jungles at a relatively lower altitude. The encounter rates are even low (0.55 individuals per kilometer for deciduous, 3.43/km for riparian and 0.65 for scrub) and has been seldom sighted in the evergreen forests. They are restricted to the elevation range of below 500 MSL having an encounter rate of 3.91 individuals/km compared to 0.18 individuals between 500 and 100 MSL, and they are never recorded above 1000 MSL (Ananda Kumar *et al.,* 2002). The other nocturnal arboreal mammals characteristic of the medium elevation wet evergreen forest – the Jerdon's palm civet *Paradoxurus jerdonii* and the small Travancore flying squirrel *Petinomys fuscocappilus* were not recorded during the present study. They were never recorded in the earlier studies of Kinloch and Lindsay. Careful night observations in several patches of evergreen forests proved futile. The anomalous absence of these arboreal animals in the Nelliampathies poses special biogeographical problems and stresses the need for an

integrated region level comparative study of species diversity and distribution which helps in the understanding of sub region level species turnover and local extinctions.

4.1 Abundance

The total number of sightings in all the sixty transects is given in the Table 4.2. The relative abundances of the diurnal arboreal mammals by line transect surveys ranged from 1.2 to 12.6 individuals/10 km. The mean group sizes ranges from 3.5 to 6.9 for the three species of primates (Table 4.3). Though all the arboreal mammals were represented in the line transect surveys, the four species giant squirrel, Nilgiri langur, lion-tailed and bonnet macaques alone had sufficient sightings to calculate the relative abundance (>10) and density (>40). Of all the sightings Nilgiri langur had the most number of records (over 55% of the total sightings) in all transects followed by lion-tailed macaque (27%) and Malabar giant squirrel (12%). Transects were divided spatially into Plateau Major (PM) and Plateau Minor (PM) in order to compare the local variation in the abundance. Following the earlier physical and geomorphologic characterization discussed in the study area part, the Plateau Proper represents the transects laid in the Nelliampathy plateau and the Plateau Minor, the region south of Mangutti Mala-Poya Mala ridge. Zone-wise individual abundances of giant squirrels, lion-tailed macaques and Nilgiri langurs were slightly higher in Plateau Minor when compared with Plateau Proper. The results (Fig. 2) are in accordance with the land use pattern of the Nelliampathy plateau where the effect of forest cover loss was felt a long time ago (Kinloch, 1923). The plateau which holds the major commercial plantations is severely fragmented and devoid of canopy. The remarkable fact is that the continuation of the declining trend in the abundance of arboreal fauna in the plateau is supported by the observed pattern.

Comparable estimates of abundance of arboreal mammals are available from the rainforest fragments of Anamalais and elsewhere. A study in the rainforest fragments of Anamalais showed that the Malabar giant squirrel is the most common species in occurrence (Umapathy and Kumar, 2000). Another study in Anamalais rainforest fragments (Ananda Kumar *et al*., 2002) that used the encounter rate per kilometer as the abundance, when compared with the present observations indicate that the major arboreal mammals in Nelliampathies are relatively less abundant than in Anamalais (Table. 4.2).

Table 4.2: Total number of sightings in Transect Surveys

No.	Transect ID	Samples	No. of sightings[§]					Total
			LTM	***NL***	***BM***	**CL**	***MGS***	
1	1	28	36 (228)	149 (534)	13 (54)	0	111	**309 (927)**
2	S	16	13 (94)	61 (200)	2 (7)	0	38	**114 (339)**
3	2	1	0	2 (4)	2 (10)	0	6	**10 (20)**
4	3	1	1 (5)	0	0	0	0	**1 (5)**
5	4	1	0	1 (6)	1 (10)	0	0	**2 (16)**
6	5	1	0	4 (32)	0	0	6	**10 (38)**
7	6	1	1 (3)	5 (16)	0	0	2	**8 (21)**
8	7	2	3 (16)	5 (8)	0	0	7	**15 (31)**
9	KP	1	2 (30)	0	0	0	0	**2 (30)**
10	MANJ1	1	2 (12)	5 (9)	1 (5)	0	4	**12 (30)**
11	MANJA	1	2 (13)	2 (5)	0	0	1	**5 (19)**
12	RP	1	0	8 (26)	0	0	6	**14 (32)**
13	S2	3	2 (16)	9 (44)	0	0	11	**22 (71)**
14	T1	1	1 (22)	3 (5)	0	0	2	**6 (29)**
15	K1	1	0	0	0	2(5)	0	**2(5)**
Total		**60**	**63 (439)**	**254 (889)**	**19 (86)**	**2(5)**	**194**	**532 (1613)**

[§]In the parentheses are the total no. of animals sighted; LTM- Lion-tailed macaque, NL – Nilgiri langur, BM – Bonnet Macaque, MGS- Malabar Giant Squirrel

This may be due the fact that the animals in highly fragmented and disturbed habitats have higher sighting probabilities than of those living in a relatively contiguous and undisturbed habitat. The southern slopes of Nelliampathy plateau or the Plateau Minor are relatively undisturbed at the canopy level. And the assumptions of the line transect methodology regarding the sighting of animals are in fact constraining the estimates of abundances to a greater extent when compared with the techniques with little or literally no assumptions like sweep surveys or visual sampling methods (but in contrast these are less rigorous in statistical terms).

TABLE 4.3 Overall relative abundance of diurnal arboreal mammals in Nelliampathies

Species	Individuals / 10 km	Mean troop size
Ratufa indica	2.7	-
Semnopithecus johnii	12.6	3.5
Macaca silenus	6.2	6.9
Macaca radiata	1.2	4.5

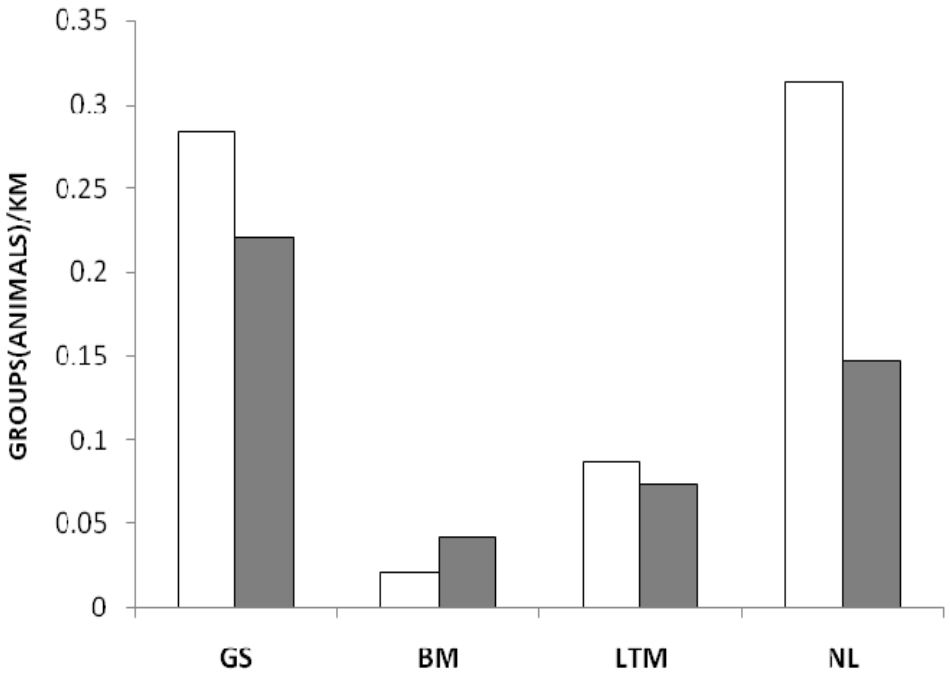


Fig. 2 Zone-wise relative abundace of major arboreal mammals, white bars Plateau Minor and grey bars Plateau Major (see the text for definitions)

Table 4.4 Abundance (sightings per km) of arboreal mammals in the Western Ghats

		LTM	BM	NL	MGS	Source[§]
Karnataka	Brahmagiri-Makut	0.004 -0.008	0.04 - 0.13	0.11	0.21	1
	Pushpagiri-Bisale	-	-	-	0.10	
	Sringeri	-	-	-	0.83	
	Sirsi-Honnavara	0.15 - 0.25	0.25 - 0.31	-	0.24	
	Nagarhole	-	-	-	0.34	
Kerala	**Nelliampathy**	**0.62**	**0.12**	**1.26**	**0.27**	**2**
Tamil Nadu	Anamalais	1.36	0.19	5.05	0.82	3

[§]1 Kumara and Singh, 2004, 2006; 2 Present study; 3 Ananda Kumar *et al*., 2002

4.2 Density of major arboreal mammals

Table 4.5 shows the results of the population densities of Nilgiri langur, lion-tailed macaque and Malabar giant squirrel. Half normal cosine model is applied in obtaining the estimates as they are found to be more robust in giving reliable results based on the Akaike Information Criteria and lower coefficient of variation in comparison with other modes such as hazard rate and normal distribution models. The Nilgiri langur appears to be the more abundant species in Nelliampathies with a density of 34.6 individuals km^{-2} followed by the lion-tailed macaque having the density of 20.5 individuals km^{-2}. The group density is also high for the Nilgiri langur in having 9.7 versus 2.37 troops km^{-2} of lion-tailed macaques. The Malabar giant squirrel is having the density of 4.3 individuals km^{-2}.

Table 4.5 Individual and group densities

Species		Estimate[§]	% CV	Confidence Interval	ESW	N
Semnopithecus	Group	9.7	8.51	8.2- 11.4	18.5	495
johnii	Individual	34.6	9.94	28.4- 42		
Macaca silenus	Group	2.37	21.1	1.5 - 3.6	18.7	60
	Individual	20.5	23	13- 32		
Ratufa indica	Individual	4.3	11.5	3.4- 5.4	21.3	129

[§]per square kilometer

The original data has got the sighting data up to 80m (Fig. 3) for the Nilgiri langur from the line, it has calculated the correction factor $\hat{f}(0)$ based on probability density function (pdf) of every sighting and reduced the strip width into 18.564 m which is called the Effective strip width (ESW). The calculations of abundances were based on the sightings falling within this effective width with reasonable probabilities to occur. Likewise the cutoff point or the ESW is calculated for lion-tailed macaque and Malabar giant squirrel were 18.7 and 21.3 m respectively.

