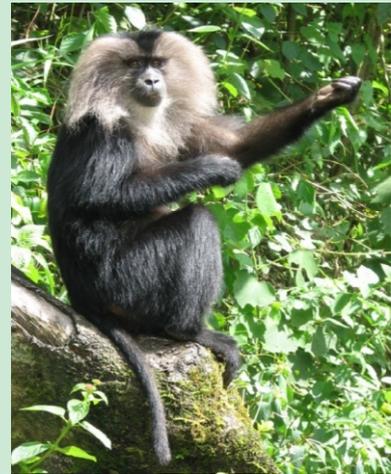# Gap analysis
of
Periyar - Agasthyamalai landscape for arboreal mammal conservation

Final Technical Report
2013

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Executive summary

Globally, the most significant threat to biodiversity is habitat loss caused by human activities. Establishing Protected Areas (PA) has often been a strategy to deal with loss in biodiversity. The Periyar – Agasthyamalai landscape in the southern Western Ghats is one of the key areas for biodiversity conservation. This landscape (5758 km^2) with vast stretches of forests supports many endemic and endangered species. Though a large part (3054 km^2) of the landscape is under Protected Area network, there is still a vast extent of biodiversity rich forests outside this network (2704 km^2). Given the forest contiguity, this landscape is expected to support viable populations of endemic lion-tailed macaque (*Macaca silenus)* and Nilgiri langur (*Semnopithecus johnii*). In addition to these, other diurnal arboreal mammals that occur in the landscape are the bonnet macaque (*Macaca radiata*), tufted gray langur (*Semnopithecus priam*), grizzled giant squirrel (*Ratufa macroura*) and the Indian giant squirrel (*Ratufa indica*). It is therefore an important site for conservation of these taxa. In order to step up ongoing conservation efforts at a landscape level, we carried out gap analysis for a community of diurnal arboreal mammals that occupy a wide array of habitats in this landscape. The main aim of the study was to identify and prioritize sites outside the current PA network that are critical for conservation of these species, assess existing PAs for adequate representation of these taxa and finally to prepare a draft of site specific recommendations for arboreal mammals conservation in the landscape.

We carried out a detailed review and collation of existing information on arboreal mammal occurrence and conducted field surveys in sites where information was poor. Gaps in information regarding arboreal mammal occurrence were identified and surveys were carried out in sites which lacked information on occurrence of arboreal mammals. Several sites in the landscape *e.g.* Ranni, Konni, Punalur, Thiruvananthapuram Forest Division, Neyyar and Peppara Wildlife Sanctuaries in Kerala and Srivilliputhur, Kanyakumari Wildlife Sanctuaries in Tamilnadu lacked recent information on occurrence of arboreal mammals. Information from secondary sources were combined with information obtained from field surveys and they were used to build species distribution modeling using a maximum likelihood estimation method. These distribution maps were then used in prioritizing sites for conservation using a tool called 'Zonation'. We used 'Additive benefit function' analysis which considers species

richness in a site rather than probability of a single species occurring while prioritizing. The result is a hierarchical ranking of the landscape based on probability of occurrence of all species in a site.

Our results indicate that a large extent (~ 1265 km^2) of important sites for arboreal mammals outside the existing network of PAs. In the Agasthyamalai landscape ~ 90% of the landscape has already been incorporated under the existing PA network. On the other hand, in the Periyar landscape, 2336 km^2 of contiguous forests exist outside the current network of Protected Areas. These forests are high priority sites for conservation of arboreal mammals. For long term persistence of these species in the landscape, it is essential that these sites are protected. Based on the results of the study, a working draft of recommendations was prepared which was discussed and finalized during a consultative workshop with managers and scientists working in the landscape. Some key recommendations include: rationalizing boundaries of Shendurney Wildlife Sanctuary to incorporate crucial sites in Kolathupuzha range and Peppara Wildlife Sanctuary to include sites in Palode and Paruthipally ranges for conservation of arboreal mammals; a contiguous stretch of 572 km^2 of high priority areas falling within Ranni, Achenkoil and Konni to be incorporated into Periyar Tiger Reserve or set aside for creation of a new PA; mitigation measures for linear barriers such as deploying canopy bridges at appropriate places to facilitate movement of arboreal mammals across the Shencottah gap, regulating traffic on roads passing through forested sites such as Angamoozhy to Vallakadavu road; habitat improvement and fostering connectivity through stream corridors in sites closer to the Shencottah gap such as in Punalur and Thenmala Forest Divisions; research recommendations such as establishing baseline population estimates and habitat assessment for long term monitoring. In Tamilnadu, key recommendations include: protection of grizzled giant squirrels outside the Srivilliputhur Wildlife Sanctuary boundary by fostering incentive based mechanism with the local farmers; dry forests of Srvilliputhur and Tirunelveli Forest Division remain vulnerable to habitat degradation due to fuel wood collection from adjoining human settlements and therefore alternative fuel resources need to be explored; private estates in the upper reaches of these two sites need to be acquired for long term conservation of these sites; in Kanyakumari WLS, the high priority sites adjoining private estates need to be monitored for habitat degradation; establishing baseline population estimates of arboreal mammals in all three sites are required.

Introduction

Habitat loss due to anthropogenic factors is widely acknowledged to be a major threat to biodiversity. In such a scenario, establishing new Protected Areas has been a strategy to check habitat degradation and consequently biodiversity loss (Gaston et al. 2008). Often sites have been designated as Protected Areas (PA) without due consideration to biodiversity values while areas which deserve protection remain neglected (Margules and Pressey, 2000; Rodrigues et al. 2004). Most PAs are established in remote and rugged terrain and in areas which are economically inviable (Margules and Pressey, 2000). While it is relatively straightforward to declare such areas as PAs, there are economic and social ramifications in declaring areas with land use practices that are in conflict with objectives of the PA (Margules and Pressey, 2000). Nevertheless, areas containing multiple land uses are also critical for conservation, especially if, they harbor native species and if located within wildlife corridors. The process of integrating such areas in PA management entails huge costs for both PA management and local communities. Therefore alternatives that seek to minimize costs while achieving conservation targets have to be explored. As a first step, in order to justify implementation of conservation measures, it is important to map key biodiversity features within the landscape. Conservation gap analysis is a method for identifying gaps in protection for species assemblages or ecosystems and assessing representativeness of biodiversity features within existing Protected Areas (Scott et al. 1993). Gap analysis provides an opportunity to map these biodiversity elements with reference to existing PAs and provides managers, conservationists and policy makers with relevant information to prioritize sites for conservation (Jennings, 2000; Oldfield et al. 2004). It is therefore, an effective tool for assessing management strategies and planning future conservation actions. Conservation actions often are species-specific, however, targeting an assemblage of species with similar habitat requirements, at a landscape level could have important implications for conservation (Margules and Pressey, 2000). Choice of species surrogates for landscape level conservation is critical as it should well represent biodiversity of the landscape (Coppolillo et al. 2004; Wiens et al. 2008).

The mountains of the Western Ghats of southern India are a global biodiversity hot spot (Myers et al. 2000). Periyar – Srivilliputhur and Agasthyamalai hills situated in the

southern extremity of this mountain range, contain some of the most expansive stretches of biodiversity rich forests and unique evergreen ecosystems. This landscape harboring many endemic and endangered species has been identified as one of the priority sites for biodiversity conservation (Ramesh et al. 1997; Das et al. 2006). Given the vast extent of forests, the Periyar – Agasthyamalai landscape is home to a suite of arboreal mammals, some of them endemic to the Western Ghats and contain unique ecosystems, such as *Myristica* swamps (Ramesh et al. 1997). The forests outside the PA network in this landscape have been historically managed for silviculture and to raise plantations of teak (*Tectona grandis*), *Eucalyptus* spp., and rubber (*Hevea brasiliensis*) since the 19th century (Chundammanil, 1993). Considerable stretches of biodiversity rich forests still lie outside this network. Yet, anthropogenic pressures continue to impact these forests unabated. While almost 90% of the Agasthyamalai hill range is under Protected Area network, in the Periyar landscape, huge extent of forests lies outside the PA network. Only two Protected Areas exists - Periyar Tiger Reserve (PTR) and Srivilliputhur grizzled giant squirrel Wildlife Sanctuary.

The Periyar - Agasthyamalai landscape harbors viable populations of endemic primates such as the lion-tailed macaque, *Macaca silenus* and the Nilgiri langur, *Semnopithecus johnii* (Easa et al. 1997; Ram, 2007; Sushma et al. 2010). In addition to these, it harbors the bonnet macaque *Macaca radiata diluta*, and the tufted gray langur *Semnopithecus priam thersites*. The grizzled giant squirrel *Ratufa macroura* and the Indian giant squirrel *Ratufa indica* are other arboreal mammals that occur in the landscape. Population status of these species outside PAs in the landscape is poorly known. Even within PAs, only Kalakad – Mundanthurai Tiger Reserve (KMTR) has been recently assessed for primates (Ram et al. 2006; Sushma et al. 2010) whereas all other areas have either never been assessed or assessed almost two decades ago (Ramachandran et al. 1992).

In order to strengthen ongoing conservation efforts in the landscape and to prioritize sites for landscape level conservation, a guild of arboreal species that best represent a wide array of habitat characteristics of the landscape – from the obligate rain forest species such as the lion-tailed macaque to the dry forests species such as the gray langur and the grizzled giant squirrel were selected for the present study. Habitat loss, habitat fragmentation and poaching are some of the imminent threats that these species face across their distributional

range (Joshua and Johnsingh, 1994; Umapathy and Kumar, 2000; Singh et al. 2002; Ram, 2007). The Conservation Assessment and Management Plans of these taxa address these issues at the regional level and do not make site-specific conservation recommendations (see Molur et al. 2003 and 2005). The chief aim of the study was to identify gaps in conservation for arboreal mammals outside the PA network, assess existing PAs for adequate representation of these taxa and draw a site-specific conservation recommendations for arboreal mammals in the landscape.

Objectives

- To determine the current distribution of arboreal mammals in the Periyar-Agasthyamalai landscape
- To determine what factors – physical variables, habitat or threats, play an important role in delineating current distributions
- To identify important forests outside the PA network that support populations of these threatened arboreal mammals and assessing potential distributions of these threatened species within PAs, and
- To draw site specific recommendations for a conservation and management plan for these arboreal mammals

Study area

Periyar – Agasthyamalai landscape consists of two mountain ranges *viz* Periyar Srivilliputhur hills and the Agasthyamalai hills spread across the states of Kerala and Tamilnadu. These two forested complexes are separated by the Shencottah gap at ~ 9° N. The main forest types in the landscape include West Coast Tropical Evergreen Forest (1A/C4), Tirunelveli Semi-evergreen Forest (2A/C3), West Coast Semi-evergreen Forest (2A/C2), Southern Moist Mixed Deciduous Forest (3B/C2), Southern Dry Mixed Deciduous Forest (5A/C3) and Carnatic Umbrella Thorn Forest (6A/C2) (Champion and Seth, 1968). This landscape harbors diverse array of fauna and flora many of which are endemic species. Although the landscape is known for its vast extent of natural forests, there are several plantations, both private and government, human settlements and reservoirs which are interspersed with the forest tracts.

The Periyar – Agasthymalai landscape encompasses various management units differing in their protection status. Whereas, the Agasthyamalai hills are well represented within the existing PA network, the Periyar Srivilliputhur hill range consists of only two PA s (Fig. 1). Among the Protected Areas in the landscape, Periyar Tiger Reserve and Kalakad Mundanthurai Tiger Reserve are the largest PA s (Table1) and among the territorial divisions Ranni Forest Division is the largest area wise. The intervening site at the Shencottah gap consists of numerous human settlements and commercial plantations exist besides a National Highway (NH 208) and a railway track that intersect the landscape.

The landscape consists of some of the oldest forest reserves in the country such as Konni Reserve Forest and these forests have been actively managed since the last two hundred years (Chundammanil, 1993). Earliest conservation initiative in the landscape was the declaration of Nellikampetty Sanctuary in 1934 to encompass area around the Thekkady lake for "game preservation". However, in 1950 this was expanded to include adjoining reserve forests and was renamed as Periyar Wildlife Sanctuary. Historically, Protected Areas in the landscape were established either for conservation of a single species or watershed conservation. For example, Kalakad Wildlife Sanctuary was established in 1977 primarily for conservation of the lion-tailed macaque and the Srivilliputhur grizzled giant squirrel Wildlife Sanctuary was established in 1988 for grizzled giant squirrel conservation. Other sanctuaries such as Shendurney, Peppara and Neyyar Wildlife Sanctuaries were established subsequent to

completion of hydroelectric and irrigation projects primarily for biodiversity and watershed conservation. A recent addition to this list of PAs in the landscape is Kanyakumari Wildlife Sanctuary which was constituted in 2007. Despite these efforts in setting aside areas for conservation, these efforts have afforded little thought to landscape level conservation planning. There still exists large stretches of forests outside this network (Table 1).

Since the main aim of the project was to identify important sites for conservation outside PAs, our primary area of interest included reserve forests and smaller Protected Areas. The study area included all territorial divisions and Protected Areas south of Periyar Tiger Reserve in Kerala while in Tamilnadu, the study area included Srivilliputhur grizzled giant squirrel Wildlife Sanctuary, Tirunelveli Forest Division and Kanyakumari Wildlife Sanctuary. Territorial divisions, reserve forests, Wildlife Sanctuaries and Tiger Reserves are various administrative units, as referred in the Indian Forest Act, 1927 and Wildlife (Protection) Amendment Act, 2002 (http://envfor.nic.in/), differing in their protection regimes.

Table 1. Total extent of area under each of the study sites in the landscape.

	Status	**Area (in km^2)**
KMTR	Protected Area	895
Kanyakumari	Protected Area	402.39
Neyyar	Protected Area	128
PTR	Protected Area	925
Peppara	Protected Area	53
Shendurney	Protected Area	171
Srivilliputhur	Protected Area	480
Total PA		**3054.39**
Achankovil	Reserved Forest	284
Konni	Reserved Forest	331
Punalur (Pathanapuram)	Reserved Forest	280
Ranni	Reserved Forest	911
Thiruvananthapuram	Reserved Forest	368
Tirunelveli	Reserved Forest	399
Thenmala	Reserved Forest	131
Total RFs		**2704**

Fig 1. Study area map showing the current Protected Area network and territorial divisions in the landscape
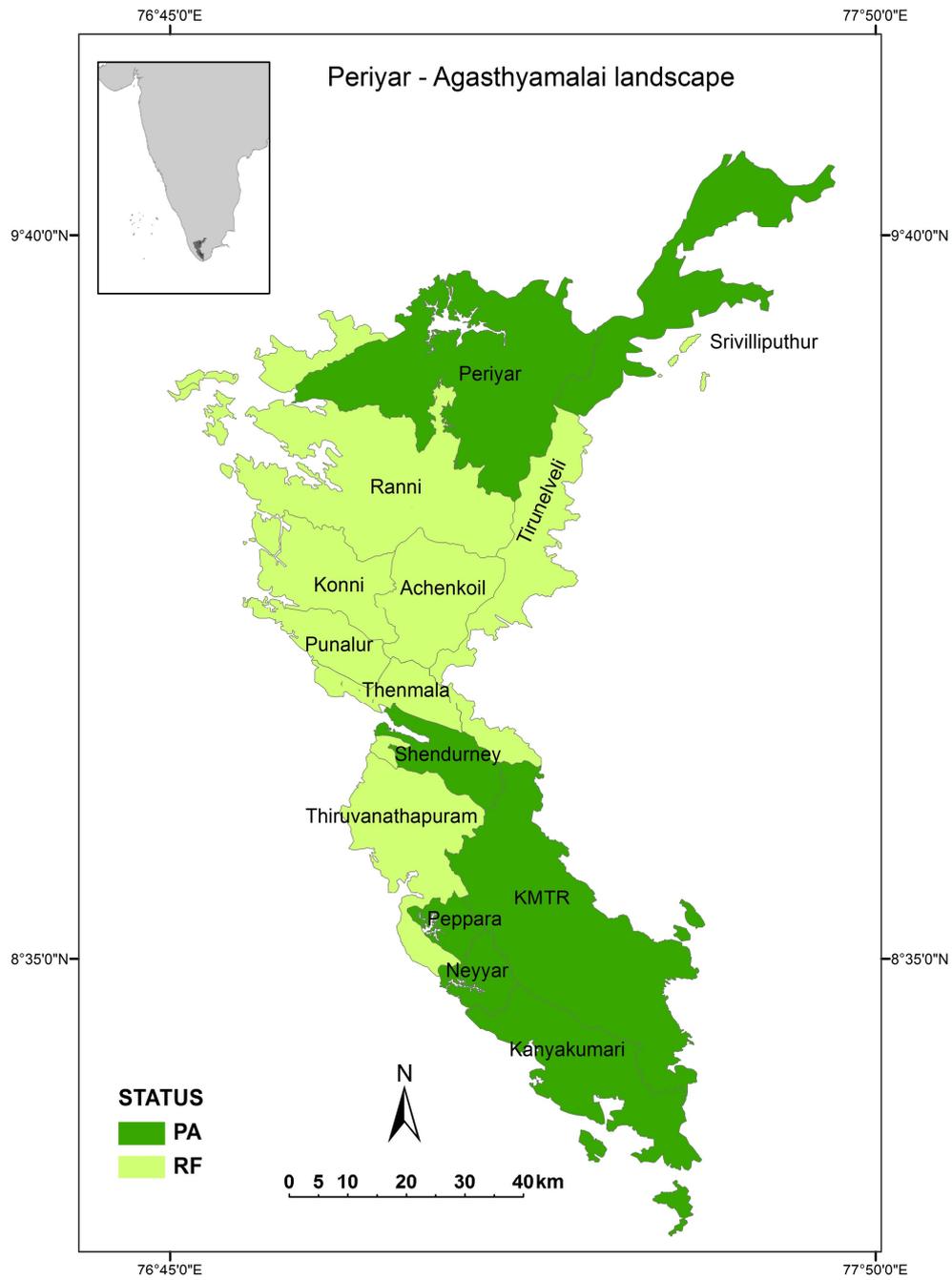
Study species

The **lion-tailed macaque (LTM)** primarily occurs in the evergreen forests of the Western Ghats of Karnataka, Kerala and Tamilnadu. Its northernmost distributional limit is the forests of Sirsi and Honnavara (14° 55' N) in Karnataka and the southernmost limit is the Agasthyamalai hills (8° 25' N) of Kerala and Tamilnadu. The LTM has unique life history traits such as delayed sexual maturity, low birth rate, longer inter-birth interval and selective feeding habits (Kumar, 1987). Habitat loss, habitat fragmentation and hunting are major threats to this species. Presently, fewer than 2500 mature individuals occur in the wild (Molur et al. 2003). The macaque is listed as Endangered by the IUCN. The **Nilgiri langur (NL)** occurs in evergreen forests, semi-evergreen, montane evergreen and moist deciduous forests of the Western Ghats from Brahmagiri hills (12° 01' N) in Karnataka to Agathyamalai hills in the southern extremity of the Ghats. It is classified as Vulnerable species (Singh et al. 2008). Poaching is the main threat faced by this primate as it has been historically hunted in many parts of its range for supposedly medicinal value of its meat (Molur et al. 2003).

Tufted gray langur (TGL) is considered as Near Threatened (Molur et al. 2008) and occurs in the southern Western Ghats in Tamilnadu and in Sri Lanka. It mainly occurs in dry deciduous forests (Molur et al. 2003). Habitat loss is considered to be the main threat to this primate though estimates of global population size are not available. The bonnet macaque **(BM)** is categorized as Least Concern and this subspecies occurs in a wide array of habitats in southern Kerala and Tamilnadu and in coastal Tamil Nadu upto Pondicherry (Singh et al. 2008). The Indian giant squirrel **(IGS)** is widely distributed in peninsular India and is listed as Least Concern (Rajamani et al. 2010). It occurs in moist deciduous forests, evergreen and semi-evergreen forests throughout its range. In many parts of range, this species is hunted for local consumption (Molur et al. 2005).

The grizzled giant squirrel **(GGS)** occurs in Sri Lanka and southern India. It is considered a Near Threatened species and it mainly occurs in riverine and dry deciduous forests (Joshua et al. 2008). In the last 25 years, the grizzled giant squirrel has undergone about 30 % decline in its population size and though it is classified as globally Near Threatened, it is endangered in India due to its current population status (Molur et al. 2005). In India, its population size is estimated to be < 500 mature individuals (Joshua et al. 2008).

Unlike the Indian giant squirrel which has a wider distribution, grizzled giant squirrel has a patchy distribution and occurs as isolated populations restricted to riparian forests of Chinnar Wildlife Sanctuary in Kerala (Senthilkumar et al. 2007), Cauvery Wildlife Sanctuary and Kanakapura Division in Karnataka (Kumara and Singh, 2006) and in Tamil Nadu it occurs in Anaimalai Tiger Reserve (Kumar et al. 2002), Palni hills (personal communication V. Meena), Hosur Forest Division (Baskaran et al. 2011) besides the study site. Habitat loss and degradation due to farming, subsistence hunting, selective logging, forest fire, continue to be significant threats for its survival (Molur et al. 2005).

Lion-tailed macaque (*Macaca silenus*)
IUCN status: Endangered
Wildlife Protection Act, India: Schedule I
Population in the wild: 3500 – 4000

Nilgiri langur (*Semnopithecus johnii*)
IUCN status: Vulnerable
Wildlife Protection Act, India: Schedule I
Population in the wild: < 20,000

Bonnet macaque (*Macaca radiata*)
IUCN status: Least Concern
Wildlife Protection Act, India: Schedule II
Population in the wild: Abundant (no estimates available)

Grizzled giant squirrel (*Ratufa macroura*)
IUCN status: Near Threatened
Wildlife Protection Act, India: Schedule I
Population in the wild: ~ 800 individuals in India

Tufted gray langur (*Semnopithecus priam*)
IUCN status: Near Threatened
Wildlife Protection Act, India: Schedule II
Population in the wild: No estimates available

Indian giant squirrel (*Ratufa indica*)
IUCN status: Least Concern
Wildlife Protection Act, India: Schedule II
Population in the wild: Abundant

Methods

Secondary data collection

In order to determine the current distribution of the study species, information from published literature, technical reports, unpublished information with other researchers, census reports were reviewed. Since secondary information was available at various spatio - temporal scale, in order to standardize information, certain basic criteria were set:

a) information should not be older than 10 years because some of the target species are reported to be locally extinct in the last two decades in sites where they occurred before (Kumara and Sinha, 2009).

b) Only point occurrences from field surveys were used since these were required for the species distribution modeling.

Field survey

Then, field surveys were carried out in areas where information was not available. Existing network of trails, animal paths and coupe roads were used for the surveys. All sighting locations of the study species were recorded using a hand held GPS. In some of the areas, where sightings were rare, surveys were repeated in an area for at least three times till detections of the target species were obtained.

Species distribution

Unique point occurrences from both field surveys and secondary sources were used to build a species distribution map for the study species using maximum likelihood method developed for 'presence only' data (Royle et al. 2012). Maximum likelihood estimation method was used instead of the more popular habitat suitability indices such as the 'MaxEnt' (Philips et al. 2006) because of the recent critical reviews of the latter method (Royle et al. 2012; Yackulic et al. 2012). We predicted probability of occurrence as:

logit $(\psi_x) = \beta_0 + \beta_i \, Z_{ix}$

where logit (ψ_x) is the log odds of ψ at location x, β_0 is the intercept paramater estimate; β_i is the parameter estimates of i covariates and Z_{ix} are the values of i covariates at location x.

Analysis was carried out in Rstudio statistical software (Rstudio, 2012) using 'Maxlike' package (Royle et al. 2012). A stepwise procedure was used in order to build models wherein each of the covariates was iteratively added to a model and the respective AIC value obtained. Model selection was based on AIC value (Burnham and Anderson, 2002). The model with the lowest AIC value was adjudged the best model. Models were ranked based on *delta* AIC. Remotely sensed surrogates were used for habitat and disturbance as covariates of species distribution in the analysis. Since all the six species differ in their ecological requirements, different sets of covariates were used for modeling suitable habitat for each of these species. Environmental variables used in the analysis are briefly described below:

Habitat eco-climatic distance This is a remotely sensed covariate that describes relative deciduousness of habitat and has spatial resolution of 250 m. It represents Mahalanobis distance from a reference class of evergreen vegetation to compute similarity of pixels to this reference class of vegetation (Krishnaswamy et al. 2009). It is a continuous variable with values ranging from 0 to ~ 36000. Values closer to zero denote evergreen vegetation and values farther from zero denotes deciduousness.

Aridity Global aridity layer (Trabucco and Zomer, 2009, http://www.cgiar-csi.org/) was used as a surrogate for productivity and local microclimatic conditions. It is used to obtain information on relative humidity at a site. It is used to quantify precipitation availability over atmospheric water demand. This layer gives the mean aridity index for the period between 1950-2000 at a spatial resolution 1 km.

Canopy height This global dataset (Simard et al. 2011, http://lidarradar.jpl.nasa.gov/) was used to obtain information on canopy height at a site. This layer with a spatial resolution of 1 km is based on data from space-borne LIDAR (light detection and ranging) images. Each pixel value represents average canopy height in meters.

Elevation A 30 m resolution ASTER GDEM version 2 image downloaded from http://asterweb.jpl.nasa.gov/data.asp was used to obtain data on elevation and slope was derived from this layer.

Bioclimatic layers Two precipitation variables describing mean annual precipitation and

precipitation seasonality were used. These datasets available at a spatial resolution of 1 km were downloaded from http://www.worldclim.org/ (Hijmans et al. 2005).