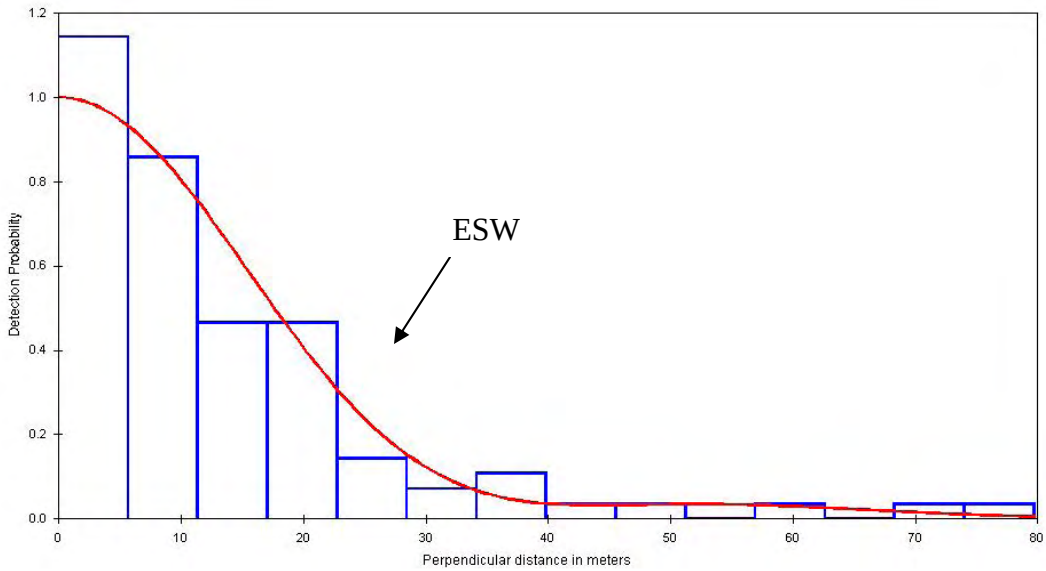


Fig. 3 Half-normal probability plot for Nilgiri langur

Only two studies were available for comparison which had adapted the line transect methodology and distance sampling application in estimating the density of arboreal mammals in the Western Ghats (Table 4.6). The first and earliest one using line transect method is on the primates of the Shendurney Wildlife Sanctuary of Kerala (Ramachandran, 1995). A total of 50.5 km were covered by transects and the population density of Nilgiri langurs was estimated to be of 7.5 troops km^{-2} with a mean troop size of 8.83. The individual animal density was 66 animals km^{-2}. In Nelliampathies, the mean troop size of the Nilgiri langur by similar total count method was 7 where as by line transect method it was only 3.5. The individual animal density was 34.6 animals km^{-2} which is the half of the density of Shendurney and troop density was 9.7 troops km^{-2}. The other study with the application of the line transect method was done on the arboreal mammals in the forest fragments of

Anamalais (Umapathy and Kumar, 2000). The density of the Malabar giant squirrel was estimated for each fragment with King's method. The values ranged from 11.4 to 64 squirrel agaisnt the 4.3 squirrels km^{-2} of Nelliampathies. Again like abundance, the density value is far greater for Anamalais than the Nelliampathies. This may be due to a couple of reasons. The first one is the forest fragments of Anamalais are of extreme sizes ranging from a mere one ha to over 2500 ha. The density was observed to increase with the decreasing fragment area. The second main reason behind the higher estimation is in the use of the King's method in the density calculations. King's method simplifies the estimation the effective strip width by only incorporating the mean sighted distance multiplied into the total length of the transects where as the correction factor applied in this study involves establishing a function of probability density estimation of each sighting (Equations 1.1 to 1.8 of the methods). By assuming the probability density function at zero distance i.e. on the line equals one, the parameter was estimated by applying half-normal distribution to the measured distances. By incorporating the unconditional probability of detecting objects through functions in the strip of transects for each species and the selection of best model based on the lower coefficient of variation and Akaike Information Criteria (AIC) subjects the estimation through a series of procedures. The density estimation hence obtained is robust and tends to give plausible figures which may indicate the real scenario.

Another study employs the total count method periodically done without employing the transect methodology in estimating the density of lion-tailed macaques (Singh *et al*., 2002). The forest fragments are divided into three groups based on their extent and the densities were ranging between 2 to 70. In the two larger fragments sizing about 25 and 30 km^2 respectively, a total of 249 animals were recorded present and the densities were calculated as 4 and 4.9 animals km^{-2}. An approximate total of around two hundred animals of lion-tailed macaques living in thirteen troops were counted in Nelliampathies by similar procedures (Table 4.7). The forests are of a mosaic in Nelliampathies compared to the explicit fragments found in Anamalais, the density calculation by similar procedures incorporating the total available geographic area of the given landscape or a fragment might give erroneous results.

Table 4.6 Population density comparison of arboreal mammals in the Western Ghats

	Lion-tailed macaque	Nilgiri langur	Malabar giant squirrel	Source[§]
Nelliampathy	20.5 (2.3)	34.6 (9.7)	4.3	1
Anamalais	2 - 70	-	11.4 - 64	2
Shendurney	-	66 (7.5)	-	3

[§]1 Present study; 2 Umapathy and Kumar, 2000, Singh *et al*., 2002; 3 Ramachandran, 1995; in the parentheses are group densities.

Table 4.7 Global population densities of primates

Region	Country	Site	ID	GD	Sps	Source[§]
Tropical Africa	Uganda	Kibale	-	1.1 – 25.5	5	1
	Kenya	Kakamega	-	9.5 - 13.6 4.3 - 6	2	2
Tropical America	Colombia	Amazonian Terra firme	1 - 30.4 0 - 20.4 3.6 - 30.9	0.2 - 4.2 0 - 3.8 0.7 - 3.1	9	3
	Brazil	Northern Espirito Santo	0.9 - 37.8	-	4	4
		Sao Paulo	23.3 - 43.2 13.2 - 42.6 7.1 - 53.8 0 - 27.1	-	3	5
	French Guiana	Counami Forest	0.4 - 6.9	-	6	6
Tropical Asia	Malaysia	Pahang	-	1.5 - 3 3 - 3.7 0.7 - 3.3	3	7
	India	**Nelliampathy**	**20.5 – 30.6**	**2.3 – 9.7**	**2**	**8**

ID - Individual density, GD - Group density and Sps - Number of species

[§]1 Worman and Chapman, 2006; 2 Fashing and Chords, 2000; 3 Palacios and Peres, 2005; 4 Chiarello and de Mello, 2001; 5 Martins, 2005; 6 De Thoisy, 2000; 7 Skorupa, 1987; 8 Present study.

4.3 Population Structure of Primates in Nelliampathies

A total number of 13 lion-tailed macaque troops with about 200 individuals and 23 Nilgiri langur troops with below 150 individuals were recorded in the present study and mapped in the Nelliampathy hills. The age sex compositions were measured for nine troops of lion-tailed macaques and 16 Nilgiri langur troops. Troop sizes for lion-tailed macaques ranged from four to 39 individuals with an average of 15.5. There were 8% of adult males, 34% of adult females, 16% of sub adult males and females and 12% of juvenile lion-tail macaques in Nelliampathies during the study period (Table 4.8). Assigning separate sex category in the sub adult group has left another 12% of the total individuals as unidentified category (37% of the lion-tailed macaques were also unidentified for Shendurney Wildlife Sanctuary as in Ramachandran, 1995). The adult male to female ratio was 1:4.36 and the overall adult to immature ratio was 1:0.71. The ratios of overall adult females to immature and infants were 1:0.85 and 1:0.52 respectively.

Table 4.8 Troop composition of lion-tailed macaques in Nelliampathies 2004 – 2007

Sl.No	Troop ID	AM	AF	CF	CI	SAM	SAF	J	UI	Total
1	Vannathi cholai I	2	2	3	3	3	2	3	4	22
2	Pakuthipalam I	1	3	2	2	0	2	3	0	13
3	Pakuthipalam II	1	7	6	6	4	1	2	0	27
4	Kuriarkutty	1	1	0	0	1	0	0	1	4
5	Oriental I	1	1	3	3	2	1	2	4	17
6	Kabir Sahib I	1	1	1	1	0	0	2	0	6
7	Karappara	2	6	7	7	4	2	3	8	39
8	Kabir Sahib II	1	1	1	1	0	0	0	1	5
9	Pakuthipalam III	1	1	2	2	0	0	1	0	7
	Total	**11**	**23**	**25**	**25**	**14**	**8**	**17**	**17**	**140**

AM = Adult male, AF = Adult female, CF = Cradling female, CI = Cradling infant, SAM = Sub adult male, SAF = Sub adult female, J = Juvenile and UI = Unidentified

In comparison, the adult male to adult female ratio (Table 4.9) of lion-tailed macaques in Nelliampathies was similar with the Silent Valley of Kerala (Joseph and Ramachandran, 2003) and Sirsi-Honnavara of Karnataka (Kumara and Singh, 2004). The adjacent Anamalais has only half of the females left as of Nelliampathies and Shendurney had even lower female ratio in comparison (Ramachandran, 1995 and Singh *et al*., 2002). The influence of habitat fragmentation in preventing the male

natal migration was speculated as the reason for lower female ratio in Anamalais (Singh *et al*., 2002). Nelliampathies had a slightly lower ratio than Silent valley but higher than the rest of the sites compared. The adult females to immature and overall adult to immature ratios were similar to that of the above sites except Shendurney which had significantly lower proportions. The higher proportion of unidentified individuals (37% of the total) and the zero representation of the sub adult female category in Shendurney might have influenced this odd phenomenon. The adult female to infant ratio was higher (1:0.52) in Nelliampathies than all these four sites.

Table 4.9 Comparison of the age sex ratios of lion-tailed macaques

	Ad M : Ad F	Ad F : Im	Ad : Im	Ad F : In	No. Of Groups	Source[§]
Sirsi - Honnavara	1:4.12	1:1.15	1:1.12	1:0.50	9	1
Silent Valley	1:5.63	1:0.90	1:0.76	--	14	2
Anamalais	1:2.11	1:1.10	1:0.84	1:0.38	6 - 9	3
Nelliampathies	1:4.36	1:0.85	1:0.71	1:0.52	9	4
Shendurney	1:1.40	1:0.28	1:0.48	1:0.30	9	5

[§]1 Kumara and Singh, 2004; 2 Joseph and Ramachandran, 2003; 3 Singh *et al*., 2002; 4 Present study; 5 Ramachandran, 1995. AD M: AD F - Adult male: Adult female, AD F: IM - Adult female: Immature, AD: IM - Adult: Immature, AD F: IN -Adult female: Infant.