Tree cover This dataset based on MODIS Vegetation Continuous Field, represents percent tree cover at a spatial resolution of 250 m (DiMiceli et al. 2011). This layer (2010 dataset) was used for the analysis. Values in the dataset range from 0 to 100.

Disturbance A remotely sensed surrogate for human influence on natural areas called the 'human footprint index' was used for the analysis (Sanderson et al. 2002). This dataset is based on the nine geographical datasets which combines population density, land transformation, power infrastructure and accessibility. This index represents values ranging from 0 to 72, with higher values indicating greater human influence.

All layers were re-sampled to a spatial resolution of 1km, approximately 30 arc seconds, using ArcGIS version 10 (ESRI, Redlands, CA). These layers were scaled and centered in order to facilitate the numerical algorithm of the maximum likelihood estimation to converge. Processing of layers and standardizing them for the analysis was carried out in Rstudio statistical software (Rstudio, 2012) using 'Raster' package (Hijmans and van Etten, 2012).

Since the lion-tailed macaque primarily inhabits the low and mid elevation evergreen forests, the following layers were used as surrogates for the habitat of the macaque: aridity and precipitation seasonality as surrogates for primary productivity, habitat eco-climatic distance, canopy height, elevation as habitat surrogates. Additionally, human impact index layer was used as a surrogate for disturbance. The Indian giant squirrel is a habitat generalist and occurs in a wide range of habitats from moist deciduous forests to evergreen forests and at an elevational range of 180 m to 2300 m (Rajamani et al. 2010). The covariates used for modeling suitable habitat were aridity, canopy height, habitat eco-climatic distance and elevation. The grizzled giant squirrel occurs primarily in the dry deciduous and riverine forests at an elevational range of 150 m to 500 m (Joshua et al. 2008). In the Periyar - Agasthyamalai landscape, it occurs in Srivilliputhur Wildlife Sanctuary and Theni Forest Division. The habitat surrogates used for modeling suitable habitat for this species were: aridity, habitat eco-climatic distance, elevation, tree cover and precipitation seasonality. The

tufted gray langur mainly occurs in drier habitats on the eastern slopes of the Western Ghats. On the contrary, Nilgiri langur occurs in a wide range of habitats such as moist deciduous, semi-evergreen, riverine, wet evergreen and montane wet evergreen forests in the Western Ghats. The following environmental covariates were used to predict suitable habitat for the langurs in the landscape: habitat eco-climatic distance, tree cover, aridity, precipitation seasonality, elevation, slope, mean annual precipitation, canopy height and disturbance to model their habitats.

Spatial conservation prioritization

In order spatially prioritize the landscape for conservation, the software 'Zonation' (version 3.1) (Moilanen et al. 2012) was used. This algorithm offers a framework for landscape level conservation planning. It identifies areas or sites that are critical for retaining biodiversity features (habitat types, species distributions, etc). The algorithm employs a cell removal rule by which it iteratively removes cells or sites which have least conservation value first and cells which are most valuable last, while minimizing marginal loss of conservation value and accounting at the same time for connectivity and priorities given for different biodiversity features (Moilanen et al. 2012). The output map consists of cell values representing proportional loss of biodiversity features/species from the landscape if a particular cell is removed during the prioritization process (Moilanen et al. 2012). For example, a value of 0.6 means that only 40 % of the species distribution remains in the landscape after that particular cell is removed. Additive benefit function (ABF) analysis was carried out, which takes into all species proportions in a cell instead one species that has the highest value in a particular cell. In other words, it ranks the sites according to number of species present at a particular cell. Additionally, study species were assigned weights according to their IUCN Redlist status. Cells which had a value ≤ 0.5 were classified as 'high priority   sites'.

Project workshop

One of the main aims of the study was to draft site-specific recommendations for conservation of arboreal mammals in Periyar – Agasthyamalai landscape. This study is the first endeavor which targets landscape level conservation specifically for arboreal mammals. Based on the results of the study, a working draft of site-specific conservation recommendations was prepared and a workshop was conducted in Thiruvananthapuram to

discuss and finalize these recommendations in consultation with managers and scientists working in the landscape. Three groups were formed for the exercise based on different sites. The northern region comprised of Periyar Tiger Reserve, Ranni, Konni and Achenkoil Forest Division. The central region comprised of Thenmala Forest Division, Shendurney Wildlife Sanctuary and the southern region consisted of Thiruvananthapuram Wildlife Division and Thiruvananthapuram Forest Division. The workshop exercise had five major components about which a set of questions were given to the participants (Annexure 3). These questions dealt with 1) species distribution in the landscape, 2) prioritization process, 3) human settlements and production landscapes within the high priority sites, 4) prevalent threats and 5) recommendations at site level. Inputs received during the workshop were incorporated and the final draft of the recommendations is presented in the following section.

Results and discussion

Distribution of arboreal mammals in Periyar – Agasthyamalai landscape

Information on arboreal mammals in Periyar – Agasthyamalai landscape was sparse. While some areas such as KMTR were recently surveyed (Ram et al. 2006; Sushma et al. 2010), others such as Kanyakumari WLS, Punalur Forest Division had never been systematically assessed for occurrence of arboreal mammals. Census reports provided little information as they were at the level of an entire division with poor or no details about sightings (Easa et al. 2002). While some of the recent published information was at the level of entire landscape (Ram, 2007; Pillay et al. 2011), others which were site specific survey reports on arboreal mammals were older than 10 y (Easa et al. 1997; Ramachandran, 1995; Joshua, 1992). Researchers who are currently working in the landscape or worked in the recent past (< 10 y) were also contacted to share unpublished information in terms point records with geo-coordinates. Only four recent surveys provided such information. Information collated and data gaps for each of the sites are summarized in the Annexure 1.

Surveys were carried out in the following areas: Ranni Forest Division, Punalur Forest Division, Thiruvananthapuram Forest Division, Shendurney Wildlife Sanctuary, Neyyar and Peppara Wildlife Sanctuaries in Kerala. In Tamilnadu, surveys were carried out in Kanyakumari Wildlife Sanctuary and Srivilliputhur grizzled giant squirrel sanctuary. Total length of trails used for the survey was 522 km and total sampled area was 1040 km^2. For species distribution modeling 123, 411,171,126, 456 and 63 unique point locations of LTM, NL, TGL, BM, IGS and GGS respectively were used.

The covariates estimated to be the most important for predicting occurrence probability of the LTM were canopy height, precipitation seasonality, habitat eco-climatic distance, elevation, aridity and disturbance. Some of the covariates showed a negative relationship with occurrence probability (Table 2 a). Precipitation seasonality, habitat eco-climatic distance and disturbance had an inverse relationship indicating that lower the values of the covariates, higher the occurrence probability. For the BM, all three covariates used were present in the final model *viz,* percent tree cover, habitat eco-climatic distance and

disturbance (Table 2 b). For the IGS, the most important covariates were aridity, habitat eco-climatic distance and elevation, the latter two being negatively related to occurrence probability (Table 2 c). Important covariates for the GGS were aridity, eco-climatic distance, elevation and percent tree cover (Table 2 d). For the TGL, important covariates included habitat eco-climatic distance, slope, precipitation seasonality, aridity and tree cover (Table 1e), while occurrence probability of NL was determined by the following: tree cover, elevation, disturbance, precipitation seasonality, canopy height, habitat eco-climatic distance and slope (Table 1 f).

While two of the study species have a wide distribution within the landscape (BM and IGS), the LTM, NL, GGS and the TGL were restricted to only certain parts of the landscape (Fig 2, 3 and 4). The latter two species occur only on the eastern slopes of the landscape (Fig. 3 and 4). The GGS occurs only in Srivilliputhur landscape and in a few adjoining sites in Theni Forest Division. The study results indicate that a large extent of the distribution (high probability) of all the study species lies outside the current PA network in the landscape (Table 3). For the LTM and NL, KMTR and PTR hold the largest extent of area under high occurrence probability among the PAs (Table 3 a, b). Outside the PA network, Ranni Forest Division has the largest extent of high occurrence area for both the species. In the case of TGL and GGS, Srivilliputhur grizzled giant squirrel sanctuary holds the largest extent of species distribution among the PAs (Table 3 c, d). While the GGS occurs only in Srivilliputhur Sanctuary, the gray langur also occurs in KMTR and Tirunelveli Forest Division.

Table 2. Parameter estimates of the species distribution model of lion-tailed macaque b) bonnet macaque c) Indian giant squirrel d) grizzled giant squirrel e) tufted gray langur f) Nilgiri langur.

a)

	Estimate	Effect	SE
Intercept	4.329		1.706
Aridity	1.013	+	0.685
Precipitation seasonality	-4.535	-	1.939
Canopy height	0.618	+	0.273
Habitat eco-climatic distance	-0.891	-	0.355
Elevation	3.471	+	1.523
Disturbance	-0.537	-	0.383

b)

	Estimates	Effect	S.E.
Intercept	5.732		3.416
Tree cover	1.710	+	0.809
Habitat eco-climatic distance	-0.956	-	0.710
Disturbance	-0.650	-	0.772

c)

	Estimates	Effect	S.E.
Intercept	10.129		2.920
Aridity	5.137	+	1.289
Habitat eco-climatic distance	-1.228	-	0.379
Elevation	-0.732	-	0.806

d)

	Estimates	Effect	S.E.
Intercept	3.211		2.393
Aridity	-0.857	-	0.749
Habitat eco-climatic distance	-1.81	-	0.78
Elevation	-0.87	-	0.984
Tree cover	0.370	+	0.775

e)

	Estimates	Effect	S.E.
Intercept	0.01		0.62
Habitat eco-climatic distance	-1.18	-	0.26
Slope	1.00	+	0.30
Precipitation seasonality	-1.02	-	0.27
Aridity	-1.48	-	0.26
Tree cover	-0.46	-	0.22

f)

	Estimates	Effect	S.E.
Intercept	2.21		0.73
Tree cover	0.90	+	0.27
Elevation	2.40	+	0.47
Disturbance	1.16	+	0.30
Precipitation seasonality	-1.14	-	0.28
Canopy height	0.36	+	0.22
Habitat eco-climatic distance	-0.31	-	0.18
Slope	-0.35	-	0.22