The troop sizes of Nilgiri langurs ranged from three to 12 with a mean group size of 7. The adult males constitute 14% of the total population and the adult females were 29%. Twenty percent were sub adults of males and females and the immature, which includes the juveniles and dependant infants, were 19% of all the total age sexed troops in Nelliampathies (Table 4.10). Twenty one percent of the total individuals in all the troops recorded were unidentified. Apart from the earlier work of Poirier in 1969 on the troop composition and structure of Nilgiri langur in Nilgiris no study was available for comparison except one from the Silent Valley of Kerala (Joseph and Ramachandran, 2003). Between the years 1993 and 1996 as a part of a primate project they have recorded the distribution and measured the demography of about 85 troops of Nilgiri langur in the Silent Valley (Table 4.11). They have categorized the troops into blocks in the reserve instead of getting the local identity of

the individual troops. The adult male to adult female ratio was almost same between these two places. But the adult female to immature and overall adults to immature ratios were greater significantly in Nelliampathies than Silent Valley.

Table 4.10 Troop composition of Nilgiri langurs in Nelliampathies 2004 - 2007

Sl.No.	Troop ID	AM	AF	CF	CI	SA	J	UI	Total
1	Dolmen	1	-	2	2	2	3	-	10
2	Alexandria	1	1	3	3	-	1	-	9
3	Open I	1	2	1	1	-	1	6	12
4	Brookland gate	1	1	-	-	3	1	1	7
5	Govindamalai	1	2	1	1	1	-	-	6
6	Anamadai	1	2	-	-	2	-	-	5
7	Periacholai	1	1	1	1	-	-	1	5
8	Kaikatty	1	1	-	-	2	-	2	6
9	Bridge	1	-	-	-	2	-	1	4
10	Karapara	1	2	1	1	2	-	1	8
11	Kabir Sahib	1	-	-	-	1	-	1	3
12	Pothumala I	1	1	1	1	2	-	1	7
13	Victoria	1	2	-	-	1	-	2	6
14	Pakuthipalam	1	2	-	-	1	1	3	8
15	Fathima	1	1	-	-	2	-	1	5
16	Thuthampara	1	2	2	2	1	-	3	11
	Total	**16**	**20**	**12**	**12**	**22**	**7**	**23**	**112**

AM = Adult male, AF = Adult female, CF = Cradling female, CI = Cradling infant, SA = Sub adult, J = Juvenile and UI = Unidentified

Table 4.11 Age sex comparison of Nilgiri langur in Nelliampathies and Silent Valley

	AD M: AD F	AD F: IM	Ad: IM	AD F: IN	No. of Groups	Source[§]
Nelliampathies	1:2.0	1:0.59	1:0.39	1:0.38	16	1
Silent Valley	1:1.99	1:0.09	1:0.06	--	85	2

[§]1 Present study; 2 Joseph and Ramachandran, 2003; AD M: AD F - Adult male: Adult female, AD F: IM - Adult female: Immature, AD: IM - Adult: Immature, AD F: IN -Adult female: Infant.

4.4 Ecological Niche Modelling – Potential distribution area

A total of ten environmental variables were reduced into two to four factors explained over 80% of the variance for the four species. The global marginality and tolerance values are given in the Table 4.12. The higher marginality and lower tolerance values indicated the choosiness of these species to particular habitat extremes. Looking at the eco-geographic variable contribution of marginality values explains this further. In the case of lion-tailed macaques, the marginality proportion is higher for forest type, medium elevation (800-1400 MSL) and distance to the river. That means the forest types found in the medium elevation influence the presence of lion-tailed macaque troops i.e. the dense and disturbed medium elevation wet evergreen forests of *Cullenia-Palaquim-Mesua* association with increase in distance to habitation in the case of disturbance (higher marginality values for the distance to the habitation). A similar look at the marginality values of the Nilgiri langurs indicates that they are showing a relatively broader preference than lion-tailed macaques in terms of elevation. Its potential distribution is spread well in the canopied evergreen forest variants of high and low elevations with a preference in areas which are receiving higher rainfall. Of the four species, the Malabar giant squirrel has a very broad niche in having higher values of marginality for all the eco-geographic variables. Both the Malabar giant squirrel and Nilgiri langur troop occurrence are greatly influenced by the rainfall. The Nilgiri marten has a strong preference for forests, medium and low elevations, avoiding the habitations and has the least sensitivity towards the rainfall.

Table 4.12 Global marginality and tolerance.

Species	Marginality	Tolerence
Ratufa indica	0.6	0.6
Martes gwatkinsii	0.8	0
Macaca silenus	0.6	0.4
Semnopithecus johnii	0.6	0.5

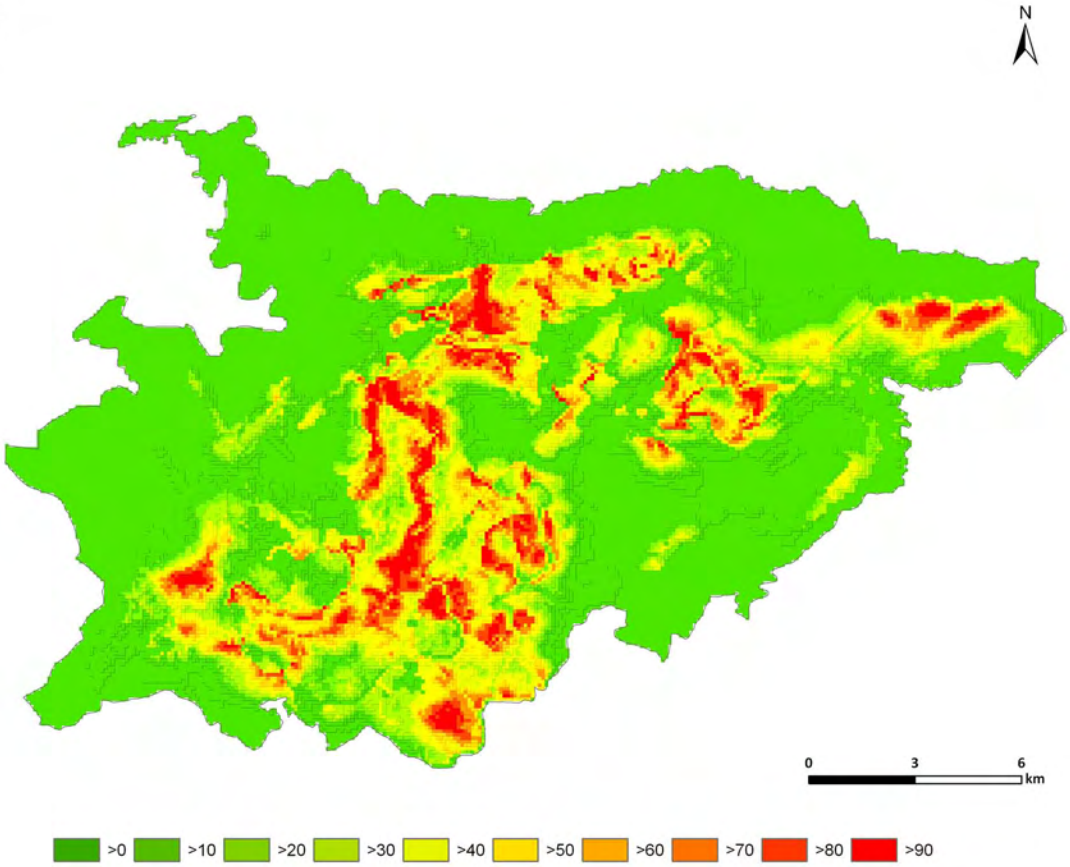
Habitat suitability maps were computed based on the above explained factors for each species using distance geometric mean algorithm and were evaluated with the cross validation procedures. The continuous Boyce indices were above 0.5 and that

indicates the four models were better than expected at random. Plates XI and XII shows the reclassified habitat suitability maps of these four species. The higher suitability of all the four species is coinciding in the plateau region and in the southern slopes or the Plateau minor. These are the regions which have the medium elevation and more or less canopied forms of land cover types such as evergreen forests and coffee and cardamom plantations with higher incidence of rainfall. The northern slope of the study area form poorer suitability areas invariably for all the four species. The difference in the environmental variables such as low precipitation, steep terrain, deciduous and savanna forms of vegetation with rocky outcrops and the absence of canopy contiguity were the reasons for the lower suitability of this area for arboreal animals in general.

The lion-tailed macaque has more restricted distribution than the other three species in visual comparison (Plate XI). The main concentration of the high suitability areas of lion-tailed macaques are in the middle portion of the Plateau proper where the climate is humid which can support a thick vegetation. The niche is more constricted and patchy than the other three species. The Nilgiri langur, on the contrary, has a greater distribution potential in the southern slopes rather than the plateau. The niche of langur troops even tends to occupy the predominant moist deciduous forests of the south eastern part along with the sparse evergreen forests of medium and lower elevations. The Malabar giant squirrel has the greater potential distribution than any other species in comparison. It has a broader niche with wide distribution in the southern slopes, plateau and even in some portion of the northern slopes. The Nilgiri marten's distribution is restricted to the Nelliampathies plateau and the southern slopes. The close resemblance of the potential distribution extent and geomorphology of Nelliampathies is noticeable. Even Nilgiri marten has high distribution potential in the plateau and southern slopes, which is clearly absent from the northern slopes. The Malabar giant squirrel and lion-tailed macaques have got broader and narrower niches respectively.

The habitat suitability maps were further classified in to suitable (>10) and not suitable (<10) categories and the suitability maps were clipped with the forest type map, the results were tabulated and was shown in the fig 4 and 5. The Malabar giant squirrels have the larger proportion of about 94% areas were suitable followed by Nilgiri langur having 73%. The Nilgiri marten and lion-tailed macaques have only 46

1



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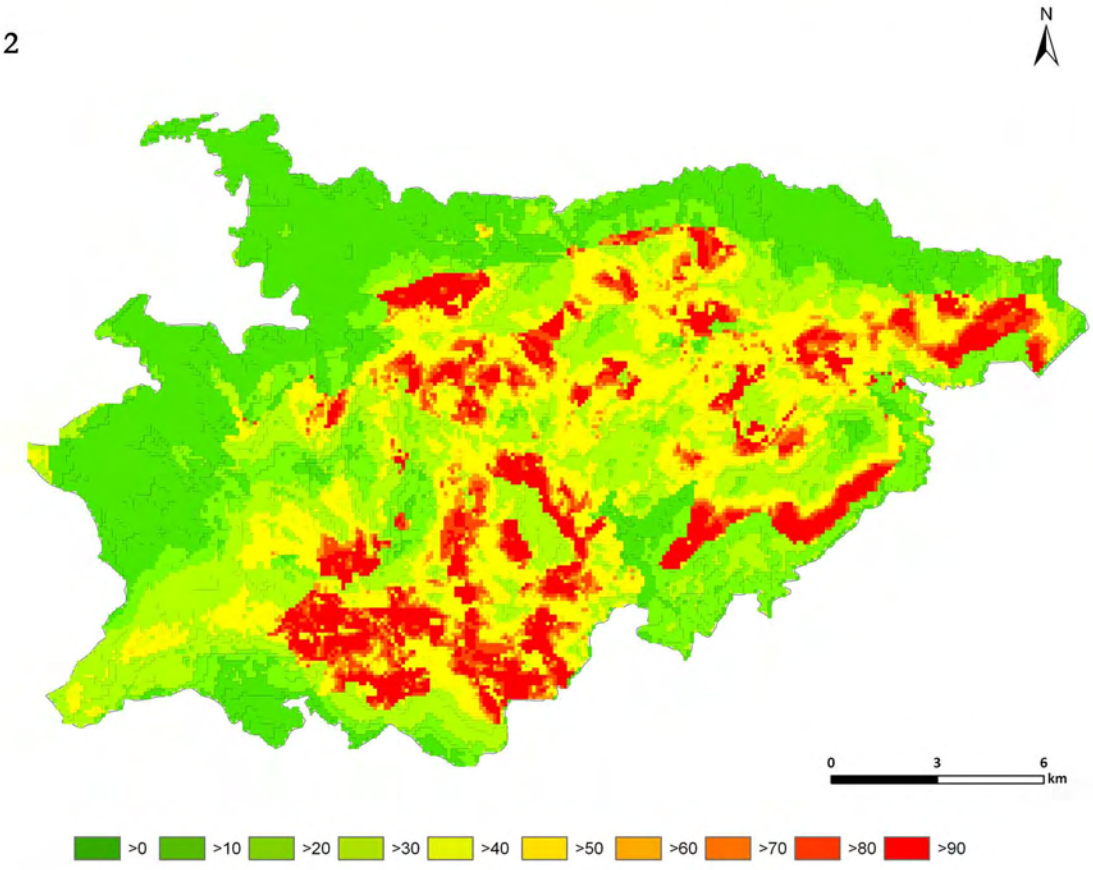

Habitat Suitability Maps of Primates : 1) Lion-tailed macaques and 2) Nilgiri langurs

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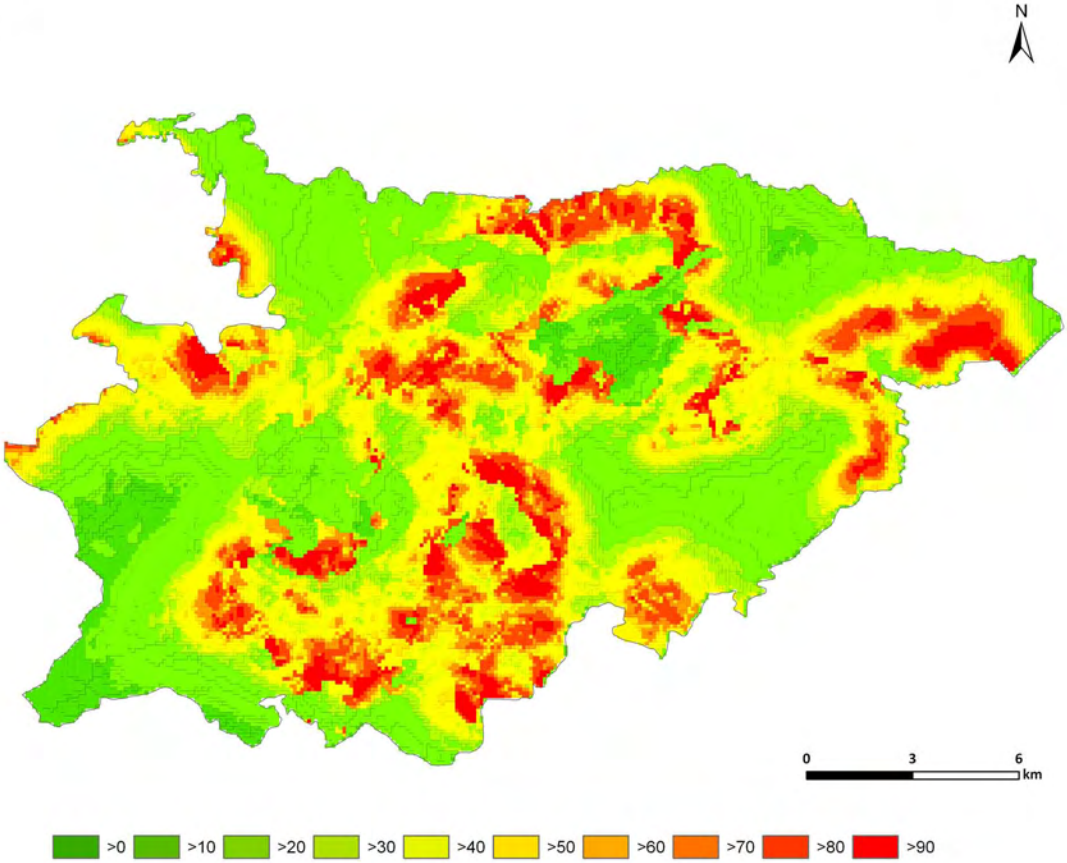

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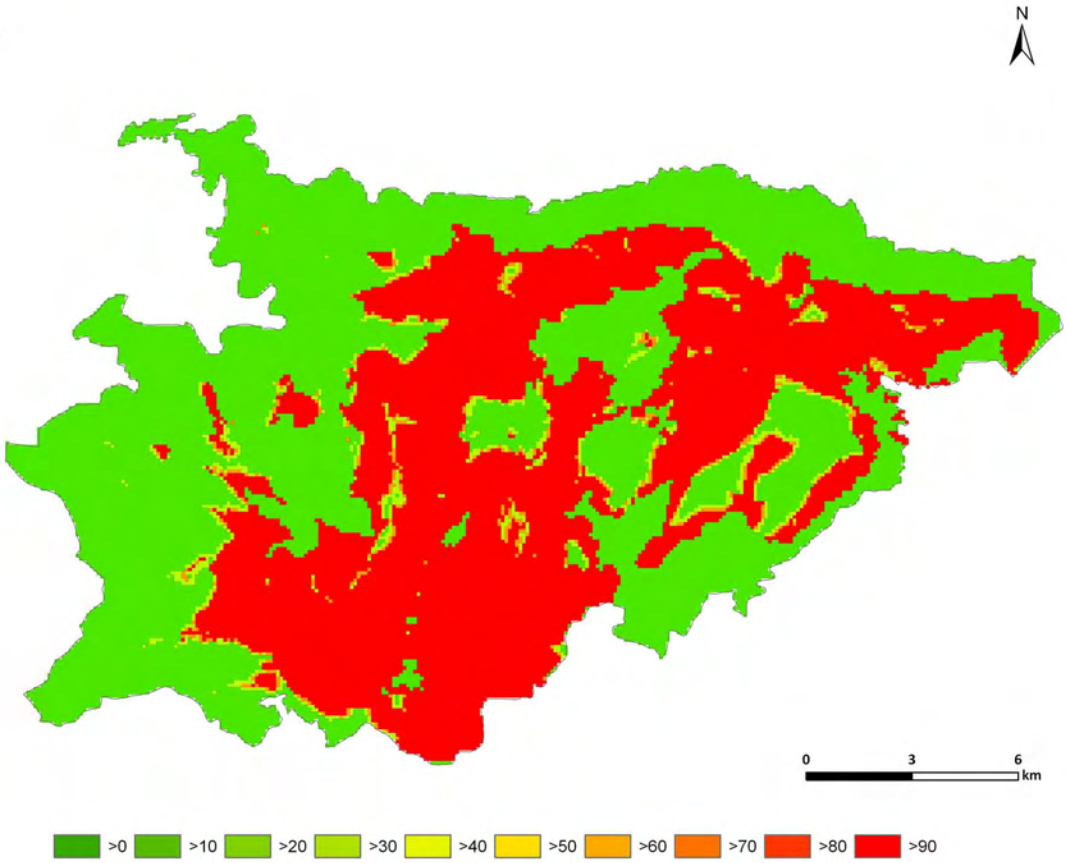


Habitat Suitability Maps of other Arboreal Mammals : 1) Malabar Giant Squirrel and 2) Nilgiri Marten

and 40% of the total geographic areas were under suitable category (Fig. 4 and 5). Forest type wise classification of the suitable areas further constrains the extent of the niches. For example, in the case of lion-tailed macaques, only 40% of the total suitable areas are falling in the category of evergreen forest type followed by another 26% in cardamom and coffee plantations. The rest of the suitable areas were either falling in deciduous forests or plantations where in the later case, the potential areas once had been transformed into non forest activities such as tea and other commercial land use changes. So the reclassification of the potential suitable habitat in the case of lion-tailed macaques will be around a mere 26% of the total geographic area of both the Plateau proper and minor of Nelliampathies.