Fig. 2. Distribution of lion-tailed macaque (LTM) and bonnet macaque (BM) in the Periyar – Agasthyamalai landscape
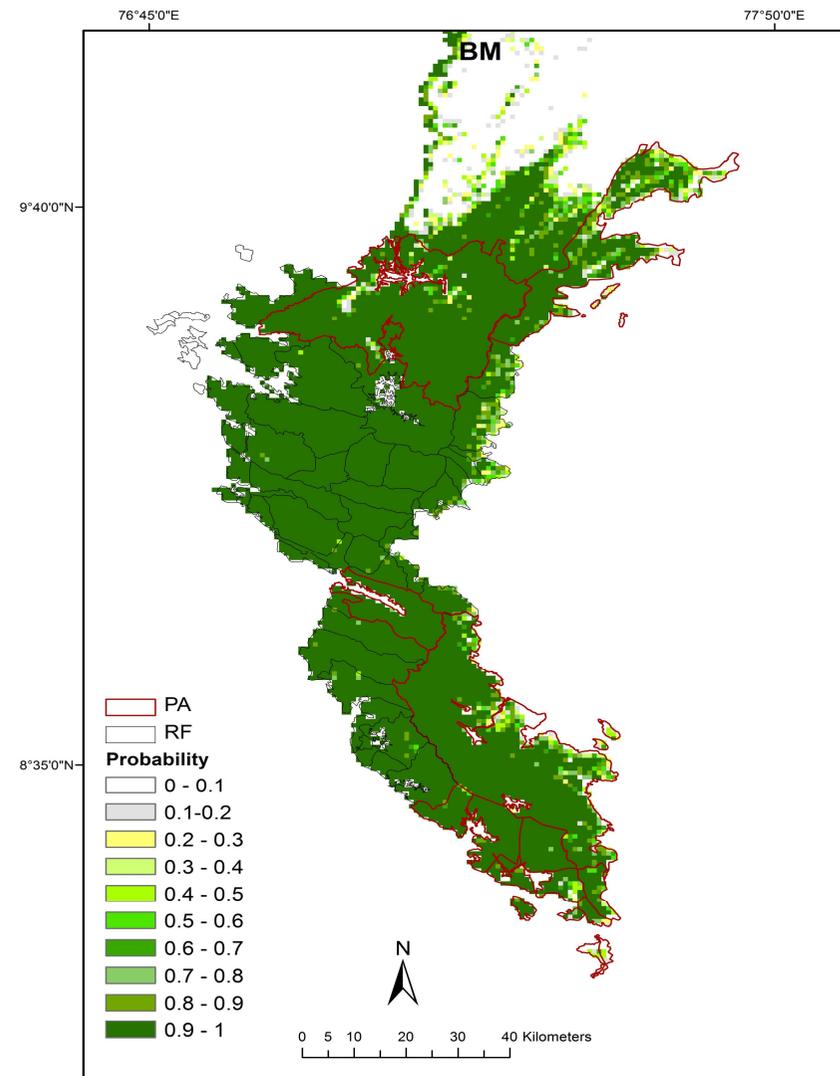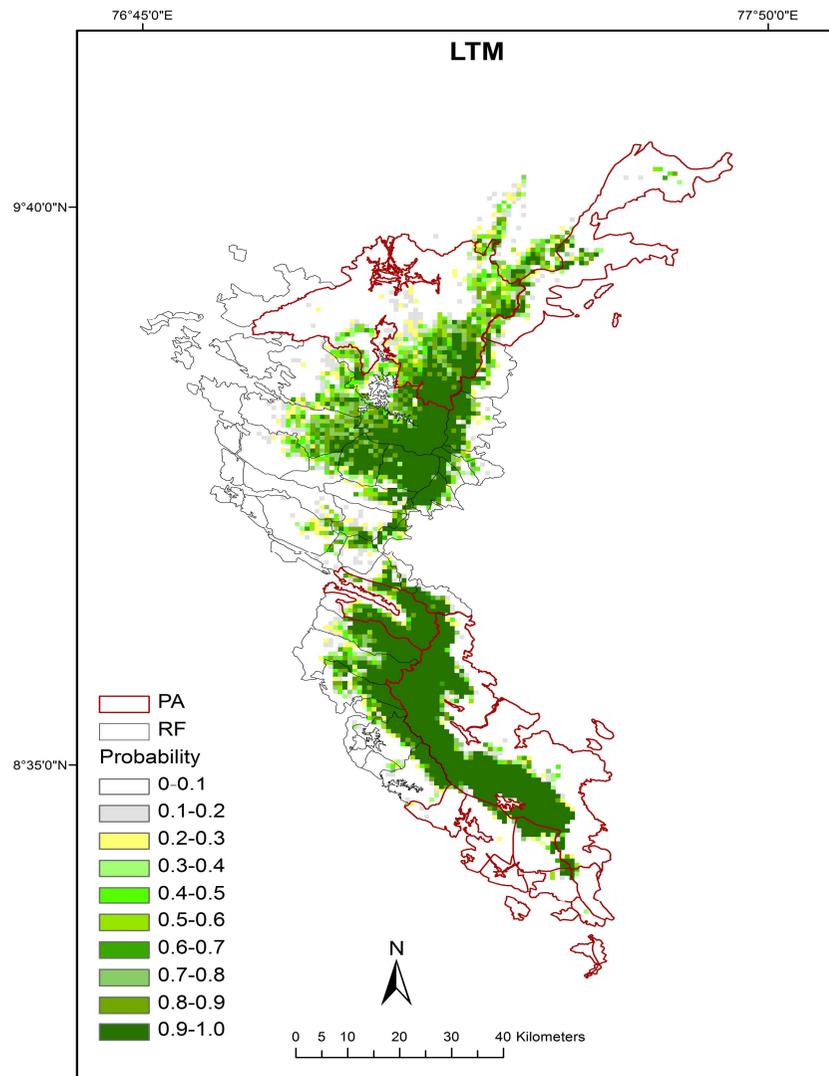
Fig. 3. Distribution of Nilgiri langur (NL) and tufted gray langur (TGL) in the Periyar – Agasthyamalai landscape
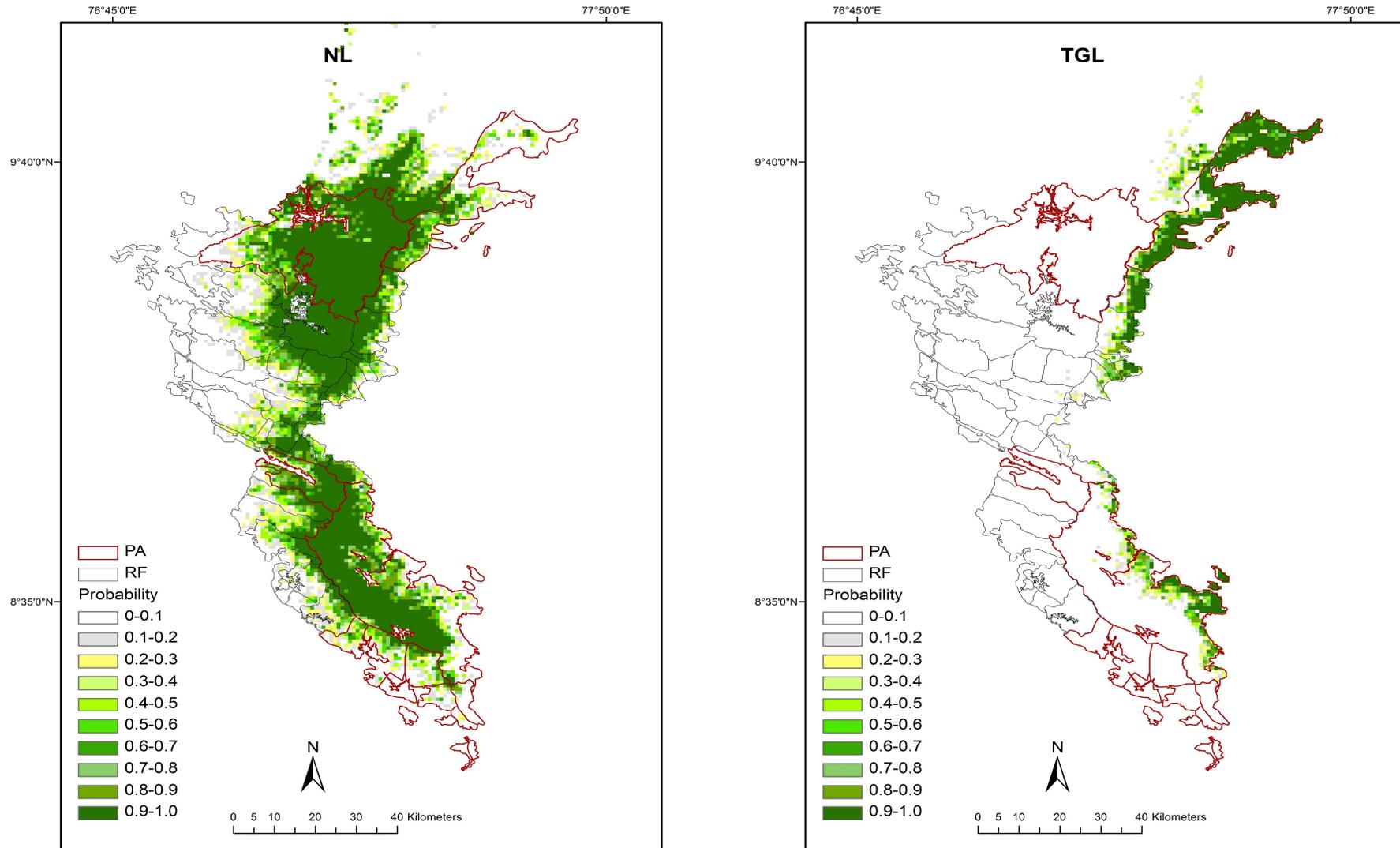
Fig. 4. Distribution of grizzled giant squirrel (GGS) and the Indian giant squirrel (IGS) in Periyar – Agsthyamalai landscape
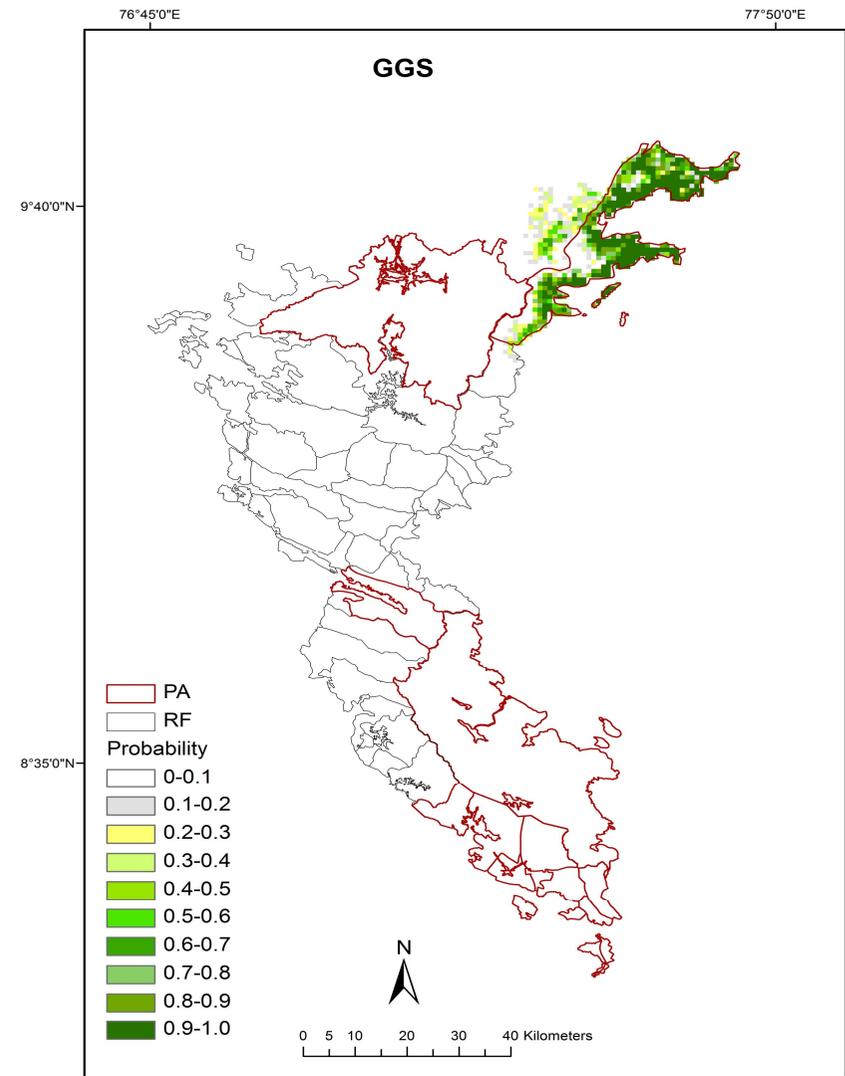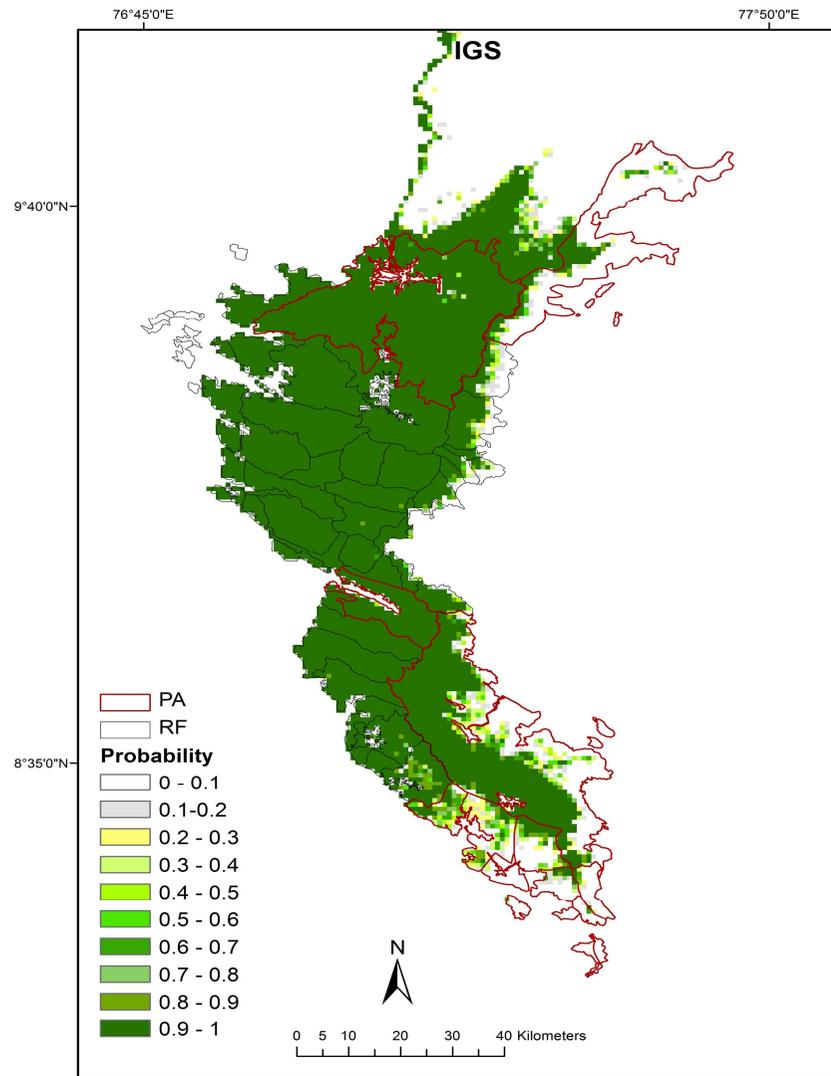
Table 3. Extent of area (in km^2) under very low, low, medium and high probability of LTM, Nl, TGL and GGS occurrence (a, b, c and d) in each of the study sites.

a.