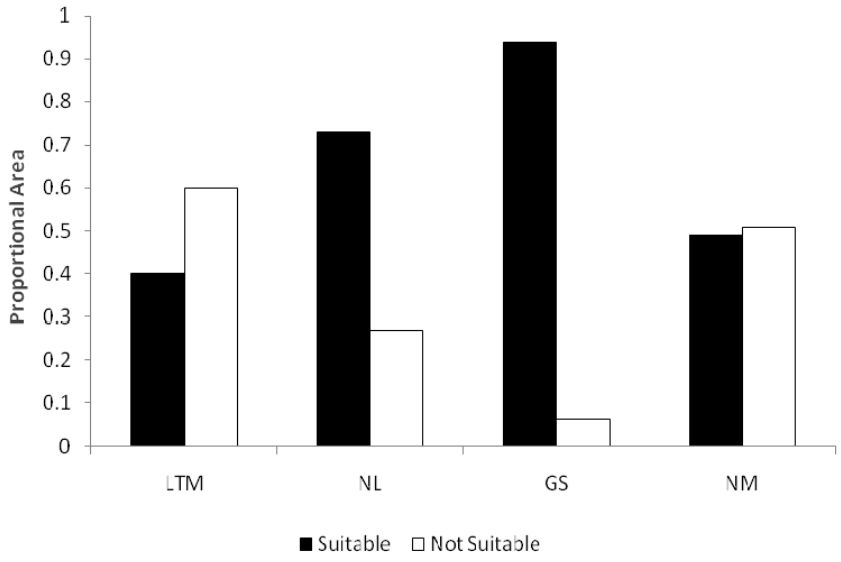


Fig. 4 Suitable areas of arboreal mammals

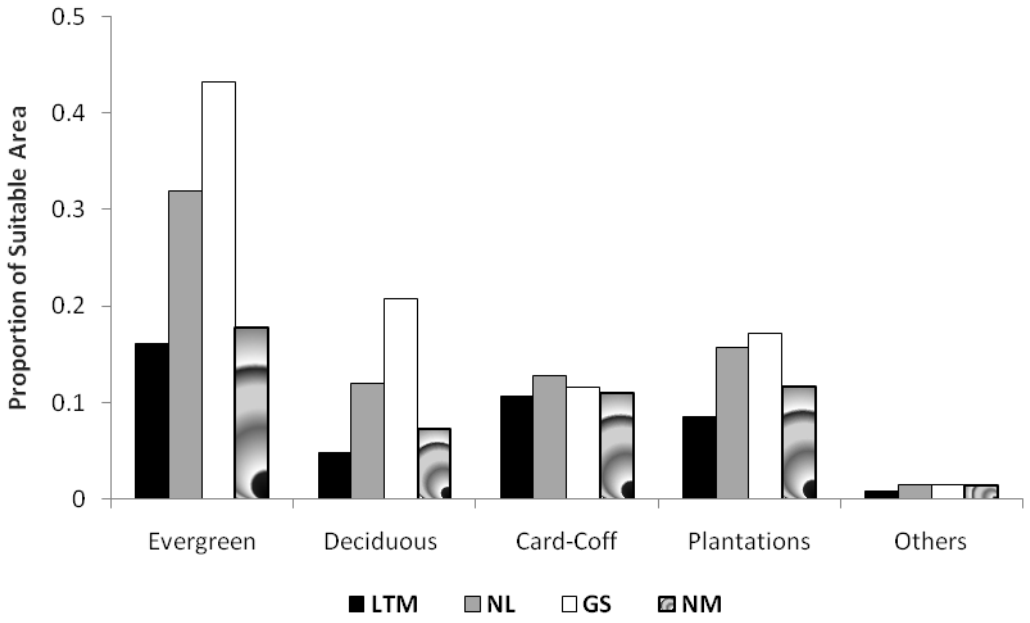
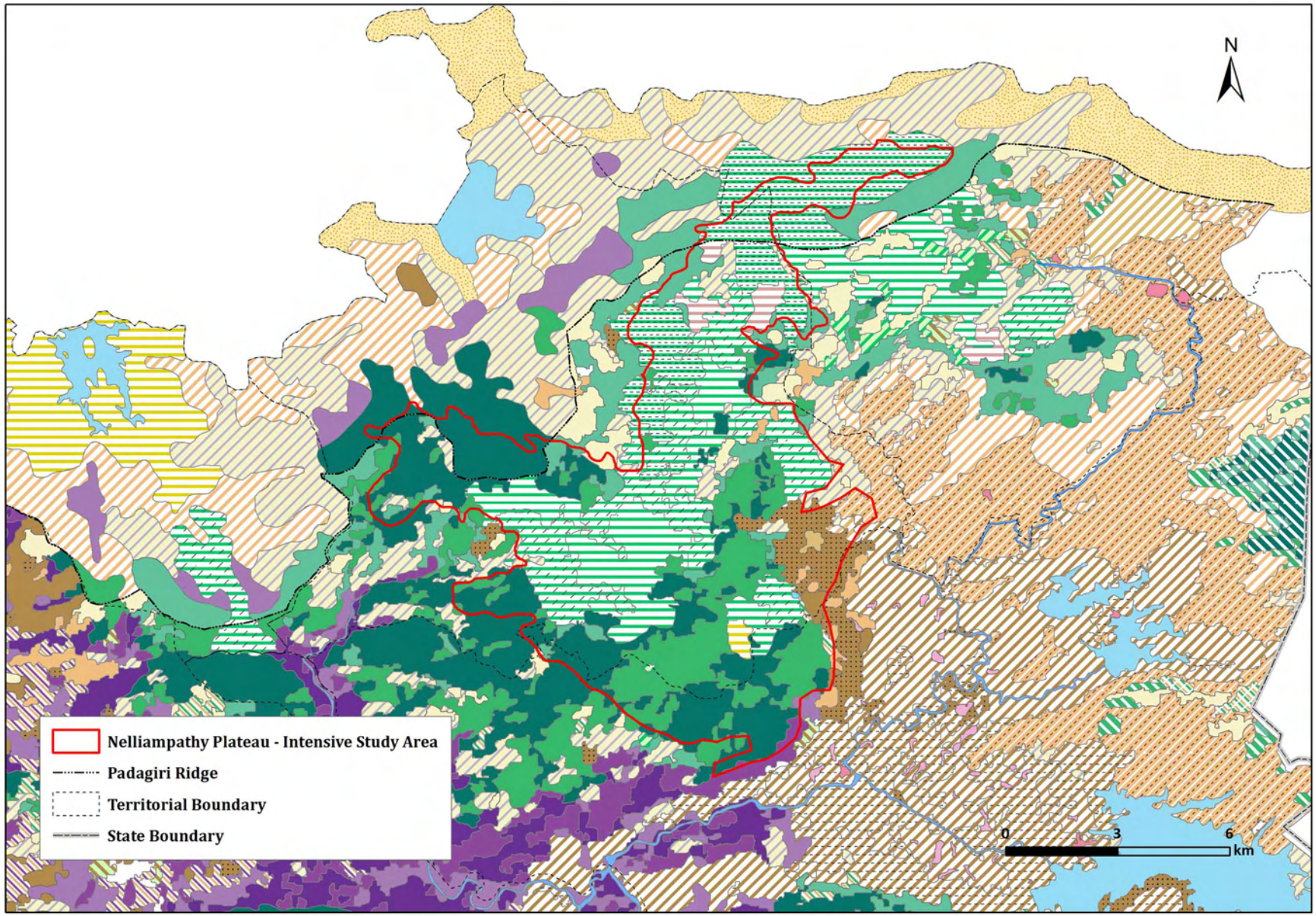


Fig. 5 Proportion of suitable areas intersected by landuse types

4.5 Food and feeding habits of arboreal mammals

A total of around 300 hours was spent in observing the feeding behaviour of lion-tailed macaques and Nilgiri langurs in the plateau region (Plate XIII). Tables 4.13 and 4.14 give the total number of food species fed by the LTM and NL respectively with their relative frequency. Lion-tailed macaques fed on a total of thirty eight plant species that includes 1 moss and 2 species each of lichens and mushrooms. Nilgiri langurs fed fifty three species with a moss and mushroom species. For both LTM and NL, *Cullenia exarillata* is the maximum utilized food species with higher percentage. Figure 16 illustrates the relative percentages of the major fifteen plant species of both the species. The second major food species is *Palaquim ellipticum* and a major number the top fifteen species were common for both LTM and NL. Though similar were the plant species, different plant parts were selected for consumption by the macaques and langurs (Figure 6 & 7). Fruits and seed were relatively more fed by the macaques where langurs prefer leaves and more flowers. Macaques fed a fair amount of mushrooms and langurs were never seen feeding on mushrooms.

Recent comparative studies on the food and feeding behaviour of LTM and NL were from Silent Valley (Ramachandran and Joseph, 2000) and Anamalais (Sushma and Singh, 2006). Four year study in the Silent Valley revealed that ninety two plant species were fed by the lion-tailed macaques in addition to a 9%



Intensive Study Area: Feeding and other behavioural observations are conducted in the plateau region (shown red).
For the legend of the forest types refer Plate 7

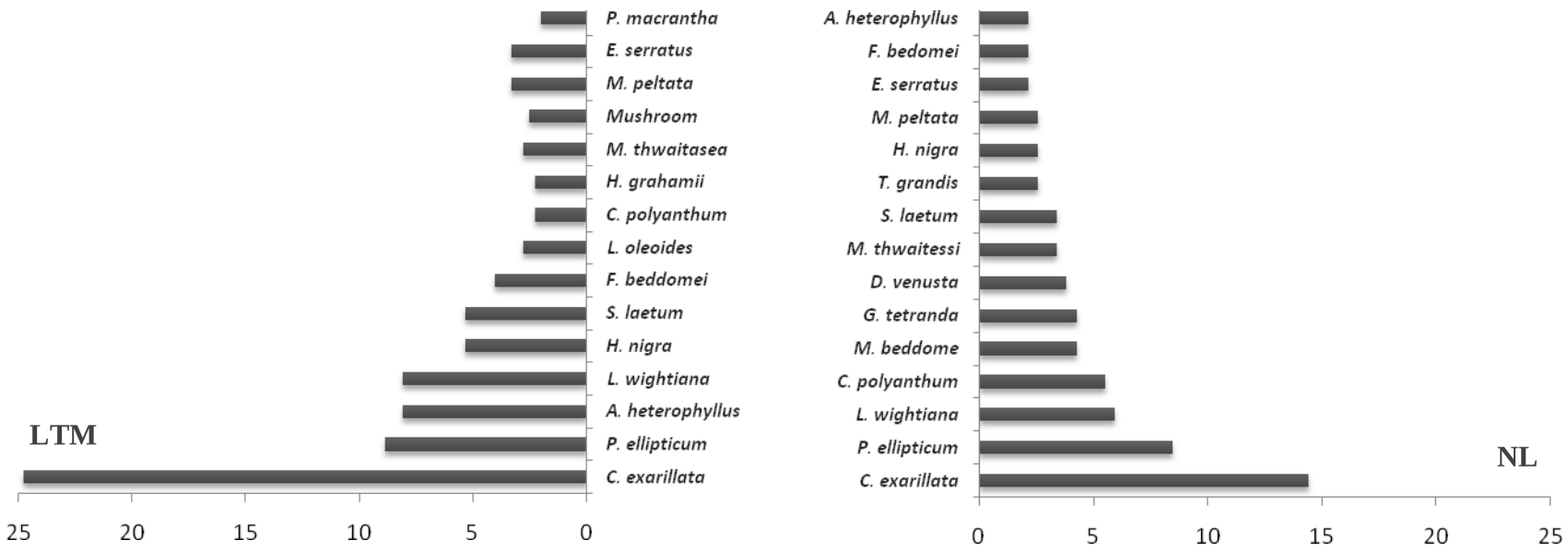


Figure 6 Overall feeding proportion of LTM and NL

of animal component in the diet. In Anamalais the LTM and NL have reported found to feed on a total of forty one and sixty four plant species respectively. The abundance of the major food species differs between the evergreen forests of Silent Valley, Anamalais and Nelliampathy forests. And also different was the effects of disturbance factors like conversion, fragmentation, logging and felling from the past management histories which very much shaped the structure, form, extent and condition of the present forests in these regions.