Division	Probability of occurrence of LTM			
	Very low (0-0.1)	Low (0.1-0.3)	Medium (0.3-0.5)	High (0.5-1)
KMTR	364.60	31.74	16.30	460.68
Kanyakumari	351.73	10.29	4.29	41.17
Neyyar	54.90	7.72	2.57	30.88
PTR	476.12	84.07	60.05	259.08
Peppara	31.74	3.43	4.29	26.60
Shendurney	33.45	7.72	5.14	103.80
Srivilliputhur	379.18	17.16	11.15	37.74
Achankovil	78.92	29.16	13.73	179.29
Konni	235.06	20.58	12.01	19.73
Punalur (Pathanapuram)	122.68	11.15	3.43	7.72
Ranni	303.69	65.20	52.33	299.40
Thiruvananthapuram	145.84	39.46	25.74	192.16
Tirunelveli	166.43	31.74	17.16	169
Thenmala	102.08	21.44	6	25.73

b.

Division	Probability of occurrence of NL			
	Very low (0-0.1)	Low (0.1-0.3)	Medium (0.3-0.5)	High (0.5-1)
KMTR	107.23	70.34	58.33	634.83
Kanyakumari	202.46	78.06	43.75	77.20
Neyyar	5.14	36.03	10.29	44.61
PTR	36.88	40.32	28.31	773.81
Peppara	20.59	18.01	5.14	22.30
Shendurney	3.43	3.43	10.29	132.11
Srivilliputhur	195.6	66.05	43.75	139.83
Achankovil	40.32	54.04	27.45	179.29
Konni	240.21	33.46	7.72	6.01
Punalur (Pathanapuram)	101.23	27.45	12.86	3.43
Ranni	214.47	102.94	55.76	347.44
Thiruvananthapuram	110.66	85.78	45.46	161.28
Tirunelveli	38.60	41.17	34.31	270.23
Thenmala	24.02	24.87	19.73	86.64

c.

Division	Probability of occurrence of TGL			
	Very low (0-0.1)	Low (0.1-0.3)	Medium (0.3-0.5)	High (0.5-1)
KMTR	625.4	64.34	40.32	140.7
Kanyakumari	398.9	2.57	0	0
Neyyar	96.08	0	0	0
PTR	878.47	0.85	0	0
Peppara	66.05	0	0	0
Shendurney	148.41	0.85	0	0
Srivilliputhur	33.45	16.4	11.15	384.33
Achankovil	297.68	3.43	0	0
Konni	287.40	0	0	0
Punalur (Pathanapuram)	145	0	0	0
Ranni	720.62	0	0	0
Thiruvananthapuram	399.77	0	0	0
Tirunelveli	186.16	46.32	31.74	120.1
Thenmala	154.41	0.85	0	0

d.

Division	Probability of occurrence of GGS			
	Very low (0-0.1)	Low (0.1-0.3)	Medium (0.3-0.5)	High (0.5-1)
KMTR	873.32	0	0	0
Kanyakumari	407	0	0	0
Neyyar	96.08	0	0	0
PTR	879.33	0	0	0
Peppara	66.05	0	0	0
Shendurney	150.13	0	0	0
Srivilliputhur	72.92	39.46	30.02	302.83
Achankovil	301	0	0	0
Konni	287.4	0	0	0
Punalur (Pathanapuram)	145	0	0	0
Ranni	720.62	0	0	0
Thiruvananthapuram	403	0	0	0
Tirunelveli	378.32	5.14	0.85	0
Thenmala	155.27	0	0	0

Fig. 5. Prioritization of sites within the landscape based on arboreal mammal species richness with reference to the current network of Protected Areas
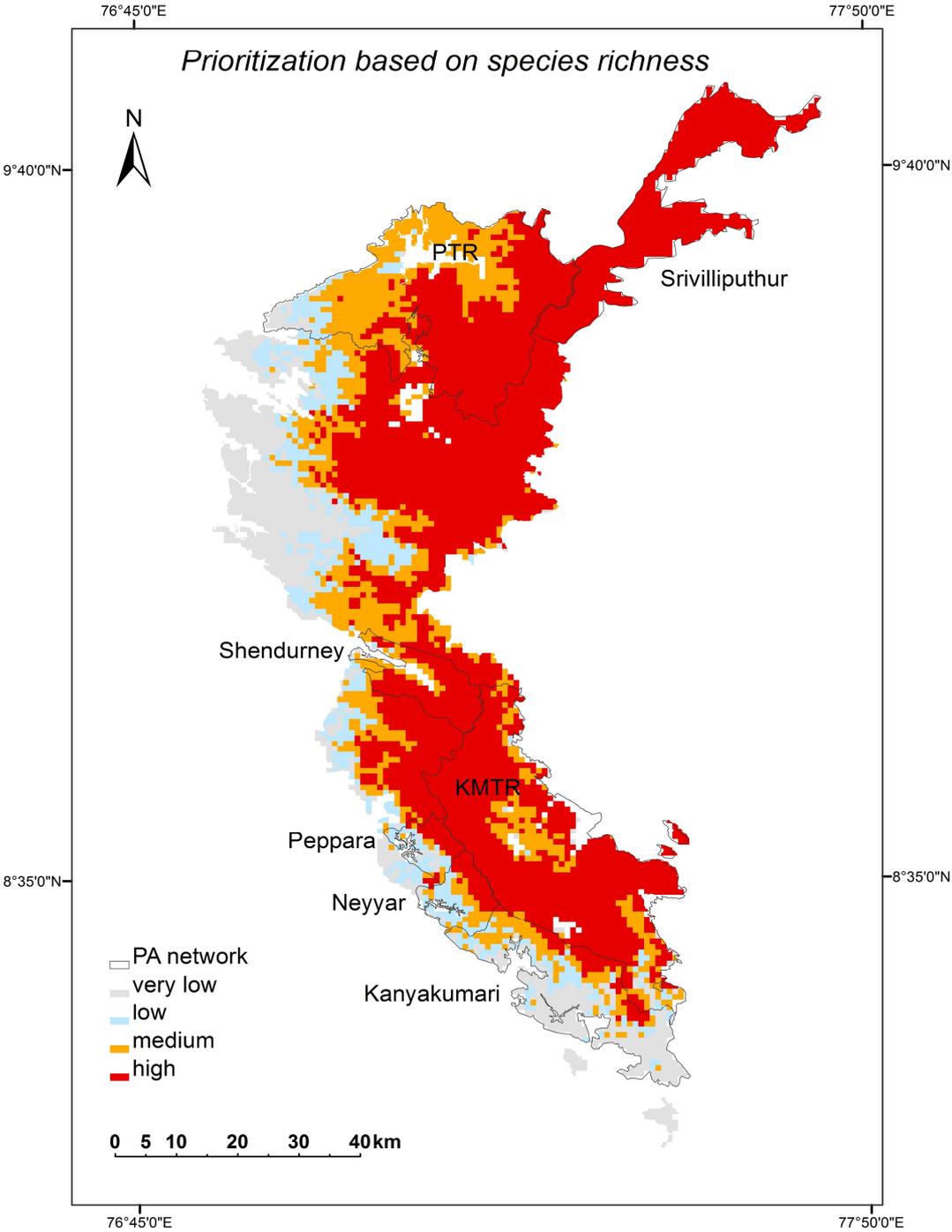
Fig. 6. Total extent of Protected Areas and territorial divisions and total area under high conservation priority for arboreal mammals in the landscape
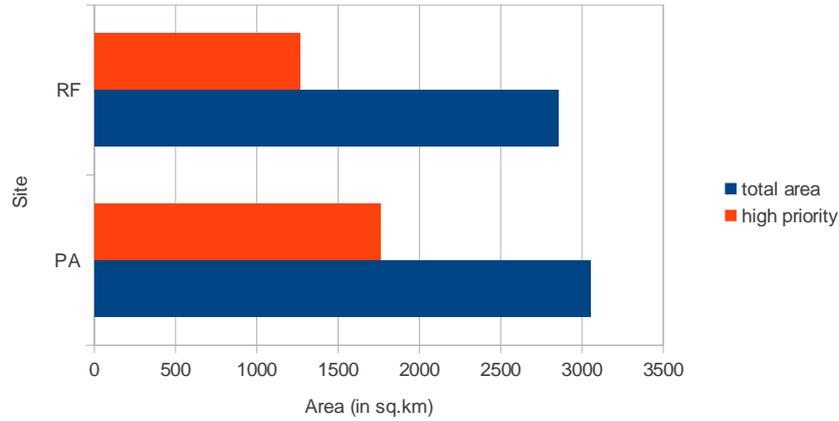
Table 4: Extent of area (in km^2) under high conservation priority sites for arboreal mammals

Division	Priority value					
	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1	Total
KMTR	137.26	122.67	59.19	132.11	252.21	703.46
Kanniyakumari	6.86	12.01	12.86	9.43	1.71	42.89
Neyyar	3.43	3.43	11.15	8.57	6	32.6
PTR	180.15	114.1	122.67	72.06	5.14	494.14
Peppara	4.3	6.01	6.86	9.43	0.85	27.45
Shendurney	11.15	14.6	22.3	35.17	30.88	114.1
Srivilliputhur	0.8	51.47	41.17	95.22	256.5	445.24
Total	292.51	292.51	262.47	359.42	556.73	1763.64
Achankovil	25.73	37.74	67.77	44.6	16.3	192.16
Konni	11.15	7.72	0	0	0	19
Punalur (Pathanapuram)	6.01	0.85	0	0	0	6.86
Ranni	72.92	99.51	96.08	67.77	24.87	361.17
Thiruvananthapuram	30.88	50.61	44.60	49.75	22.3	198.17
Tirunelveli	31.74	90.07	76.35	58.33	78.92	335.43
Thenmala	19.73	11.15	12.01	1.71	0	44.6
Total	253.06	332.81	314.01	226.45	138.96	1265.29

Conservation planning

A large extent of area under high priority sites occurs outside the PA network in the landscape (Fig. 5). Total extent of Protected Areas in Periyar - Agasthyamalai landscape is about 3054 km^2, whereas area under various RF s (Territorial Divisions) is about 2704 km^2 (Fig. 6). Area under high priority sites for arboreal mammal conservation within the PA s and RF s is 1763 km^2 and 1265 km^2 respectively (Table 4). Among the PAs, extent of high priority sites was highest for KMTR followed by Srivilliputhur grizzled giant squirrel WLS (Table 4). Among the territorial divisions, Ranni Forest division had the largest extent of area under high priority sites (361.17 km^2) (Table 4). Although the extent of high priority sites was small in Punalur, Konni and Thenmala divisions, these sites are nevertheless important for arboreal mammals as they are situated at the Shencottah gap and hence important as corridor sites for these species. In the case of two sites, Srivilliputhur and Tirunelveli Forest Division, almost 90 % of their total extent covers high priority sites for conservation of arboreal mammals.

The study reports that there is still a huge extent of high conservation priority area outside the PA network in the Periyar - Agasthyamalai landscape (Fig. 5). While nearly 90 % of the Agasthyamalai landscape south of the Shencottah gap is under protected area network, north of the Shencottah gap only two protected areas exist for an area of 2600 km^2. The region south of Periyar Tiger Reserve especially contains unbroken stretches of forests, hence making them an important region for arboreal mammal conservation. Even within the Agasthyamalai landscape, there are high priority areas outside the current PA network and their extent is much larger than within some of the smaller PA s such as Peppara and Neyyar WLS. The study brings out certain key points for arboreal mammal conservation. Some of these sites such as Vadasserikara range in Ranni Forest Division and Pathanapuram Range in Punalur Division harbor the endangered lion-tailed macaque which was hitherto not reported.

The high priority sites in Vadasserikara and Goodrical ranges form a contiguous stretch of nearly 360 km^2 (Fig. 7). These sites emerge as the largest contiguous stretch outside the existing PA network. Unlike many other sites in the southern Western Ghats which are highly fragmented such as the Anamalai hills (Singh et al. 2002) these sites in Ranni division still contain vast stretches of forests despite developmental activities. It is therefore necessary to protect these forests either

incorporating these areas into Periyar Tiger Reserve or creating a new PA. Other high priority sites in the Periyar landscape in terms of extent of area, were located in Kallar and Kanayar ranges of Achenkoil Forest Division (Fig. 8). In addition to these sites, other sites which are important for arboreal mammal conservation are Punalur and Thenmala Forest Divisions (Fig. 9 and 10). These sites situated near the Shencottah corridor are crucial for the endangered lion-tailed macaque which is a habitat specialist and is affected by habitat fragmentation. Its persistence in these sites necessitates habitat conservation and restoration of corridor across the Shencottah gap. Presence of linear barriers such as the busy national highway and the rail track poses a major problem for dispersing individuals especially since there have been known cases of road kills of these species (Kumara et al. 2000; Raman, 2011). To mitigate adverse effects of these linear barriers and foster connectivity for arboreal mammals, canopy bridges should be used at potential crossing points (Goosem, 2007; Laurence et al. 2009; Raman, 2011). Power-lines are another major linear barrier in the landscape. There have been instances where low lying power-lines have caused mortality of arboreal mammals (Raman, 2011). In the following section, site specific conservation recommendations for arboreal mammals are summarized.

Ranni Forest Division

Ranni Forest Division is the largest territorial division in Kerala with an area of 1059 km^2. It has three ranges namely Vadasserikara, Goodrical and Ranni ranges. Field surveys were carried out in two of these ranges – Vadasserikara and Goodrical. Goodrical range is the largest with an area of 653 km^2. Although this division has vast stretches of natural forests, there are several plantations which are under active forestry regimes. In addition to these, harvesting of reed from natural forests is carried out on a regular basis under the supervision of the Forest Department. Four of the study species occur in this division – LTM, NL, BM and IGS.

Easa et al. (1997) reported about 4 troops of LTM from this division. But given the extent of habitat, this division could potentially hold a larger population. Other reports estimated about 12 groups for cardamom hills landscape (Kumar, 2001). However, there has been no serious attempt to estimate its population size at this site. Results from the species distribution modeling indicate that large portion of suitable habitat exists for the LTM and NL in Goodrical range to the east of Kakki reservoir and eastern portion of Vadasserikara range. Results from the prioritization analysis indicate that 361 km^2 of the division consists of high priority sites for arboreal mammals.

Threats

Potential threats to arboreal mammals in this Division are poaching, habitat degradation due to recurring incidence of fire, invasive species, developmental activities related to Sabarimala pilgrimage, and linear barriers such as roads and power lines which affect the movement of arboreal mammals.

Recommendations

- A major problem that exists in many parts of the Western Ghats is a clear lack of baseline data on population estimates and regular population monitoring program for many species. Therefore, establishing baseline information on population of arboreal mammals is recommended.

- The study results indicate a large extent of high conservation priority area for arboreal mammals in many parts of Goodrical and Vadasserikara ranges. These sites include forests situated east of Kakki reservoir and south-eastern parts of the division covering forests in Gurunathanmannu forest station. These areas contain remote unbroken stretches of forests. Given that the division is one of the few remaining sites in the entire Western Ghats with large stretches of suitable habitat especially for the globally threatened species such as the Nilgiri langur and the lion-tailed macaque, it is recommended that the high priority sites may be incorporated into the existing boundary of Periyar Tiger Reserve. Habitat conservation should be given importance since these forests include many endemic flora such as *Nageia wallichiana*. Absence of human settlements in these forests make them amenable to conservation initiatives.

- Two major roads which traverse through Goodrical range are the Plapally – Moozhayar – Vallakadavu road and the Ranni – Pampa road which lead to Sabarimala. The former road is mainly used by the Electricity Board officials and more recently by tourists while the latter is primarily used by the Sabarimala pilgrims. The road from Plapally to Vallakadavu passes through pristine stretches of forests and the study reports presence of lion-tailed macaque and Nilgiri langur in the forest stretch along this road near Moozhayar. Since this road passes through prime wildlife habitats, it is recommended that traffic regulations in terms of time restrictions and restriction on number of vehicles be imposed. This road should not be widened lest the canopy cover is broken.

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- Continued incidences of fire leading to forest degradation is a concern. Therefore, adequate measures to check fire incidence are required.

- Enhanced patrolling to control poaching is required

- In degraded habitats, inputs to ensure adequate regeneration of native species are required.

Fig. 7. Conservation priority sites in the Ranni Forest Division
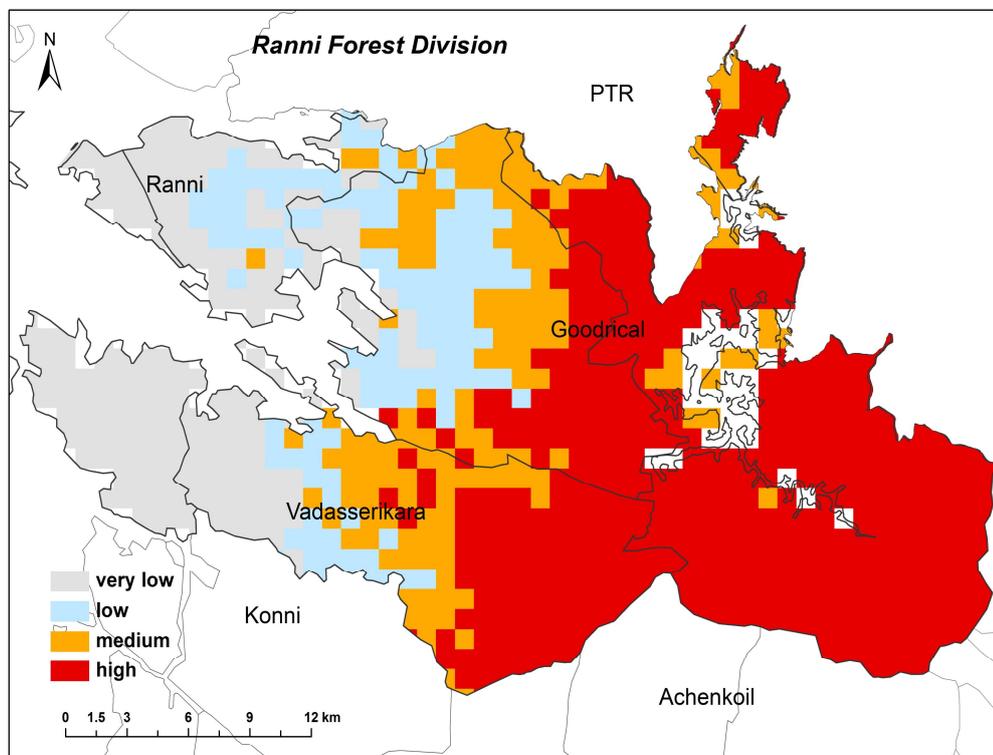
Achenkoil Forest Division

Total extent of this division is 192.16 km^2. There are three ranges in this division – Kanayar, Kallar and Achenkoil. Surveys were not carried out in this division. However, results from other ongoing projects in FERAL show presence of four study species – LTM, NL, IGS and BM. Presence of the endangered lion-tailed macaque was reported from Kanayar and Achenkoil ranges. Results indicate high priority sites adjoining Ranni Division and Tirunelveli Division (Fig. 8) amounting to an area of about 188 km^2.

Threats

Proposed hydroelectric project on Kallar river, poaching, pilgrimage, linear barriers such as roads and powerlines and invasive species.

Recommendations

- The high priority areas do not contain any human settlements. It is recommended that these areas along with the high priority sites in Vadaserrikara, Goodrical, Mannarapara and Naduvathumuzhy ranges (~ 572 km^2) may be declared as a new PA in order to provide highest protection to these forests.

- Proposed conversion of Achenkoil to Konni into a State highway should not be implemented as this is going to widen the road and destroy canopy continuity for arboreal mammals. Even the use of the existing road from Achenkoil to Konni should be regulated and traffic should be controlled by imposing strict rules.

- Proposed hydro-electric project on Kallar river should not be implemented as this is going to submerge large tracts of forests that fall within the high priority sites

- Protection measures to be strengthened to control poaching incidences such as additional manpower for patrolling.

Fig. 8. Conservation priority sites in Achenkoil Forest Division
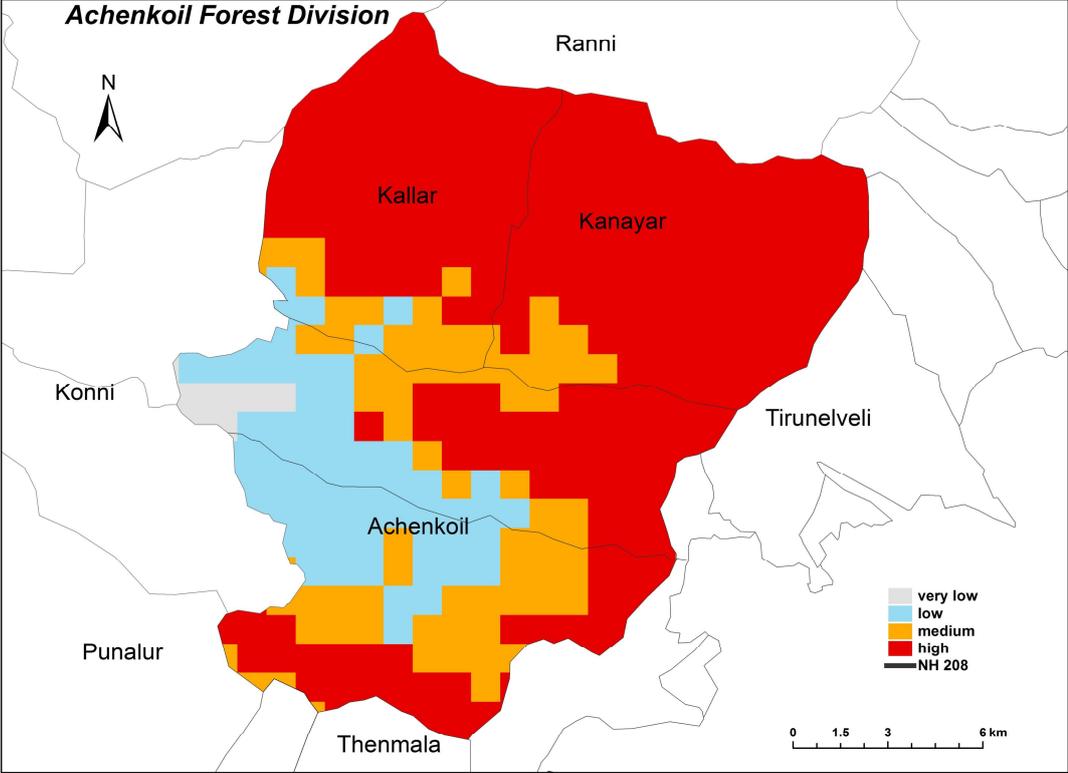
Konni Forest Division

Total are of this division is 331.66 km^2. A large extent of this Division is under plantations. There are three ranges namely Konni, Naduvathumuzhy and Mannarapara. There are settlements in all the three ranges within the forest areas. Surveys could not be undertaken in this site due to limited time and no secondary information was available for this site. However, species distribution maps of LTM and NL indicate suitable habitats, albeit only to a lesser extent (Fig. 2 and 3), in Naduvathumuzhy and Mannarapara ranges adjoining Punalur, Achenkoil and Ranni divisions. Presence of LTM and NL in the two ranges was also confirmed during the workshop exercise. An area of about 19 km^2 of this division contains high priority sites for the arboreal mammals and these sites are located in Naduvathumuzhy and Mannarapara ranges.

Threats

Poaching, enclosures, recurrent fire, invasive species such as *Mimosa invisa* and *Mikania macrantha.*

Recommendations

- Surveys need to be undertaken to locate if there are any remnant populations of these primates and their habitats conserved and where required, these habitats should be improved or restored with trees that are important for arboreal mammals.

- Remnant populations must be protected against poaching through enhanced patrolling

- Better mitigation measures to control recurring incidences of fire

- Presence of invasive species in high priority sites such as *Mikania macrantha* and *Mimosa invisa* suppress regeneration of native species. Adequate measures are required to be taken to control proliferation of invasive species

- Awareness programs for local communities in order to educate them about arboreal mammals and their importance

- Including the tribal communities in Participatory Forest Management in order to involve them in conservation of arboreal mammals.