Table 4.13 List of Species fed by lion-tailed macaques

No.	Species	Family	Percentage
1	*Cullenia exarillata*	Bombacaceae	24.75
2	*Palaquium ellipticum*	Sapotaceae	8.84
3	*Atrocarpus heterophyllus*	Moraceae	8.08
4	*Litsea wightiana*	Lauraceae	8.08
5	*Holigarna nigra*	Anacardiaceae	5.30
6	*Syzygium laetum*	Myrtaceae	5.30
7	*Ficus beddomei*	Moraceae	4.04
8	*Litsea oleoides*	Lauraceae	2.78
9	*Callophyllum polyanthum*	Clusiaceae	2.27
10	*Holigarna grahamii*	Anacardiaceae	2.27
11	*Mesua thwaitasea*	Clusiaceae	2.78
12	Mushroom (2 species)		2.53
13	*Macaranga peltata*	Euphorbiaceae	3.28
14	*Elaeocarpus serratus*	Elaeocarpaceae	3.28
15	*Persea macrantha*	Lauraceae	2.02
16	*Mangifera indica*	Anacardiacea	1.77
17	*Ficus nervosa*	Moraceae	1.52
18	*Caryota urens*	Poaceae	2.27
19	*Mesua ferrea*	Clusiaceae	1.26
20	*Myristica beddome*	Myristicaceae	1.01
21	*Ficus nervosa*	Moraceae	1.01
22	*Drypetus venusta*	Euphorbiaceae	1.01
23	*Litsea floribunda*	Lauraceae	0.76
24	*Ficus microcarpa*	Moraceae	0.51
25	*Canarium strictum*	Burseraceae	0.25
26	*Palaquium ravii*	Sapotaceae	0.25
27	*Syzygium lanceolatum*	Myrtaceae	0.25
28	*Garcinia morella*	Clusiaceae	0.25
29	*Elaeocarpus tuberculatus*	Elaeocarpaceae	0.25
30	*Drypetus oblongifolia*	Euphorbiaceae	0.25
31	*Calamus sps.*	Poaceae	0.25

32	*Achronychia pedunculata*	Rutaceae	0.25
33	*Cinnammomum malabaricum*	Lauraceae	0.25
34	*Macaranga indica*	Euphorbiaceae	0.25
35	Lichen (2 species)		0.25
36	Moss (1 species)		0.25

Table 4.14 List of Species fed by Nilgiri langurs

No.	Species	Family	Percentage
1	*Cullenia exarillata*	Bombacaceae	14.41
2	*Palaquium ellipticum*	Sapotaceae	8.47
3	*Litsea wightiana*	Lauraceae	5.93
4	*Calophyllum polyanthum*	Clusiaceae	5.51
5	*Myristica beddome*	Myristicaceae	4.24
6	*Gomphandra tetranda*	Icacinaceae	4.24
7	*Drypetus venusta*	Euphorbiaceae	3.81
8	*Mesua thwaitessi*	Clusiaceae	3.39
9	*Syzygium laetum*	Myrtaceae	3.39
10	*Tectona grandis*	Verbenaceae	2.54
11	*Holigarna nigra*	Anacardiaceae	2.54
12	*Macaranga peltata*	Euphorbiaceae	2.54
13	*Elaeocarpus serratus*	Elaeocarpaceae	2.12
14	*Ficus bedomei*	Moraceae	2.12
15	*Artocarpus heterophyllus*	Moraceae	2.12
16	*Persea macrantha*	Lauraceae	2.12
17	*Garcinia gummu-gutta*	Clusiaceae	2.12
18	*Cinnamomum malabatrum*	Lauraceae	1.69
19	*Dimocarpus longan*	Sapindaceae	1.69
20	*Mangifera indica*	Anacardiaceae	1.27
21	*Grewia tiliaefolia*	Tiliaceae	1.27
22	*Terminalia bellerica*	Combretaceae	0.42
23	*Terminalia paniculata*	Combretaceae	0.85
24	*Elaeocarpus tuberculatus*	Elaeocarpaceae	0.85
25	*Canarium strictum*	Burseraceae	0.85
26	*Mallotus tetracoccus*	Euphorbiaceae	0.85
27	*Knema attenuata*	Myristicaceae	0.85
28	*Acronychia pedunculata*	Rutaceae	0.85
29	*Vitex altissima*	Verbenaceae	0.85
30	*Nothopodytes mimmoniana*	Icacinaceae	0.85
31	*Ixora bractiata*	Rubiaceae	0.85
32	*Piper wightii*	Piperaceae	0.42
33	*Piper nigrum*	Piperaceae	0.85
34	*Psidium gujava*	Myrtaceae	0.85
35	*Olea dioica*	Oleaceae	0.42
36	*Mesua ferrea*	Clusiaceae	0.85

37	*Artocarpus hirsutus*	Moraceae	0.85
38	*Holigarna grahamii*	Anacardiaceae	1.27
39	*Ficus nervosa*	Moraceae	0.85
40	*Syzygium lanceolatum*	Myrtaceae	0.85
41	*Litsea oleoides*	Lauraceae	0.42
42	*Prunus ceylanica*	Rosaceae	0.42
43	*Xanthophyllum arnotianum*	Xanthophyllaceae	0.42
44	*Entada rheedi*	Mimosaceae	0.42
45	Mushroom 1 sp		0.00
46	*Palaquim ravii*	Sapotaceae	0.42
47	*Garcinia morella*	Clusiaceae	0.42
48	*Aglaia lawii*	Meliaceae	0.42
49	*Reinwardtiodendron anamalaiense*	Meliaceae	0.42
50	*Calicarpa tomentosa*	Verbenaceae	0.42
51	*Coffea arabica*		2.54
52	Moss 1 sp		0.42
53	Other		0.42

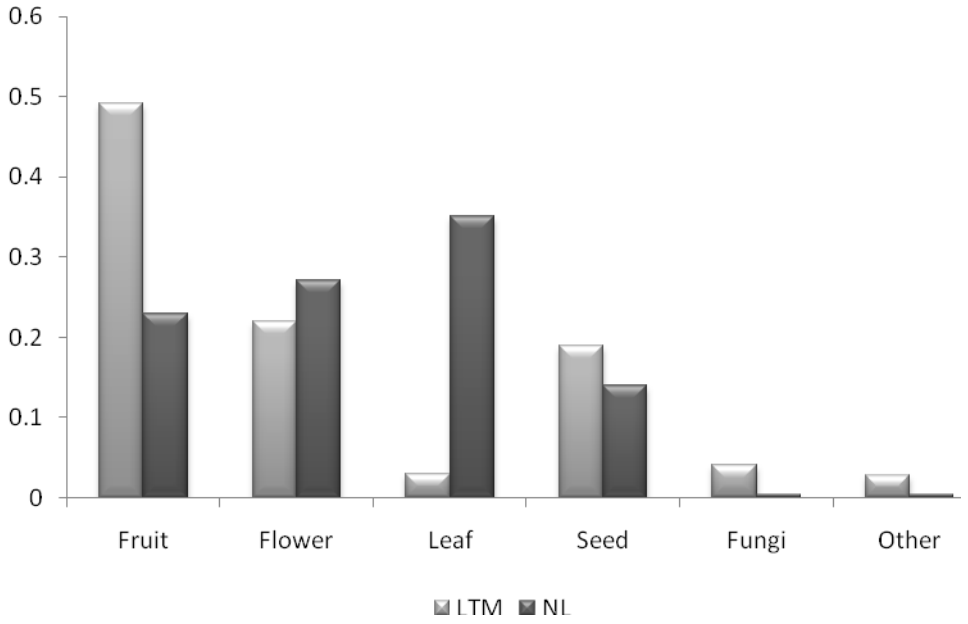


Figure 7 Diet proportions of LTM and NL

4.5.1 Seasonal variation

Season wise analysis showed that there is significance difference in the proportion of different food items taken for feeding (Table 4.15). Fruits and seed were largely preferred and consumed by the lion-tailed macaques during the monsoon. In

the same period, Nilgiri langur fed largely on their primary diet leaves followed by floral parts and seeds. The post monsoon season was marked by a shortage in the fruit availability and the macaques were shifting to feed on flowers than before. Same was the situation for langurs in this period with higher proportional usage of flowers. Dry season was also had the same conditions as of the post monsoon season where the fruit availability is limited further and of the competition for floral feeding. The incidences of the search for other food sources such as the mushrooms and gleaning for insects and probably for reptiles were also recorded mostly in the post monsoon and dry seasons.

Table 4.15 Seasonal variation in the diet

	Season	Fruit	Flower	Leaf	Seed	Fungi	Other	χ^2
LTM	Dry	49	17	5	10	2	3	100.85
	Monsoon	136	22	2	22	3	2	296.60
	Post monsoon	54	46	2	12	5	3	134.42
NL	Dry	11	10	31	6	-	1	44.30
	Monsoon	21	23	55	16	-	1	67.27
	Post monsoon	7	20	30	2	-	1	52.83

for LTM $df = 5$ and for NL $df = 4$, $p < .001$

4.5.2 Diet diversity and overlap

The lion-tailed macaque had used a total of seventy three resource states or food items belonging to thirty plant species where as Nilgiri langurs utilized hundred and two food items (or resource states) of fifty three species. The overall niche breadth values calculated by Levin's measure were 0.119 for LTM and 0.202 for NL (Table 4.16). For both the species there is a reduction in the values for dry season due to the relatively low food availability. Less than half of the total food items or resource states and food species were available during the dry season. The post monsoon season had also the same trend. The monsoon only had the higher number of food items and species among the three seasons. The higher niche breadth values were during the monsoon season for NL and post monsoon for LTM. The decline in the fruit availability after the monsoon and shifting of preference towards flowers and

floral buds may be the reason behind the larger values for LTM in the post monsoon period.

Table 4.16 Niche Breadth - Levin's measure

	Season	Niche breadth	Food species	Resource States
LTM	Dry	0.181	16	28
	Monsoon	0.219	27	45
	Post monsoon	0.235	29	36
	Overall	**0.119**	**37**	**73**
NL	Dry	0.312	27	48
	Monsoon	0.381	42	62
	Post monsoon	0.332	28	41
	Overall	**0.202**	**53**	**102**

The overall niche overlap calculated using the Morisita's measure was 0.47 between the lion-tailed macaque and Nilgiri langurs (Table 4.17). The overlap was high in the post monsoon season (0.52) and low in the monsoon (0.4). As seen in the previous table, the niche breadth of the lion-tailed macaque is expanding in the post monsoon season due to the paucity of fruits and the shift in the preference for flowers and floral buds especially of *Cullenia* and hence the higher values of overlap in this season. This was again supported by a similar study in the Anamalais (Sushma and Singh, 2006) where a relative increase in the overlap was observed in the post monsoon season. The reason for this was attributed to the increase in the consumption of *Cullenia* flowers by the macaques against the langurs in the post monsoon period. The overlap values are in general higher for Nelliampathies when compared to that previous study in Anamalais.