Fig. 9. Conservation priority sites in the Konni Forest Division
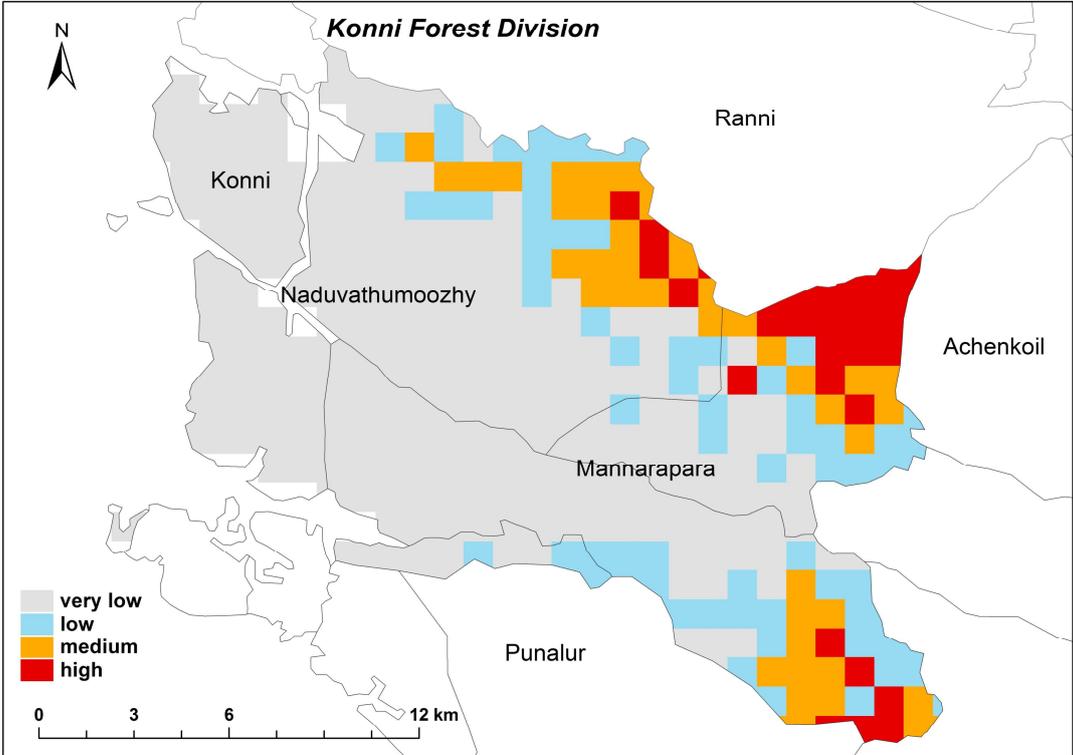
Punalur Forest Division

Punalur Forest Division has two ranges namely Pathanapuram and Anchal. Surveys were carried out only in Pathanapuram range. Pathanapuram range has an area of 131 km^2. Although a large part of this range is under plantations, there are still remnant patches of forests which harbor endemic species. The study results indicate that about 6.8 km^2 of the Pathanapuram range include high priority sites for arboreal mammals. This Division lies just north of the Shencottah gap and therefore a crucial corridor for arboreal mammals between the southern and northern populations. The survey reports the presence of four of the study species *viz.* lion-tailed macaque, Nilgiri langur, Indian giant squirrel and the bonnet macaque in this division. This is the first report of LTM and NL from the site. Presence of LTM is reported from the degraded evergreen forest patch adjoining Ambanaad estate.

Threats

Habitat degradation caused by fuelwood collection, livestock grazing around enclosures, and poaching.

- Primates groups must be located and intensive population surveys of these groups are recommended. These vulnerable groups have to be enumerated and should be monitored at regular intervals.

- Habitat assessment should be undertaken in sites which harbor these vulnerable primates for their long-term viability as persistence of these arboreal mammals is determined by various habitat correlates such as habitat quality, tree density, canopy height etc. (Umapathy and Kumar, 2000; Sridhar, et al. 2008).

- These groups remain vulnerable to habitat fragmentation as the extent of suitable habitat is small and is restricted to the hilltop. Sites containing these troops are surrounded by plantations and hence remain vulnerable to other potential threats such as habitat degradation and poaching.

- Regular patrolling to check poaching incidences is required.

- These remnant patches of forests harboring these primates should be excluded from forestry operations and should be protected by establishing Conservation Reserve. Failed plantations

in or close to these sites should be phased out and reverted to natural forests with assisted regeneration. Also softwood plantations which are not generating revenue may be reverted to natural forests.

- Connectivity between forest patches harboring these primates and other forests which have resident populations should be restored. Lion-tailed macaque is especially vulnerable to habitat fragmentation and adverse effects of fragmentation include skewed age-sex ratio and presence of large number of adult males in a group due to lack of dispersal (Singh et al. 2002). Previous recommendations for forest primates include fostering connectivity through stream corridors where they exist and planting of food trees of these primates such as *Artocarpus heterophyllus* in these corridors (Singh et al. 2002).

Fig. 10. Conservation priority sites in Pathanapuram range of Punalur Forest Division

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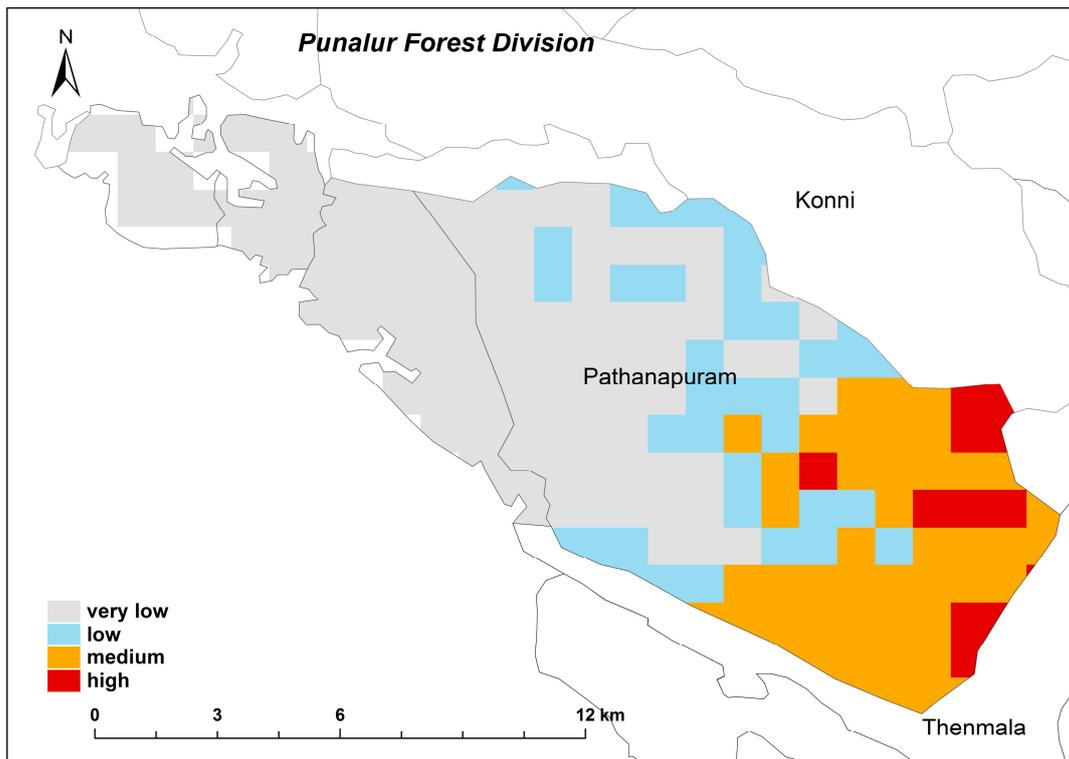
Thenmala Forest Division

Like the Punalur Forest Division, Thenmala Forest Division, lies at the Shencottah gap. In 1984, an area of 171 km^2 from Thenmala Forest Division was carved out to establish Shendurney Wildlife Sanctuary in order to conserve its endemic flora and fauna. Total area of the Division is 131 km^2. Thenmala division consists of two ranges – Ariankavu and Thenmala. Surveys were not carried out in this division. However, recent information on arboreal mammals for this site was obtained from other ongoing projects at FERAL. Arboreal mammals present in this division include the LTM, NL, BM, and IGS. Both the ranges harbor the study species. In the southern portion of the division, their populations are contiguous with Shendurney Wildlife Sanctuary and the populations in the northern portion are contiguous with Achenkoil Forest Division. The National Highway (NH 208) and a rail road connecting Shencottah to Punalur pass through this division. Due to these linear barriers there is very little canopy continuity across Shencottah gap and hence a tenuous link across this gap for the arboreal mammals especially for the endangered lion-tailed macaque. It is important to restore this connectivity in order to facilitate dispersal of adult males. About 44.6 km^2 of the division consists of high priority sites for arboreal mammals (Table 3).

Threats

Linear intrusions (roads, powerlines, railway track), encroachments along these linear intrusions, poaching, enclosures, livestock grazing and fuelwood collection around enclosures, invasive species.

Recommendations

- Nilgiri langur and LTM groups in the Division need to be located and baseline population information need to be established.

- Habitat assessments need to be carried out in forest patches where these threatened primates exist especially around the settlements so that these habitats can be monitored on a long-term basis.

- Southern portion of the division, Reserve Forest adjoining Rosemala contain high priority sites for arboreal mammals. These may be annexed to Shendurney WLS. Conservation Reserve may be established to protect few remaining patches of the moist forests in the northern portion of the division adjoining Suvarnagiri estate.

- Habitat improvement in degraded forest patches near the Shencottah gap as a long term measure in order to facilitate habitat use and dispersal of individuals across the gap.

- Patrolling should be strengthened in order to check incidences of poaching

- There are only a few points across the National Highway and the railway track which have natural vegetation on either sides. Potential crossing points near Kottavasal also coincide with prioritized sites for arboreal mammal conservation. Canopy bridges near Kotavasal to be deployed in order to facilitate arboreal movement across the gap. Other potential crossing points are near the MSL corridor where canopy bridges can be placed at appropriate locations.

Fig. 11. Conservation priority sites in Thenmala Forest Division
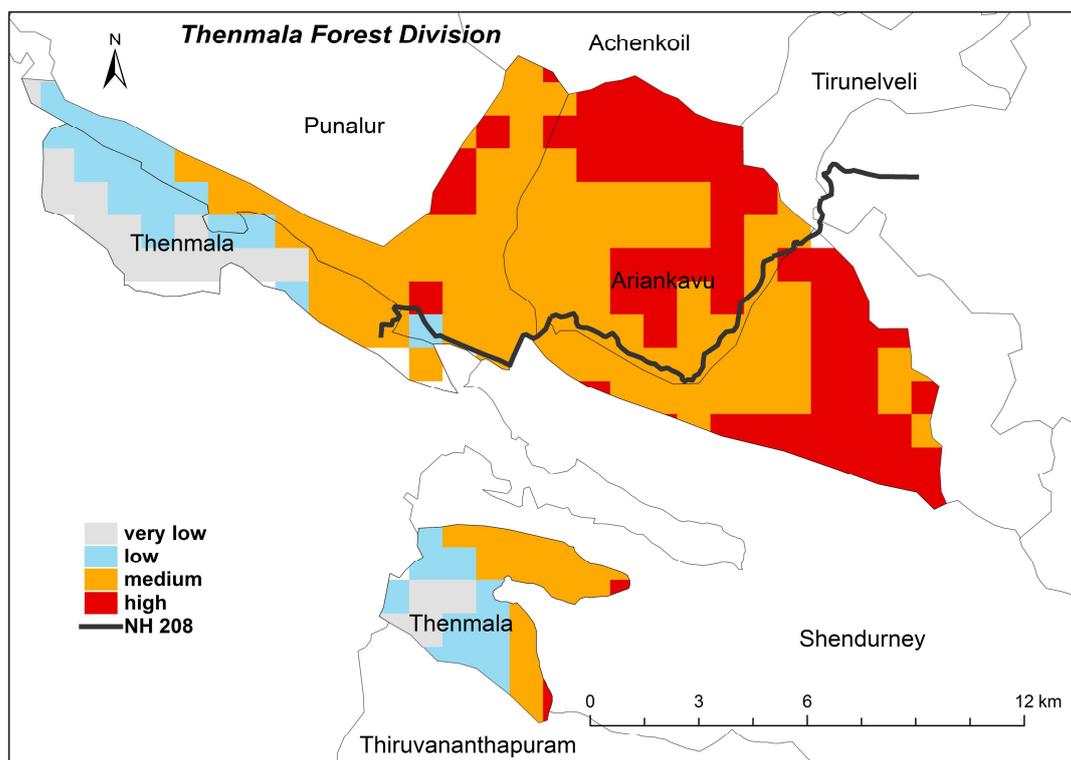
Shendurney Wildlife Sanctuary

Shendurney Wildlife Sanctuary was formed in 1984 after the completion of Kallada hydroelectric project. It is one of smaller sanctuaries in the Agasthyamalai landscape with an area of 171 km^2. Earlier surveys reported viable populations of primates from this site (Easa, et al. 1997; Ramachandran, 1995). This site is known for high levels of endemism and contains some of the best preserved evergreen forests in the Agasthyamalai landscape (Ramesh et al. 1997). An area of 114.1 km^2 of this sanctuary covers the best habitat for arboreal mammals.

Threats

Poaching near enclosures

Recomendations

- The forests of Shendurney are contiguous with the forests of Thiruvananthapuram Forest Division and Thenmala Forest Division. This offers an opportunity to redraw the boundaries of Shendurney Wildlife Sanctuary so as to include important sites in both these Territorial Divisions thereby enhancing protection levels locally. RFs near Rockwood and Kallar estates and Rosemala may be incorporated within the sanctuary boundary.

- Shendurney WLS is one of the key sites for arboreal mammals conservation in the Agasthyamalai landscape as it adjoins KMTR which is considered to be an important site for conservation of the endangered LTM . Prevalence of poaching near enclosures render these primate groups vulnerable. Patrolling should be strengthened to check poaching incidences.