TABLE 4.17 Morisita's index of niche overlap – LTM vs.NL

Season	Niche Overlap
Dry	0.498
Monsoon	0.404
Post Monsoon	0.520
Overall	**0.474**

Three major reasons can be cited and explained for the differences in the niche overlap extend between the Nelliampathies and Anamalais. First reason is the difference in the method of the data collection. The authors of the Anamalais study employed instantaneous sampling whereas the present study employs *ad libitum* sampling. The second one was the extent of the intensive study sites. A small area of isolated fragmented patch limits the movement of animals to a smaller distance and increases the detectability and thus guarantees the contact between the observer and the animal which is a prerequisite of employing any quantifiable methodologies which can lead to better results. The condition of the Nelliampathies is that (and the intensive study area also) it is having a mosaic type of vegetation with alternating coffee plantations, cardamom plantations and evergreen forests, where in most of the areas there is little difference in the canopy or at least there is some canopy contiguity. Contact hours are less and uncertain in a contiguous forest with closed canopy and thick middle storey as the visibility is low when compared to a disturbed fragment with smaller area. The final reason is that, as hinted earlier, the structure, form and condition of the existing stands which is the result of the past management strategies and land use history. For example, the following table gives the density and basal area for important food species of LTM and NL (Table 4.18). Any difference in the availability of major food resources brings changes in the competition. A comparison with the availability of these similar resources in the other areas - Silent Valley and Anamalais with that of Nelliampathies will explain the difference in the resource use and competition.

Table 4.18 Density and basal area of selected tree species in Nelliampathies

No.	Species	Family	Density	Basal Area
1	*Cullenia exarillata*	Bombacaceae	28-150	7.57 - 35.11
2	*Pallaquium ellipticum*	Sapotaceae	8-327	1.07-29.43
3	*Holigarna nigra*	Anacardiaceae	2-28	0.02-6.72
4	*Litsea wightiana*	Lauraceae	0-274	0-0.78
5	*Mesua thwaitacea*	Clusiaceae	5-80	0.01-14.66
6	*Syzygium gardneri*	Myrtaceae	4-36	0.06-2.31
7	*Persea macarantha*	Lauraceae	2-14	0.03-1.07

8	*Garcinia morella*	Clusiaceae	2-34	0.03-0.38
9	*Myristica beddomei*	Myristicaceae	21-68	0.64-2.26
10	*Calophyllum polyanthum*	Clusiaceae	1-60	0.4-20.61
11	*Drypetes oblongifolia*	Euphorbiaceae	0-92	0-1.75
12	*Elaeocarpus serratus*	Elaeocarpaceae	0-8	0.004-1.07
13	*Cinnamomum malabatrum*	Lauraceae	5-20	0.03-1.87

Ramachandran, 2009

4.6 Behaviour of lion-tailed macaques - Time budget and activity pattern

The lion-tailed macaques of Nelliampathies spent the largest time on feeding (26%), followed by moving (23.7%) and resting (22.2%). These three major activities constitute over 72% of the total activities done by the macaques. Next to that, aggressive behavior constitutes 7%, grooming 6.2%, play 5% and sex 4% of the total activities recorded. There is a significant variation in the overall time spent on different activities (Kruskal-Wallis test, $p < 0.01$).

Table 4.19 gives the comparison of the time budgets between the troops at Varagalaiar-Anakunthi (Kurup and Kumar, 1993) and Puthuthottam (Menon and Poirier, 1996). The most time consuming activity of the troops at all the three sites was feeding. The second most frequent activity in Nelliampathies is ranging or moving activity, which constitutes about 23.7% of the total time spent. The lion-tailed macaques of Varagalaiar-Anakunthi (VA) had spent only 15% of time in ranging whereas the troops in Puthuthottam (PT) spent over 35% of the total time in moving.

This particular activity pattern, ranging or moving explains the local patch availability and selection of LTMs among these three sites. The PT is a very small forest fragment bounded by tea and other monoculture plantations where the food availability is very low. The macaques had to traverse the vast unsuitable patch to find new food resource in a good quality patch and hence the time was spent more. In comparison, in the protected area of Anamalais in the same Valparai Plateau, the troops of VA had spent only 15% of their daily time in ranging. In Nelliampathy Plateau, the four troops studied were located more or less close to the cardamom and

coffee plantations of various stand qualities. The evergreen forests at some patches in the plateau near the coffee and cardamom plantations had undergone two selection felling series. This could have been negatively affecting the feeding behavior of macaques with the availability of good quality food resource trees selected and removed by the felling practices in the past.

Table 4.19 Comparison of time budgets among different groups

Activity	**Nelliampathy[1]**	**Puthuthottam[2]**	**Varagalaiar/ Anakunthi3**
Feed	26	17.9	27.8
Forage	5.8	23.7	26.7
Aggression	7	-	-
Play	5	-	-
Groom	6.2	-	-
Move	23.7	34	15
Rest	22.2	16	27.8
Sex	4	-	-
Other	-	8.4	3.5

1 Present study; 2 Menon & Poirier, 1996; 3 Kurup & Kumar, 1993

But at the same time, foraging, the active search for food items was low in Nelliampathy troops when compared to the other two sites. The activity resting was comparable with the two troops on Anamalais. Again the trend was same, very less time spent resting in a highly disturbed Puthuthottam fragment (16%), a larger time spent on the protected shola forest in Varagalaiar (28%) and it was only 6% in Nelliampathies. But foraging percentage was found to be high during the post monsoon season where the fruit availability of *Cullenia*, *Ficus*, *Syzigium* and *Litsea* become rare or absent. This trend is also similar with the Varagalaiar shola troops where the macaques are found to search for food more during the dry season in April (Kurup and Kumar, 1993).

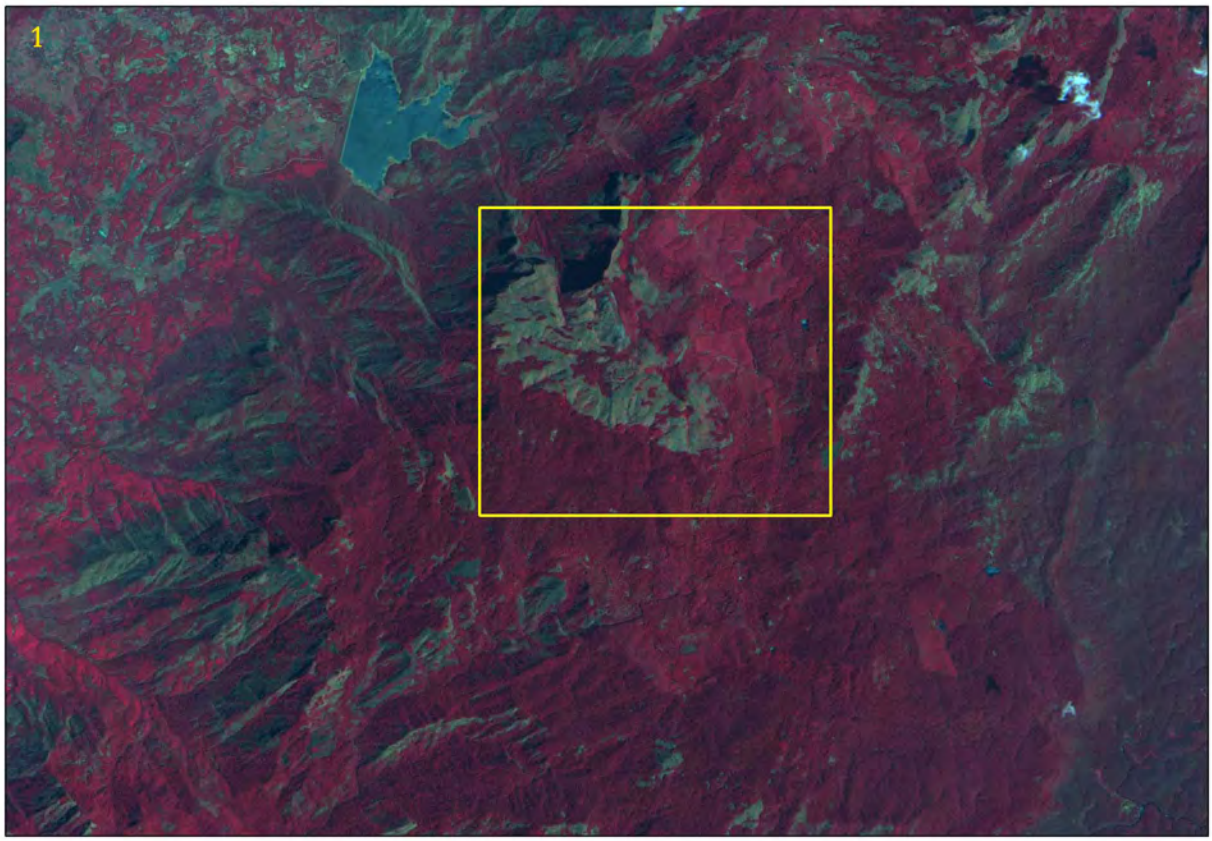
The former study had grouped the activities of grooming, mating and other agonistic activities to one group called social interactions and found that the groups were seen spending over 3.5% of their total daytime. But in Nelliampathies, all these three activities amounts to over 17% of the total time excluding the social behavior of playing activities. The sub adult and juvenile macaques were seen spending almost 5% of their total time in playing. The fine partitioning of the activities is revealing interesting facts about the social behaviour of the female bonded lion-tailed macaques

in the wild. Based on the reconciliation behaviour observed in captive and free ranging macaques, the lion-tailed macaques has been classified into Grade III of social tolerance (Thierry, 2007) in a scale of 4 (1 Strong to 4 weak).

But recent evidences (Singh *et al*., 2010) suggest that the lion-tailed macaque males have a bonded and aggressively organized social system than previously thought. This study also shows that the lion-tailed macaque troops in Nelliampathies spent relatively larger time in social interactive activities like playing, grooming and mating. Except the adult males and females with cradling infants, all the macaques were observed to play during the rest hours in the day time. Among the sub adult and juvenile males, homosexual behaviour was also observed several times. The sub adult males engage in same sex courtship and mounting several times during the study period. This particular same sex mating behaviour of female and male sexes was earlier observed directly in macaque societies with several lines of evidences (Vasey and Jiskoot, 2009). The mounting and mounted males were seen expressing facial gestures, postures and vocalizations.

4.7 Arboreal corridors in Nelliampathy Plateau

The remote sensing analysis done with the satellite image of IRS P6 data through supervised classification is given in Plate XIV. The vegetation pattern revealed through the classification is of a mosaic type with the mixture of coffee and cardamom plantations in between the evergreen forests. Nearly two third of the evergreen formation in the plateau region is cleared for tea cultivation almost 60 years back. The remaining natural forests in the plateau on either side, to the west-southwest and the east-north east is connected by the mosaic of the coffee, cardamom and other natural remnant stands. The Karapara River is traversing the plateau from the north and flowing down to the west-south west. The geological fracture in plateau region is utilized by the Karapara River to drain down in a rocky substratum of charnockite terrain. The land use practices resulting in a mosaic type of vegetation offers a limited connectivity through the canopy. The coffee plantations are often heavily manipulated to create gaps in the canopy for more sunlight which gives a better yield. Though not drastic as coffee, the cardamom plantation is also subjected to alterations in the canopy. What has resulted is the creation of more gaps in the canopy which has directly affected the arboreal pathways of lion-tailed macaques,



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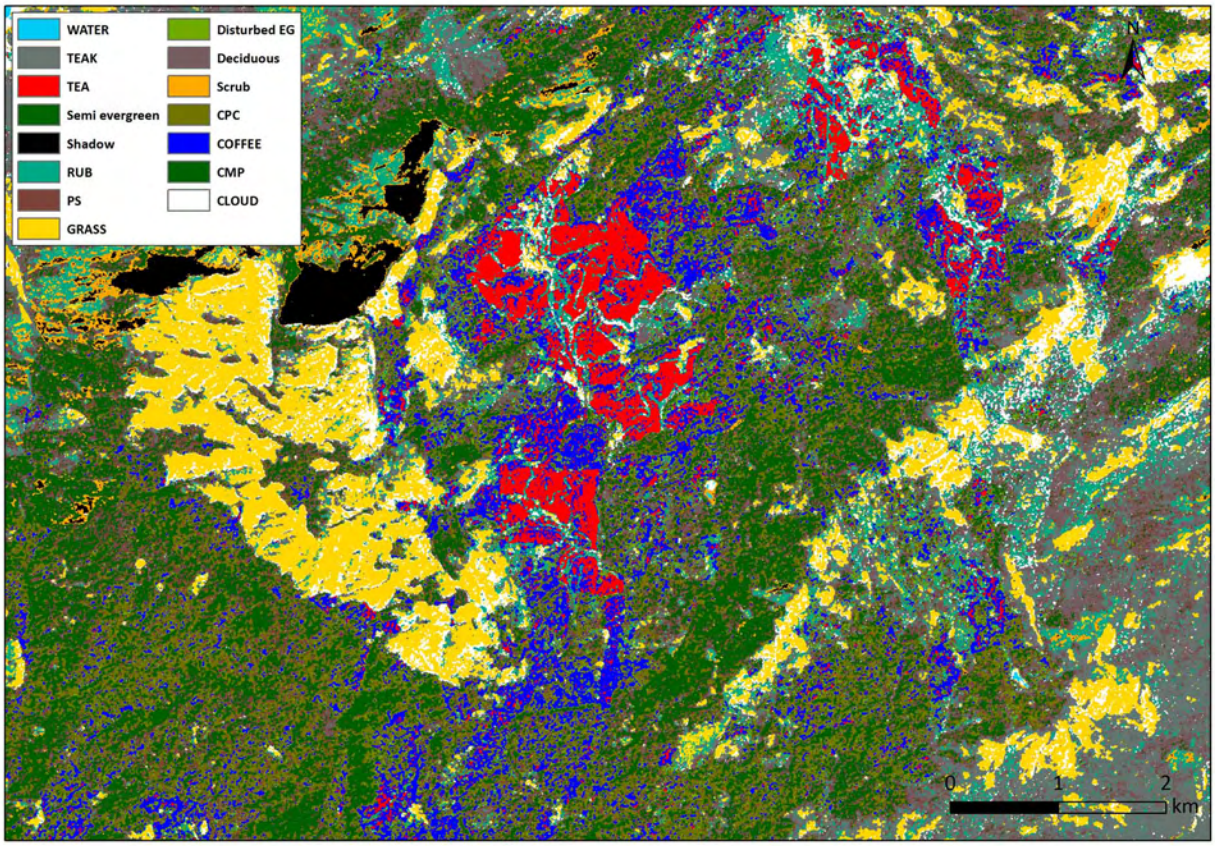


Canopy connectivity and Arboreal pathways: 1) IRS P6 5m reslolution multispoectral satellite image of Nelliampathies and 2) Supervised classification of image showing the habitat mosaic of the plateau region interrupted by tea and coffee plantations (box in1 is enlarged in 2)

Nilgiri langurs and Malabar Giant squirrel. In addition to this stress, the power line along the road poses grave threat to the life of these animals.

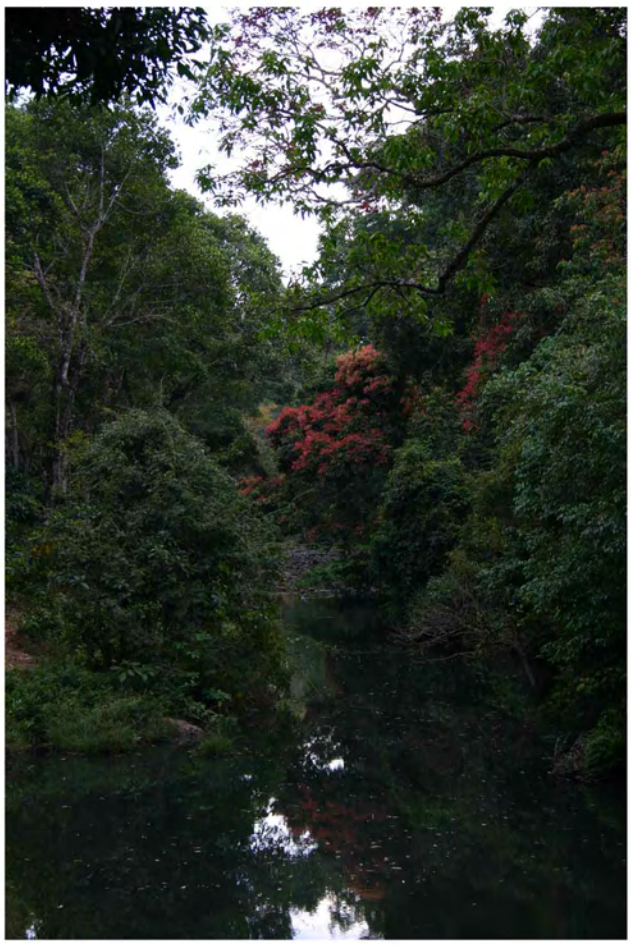
During the study period three incidences of lion-tailed macaque deaths by electrocutions and two incidences of Nilgiri langur electrocutions were recorded. Moreover the trend in the current land use practice is that the cardamom plantations are either abandoned or converted into coffee plantations (Plates XV and XVI). The cardamom to coffee conversion in some of the places in the plateau is more detrimental than the earlier times. For example, the Pullala cardamom and the Thuthampara coffee plantations. Considerable extent of cardamom areas were converted to coffee plantations in Pullala estate by removing the whole vegetation and planted with only coffee. There are no trees of upper strata left over. Second case is the Thuthampara estate. Thuthampara estate is also devoid of any continuous trees for serving as an arboreal pathway. Recently a larger portion of Nelliampathy range is marked to be added to a Tiger Reserve in the nearby Parambikulam area. Parambikulam and Nellimapathy, though in the same landscape unit have different bioclimatic conditions and hence undergone different land use regimes. Former being in a deciduous biotope had experienced extraction of timber and clear felling for severe plantation management by the state. But Nelliampathy plateau region is a evergreen biotope mainly subjected in the past to selection felling practices for plywood extraction. And the plantations in the plateau leased by the private land holders where the state government exercises only minimal control. The current Nelliampathy forest range has predominant evergreen vegetation which is fundamentally different from the perspective of the tiger conservation. At the same time, the Kollengode range which has a substantial amount of grasslands and secondary savanna moist deciduous forests which can support more prey species like spotted deer and wild boar are ignored for the purpose of annexing to the tiger reserve. Thus while considering the local habitat peculiarities of Nelliampathy plateau where the terrestrial animals are in very low densities and arboreal fauna is abundant, the idea of including these areas in to a tiger reserve is a biased and unscientific argument. With the arboreal mammal perspective, what is required is the regulated plantation activities with the least harmful effect to the lion-tailed macaques and Nilgiri langurs. If the arboreal mammal population of the Nelliampathy plateau is to be conserved, it is only possible with the participation of the active stake holders - the

Tea plantations

Conversion of cardamom to coffee

Canopy discontinuities in the Plateau

Tea plantations on either side of the Karapara river (indicated by red arrow)



Remaining connections at few localities along the Karapara river

Karapara Corridor

plantation management and people in the plateau. Now the macaques and langurs are freely ranging and using the cardamom areas and well canopied parts of the coffee plantations. An intensive follow up study on the “Karapara corridor” is much warranted to understand the dynamics of arboreal mammals in Nelliampathies.

5. Conclusions

The following conclusions are made from this study:

Eleven arboreal mammal species were recorded from the evergreen forests of the Nelliampathy plateau through this study. The nocturnal Malabar slender loris, Malabar spiny tree mouse and Nilgiri marten are the rare and endemic arboreal mammal species recorded from the plateau. Apart from this, large populations of the endangered lion-tailed macaque and the vulnerable Nilgiri langur were also recorded. The relative abundances of diurnal arboreal mammals were ranging from 1.2 to 12.6 individuals per 10 km and the mean group sizes of primates ranges from 3.5 to 6.9.

The population densities of the lion-tailed macaques, Nilgiri langurs and giant squirrels were calculated and the results are comparable with other areas in Western Ghats.

A total number of 13 troops of lion-tailed macaques with 200 individuals and 23 troops of Nilgiri langurs with around 150 individuals were recorded. The age sex compositions were measured for nine troops of lion-tailed macaques and 16 troops of Nilgiri langurs. The overall troop sizes of all primates in Nelliampathies were ranging from four to 39 individuals with an average of 15.5.

Habitat suitability analysis was done by GIS modeling method – Ecological Niche Factor Analyis (ENFA). Suitability surfaces were created and conservation implications were analyzed with the current land use practices.

A supervised multispectral satellite image classification was done in remote sensing platform to map the canopy connectivity of the plateau region. The results are analyzed and the shortcomings in current management approaches were discussed. A follow up study is proposed to understand the canopy connectivity and arboreal mammal dynamics in the plateau region.

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Citation:
Ramachandran, K.K. and Suganthasakthivel, R. 2010. Ecology and behaviour of the arboreal mammals of the Nelliampathy Forests. KFRI Research Report No.382. iv + 60 p including 16 colour plates.