Fig. 12. Conservation priority sites in Shendurney Wildlife Sanctuary
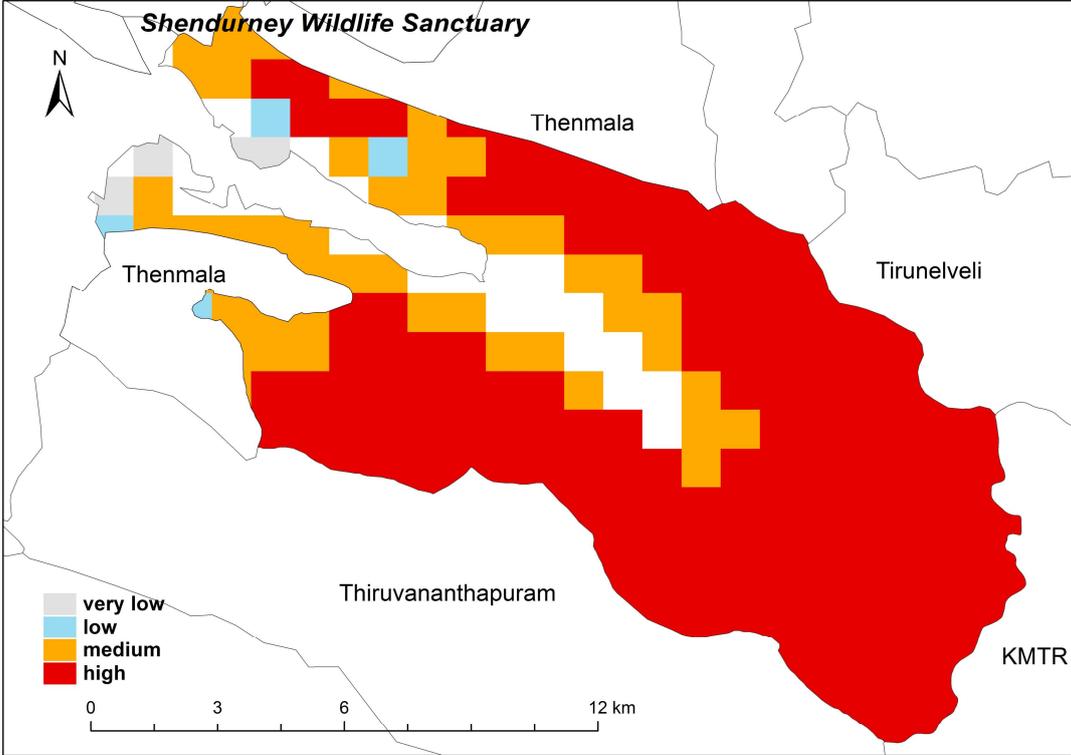
Thiruvananthapuram Forest Division

Total area of Thiruvananthapuram forest division is 368.6 km^2. This division has three ranges – Koluthupuzha, Palode and Paruthipally. There are several enclosures located inside this division. Our results indicate that about 198.17 km^2 of the division contains priority areas for conservation of arboreal mammals. Earlier studies have also highlighted the significance of these reserved forests for conservation of endemic species (Ramesh et al. 1997; Das et al. 2006).

Threats

Poaching, habitat degradation near enclosures and tourism sites such as Ponmudi and Kallar, litter along trek routes

Recommendations

- High priority sites in Koluthupuzha range adjoining Shendurney Wildlife Sanctuary as indicated in the map (Fig. 8) may be included under the existing Protected Area (Shendurney WLS) to fortify protection to these sites.

- Defunct and non-functional estates such as Bonacaud Estate should be acquired in the long run.

- Additionally, intensive surveys of these species need to be undertaken and baseline information needs to be established for long-term monitoring.

- Regular patrolling to control poaching especially near the inter-state border

Fig. 13. Conservation priority sites in Thiruvananthapuram Forest Division
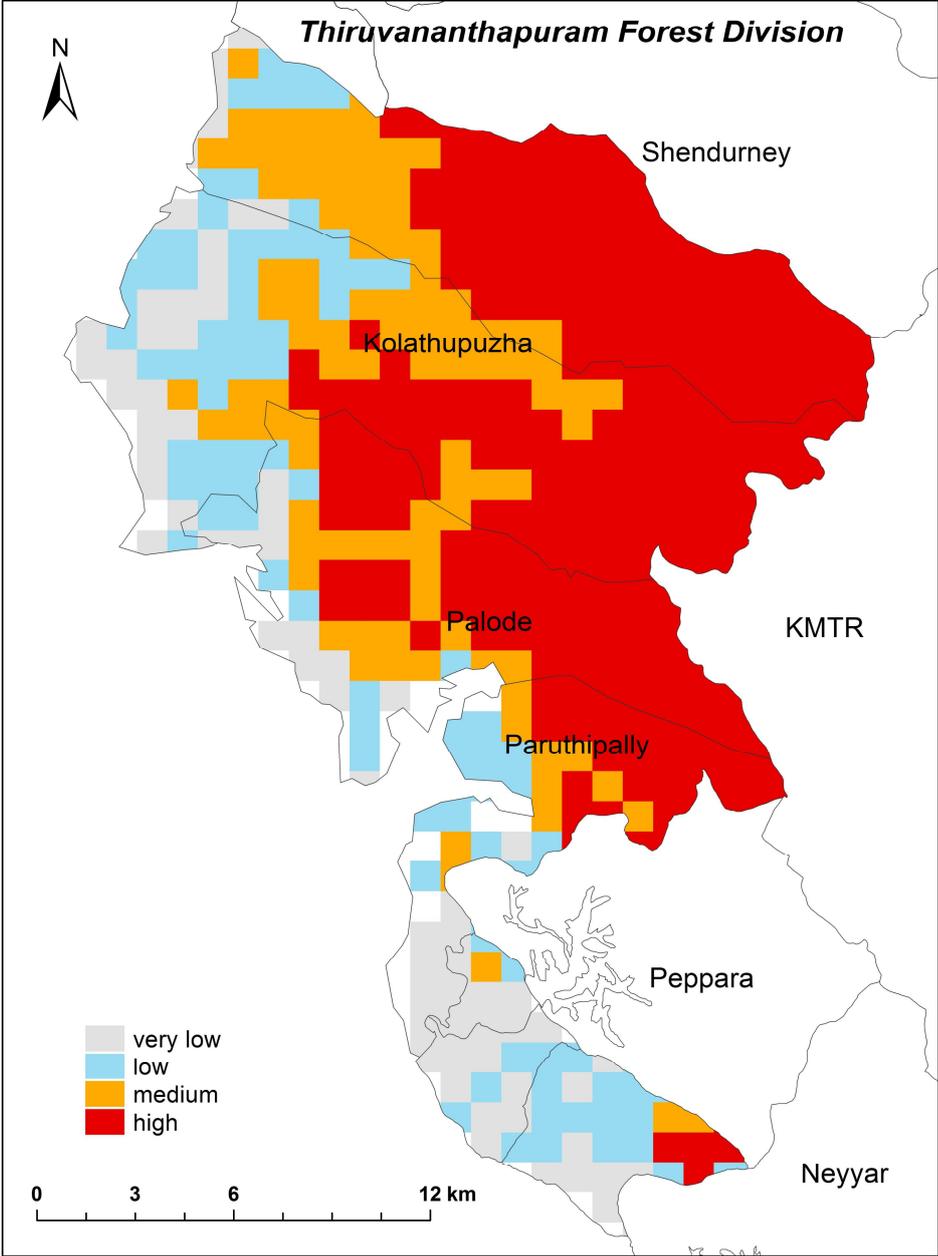
Thiruvananthapuram Wildlife Division

Two small Wildlife Sanctuaries come under the purview of Thiruvananthapuram Wildlife Division – Neyyar Wildlife Sanctuary and Peppara Wildlife Sanctuary. Surveys were carried out in the two sanctuaries. Four of the study species occur in these sites - LTM, NL, BM and IGS. About 32.6 km^2 of Peppara WLS and 27.45 km^2 of Neyyar WLS constitute best habitats for arboreal mammals and these sites are located along the interstate border (Table 1). There are several tribal settlements inside these Sanctuaries (a total of 41 settlements).

Threats

Annual pilgrimage to Agasthyarkoodam situated in Neyyar WLS.

Recommendations

- Potential threat of habitat degradation exists due to heavy influx of pilgrims annually to visit to Agasthyarkoodam situated on the interstate border
- High priority sites in the adjoining Palode and Paruthipally ranges may be added to Peppara WLS in order to fortify these sites which will also increase the area of the PA.

Fig. 14. Conservation priority sites in Peppara and Neyyar Wildlife Sanctuaries
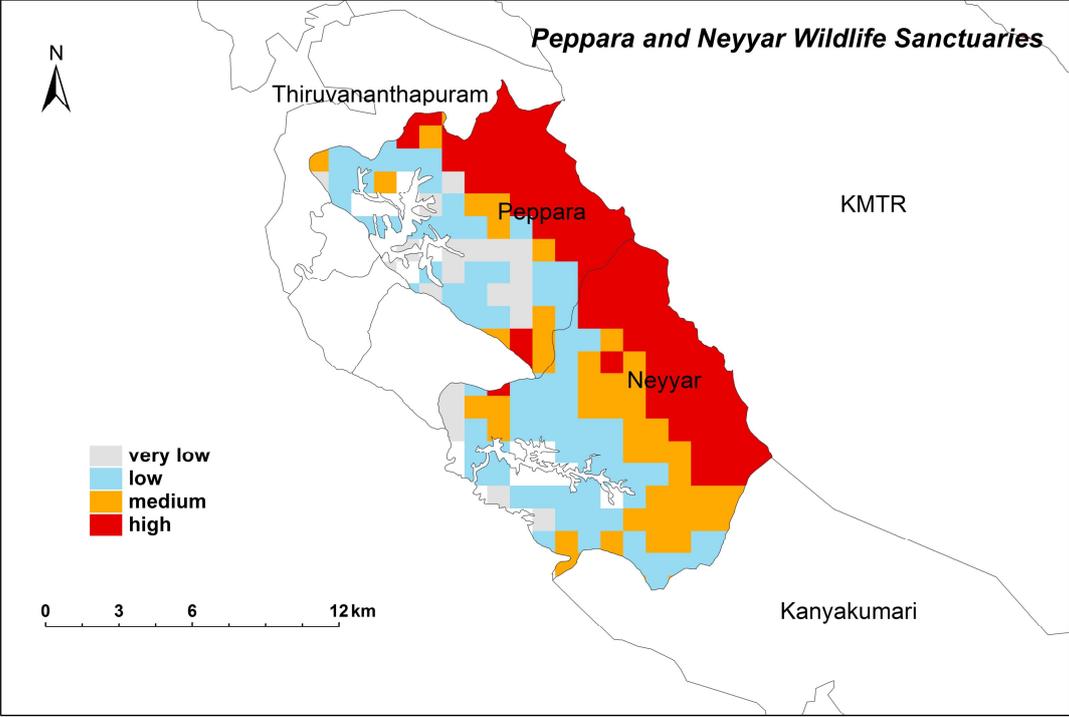
Tirunelveli Forest Division

This is one of oldest divisions in the country. Total extent of the division is about 399 km^2. About 360 km^2 of the division has been proposed for declaration of Nellai Wildlife Sanctuary by the Tamilnadu Forest Department and the decision regarding the same is pending. This division lies at the Shencottah gap making it an important corridor for arboreal mammals in the landscape. Surveys were not carried out in this division but information about occurrence of arboreal mammals was obtained from ongoing projects of FERAL. Except the grizzled giant squirrel, all other study species occur in this division. Our prioritization exercise indicates that about 335.43 km^2 constitute high priority sites for arboreal mammals. This is because it includes significant amount of tufted gray langur habitat in the landscape (Fig. 4). The langur has a patchy distribution and primarily occurs in drier forests of Tirunelveli Forest Division, KMTR and Srivilliputhur grizzled giant squirrel sanctuary in the landscape. LTMs are present in all the ranges of the division. These ranges from north to south adjoin the forested landscape of Periyar Tiger Reserve, Ranni and Achenkoil. The forests of Courtallam range are contiguous with the forests in Kalakad Mundanthurai Tiger Reserve in the south and with Shendurney Wildlife Sanctuary in the west making it a large block of evergreen forest habitat for the lion-tailed macaque and the Nilgiri langur. But, there are also private estates in the upper reaches of the Division.

Threats

Habitat degradation of dry forests due to human settlements and agricultural fields that abut the reserve forest boundary, potential threat of poaching and encroachment around the enclosures inside the division in the upper reaches.

Recommendations

- Given the importance of this division for arboreal mammals conservation, the proposed Nellai Wildlife Sanctuary must constitute all these high priority sites including the habitat of the tufted gray langur.

- For long term conservation of these sites, it is essential that many of these estates be acquired gradually and habitat should be restored in these sites.

- Population surveys of the gray langur need to be undertaken in order to establish baseline

population estimates. There are no population estimates available for this species throughout its distribution. At best there exist only rough estimates for this species (Molur et al. 1995). Baseline population estimates should also established for other species (LTM, NL and BM) for long – term monitoring.

Fig. 15. Conservation priority sites in Tirunelveli Forest Division
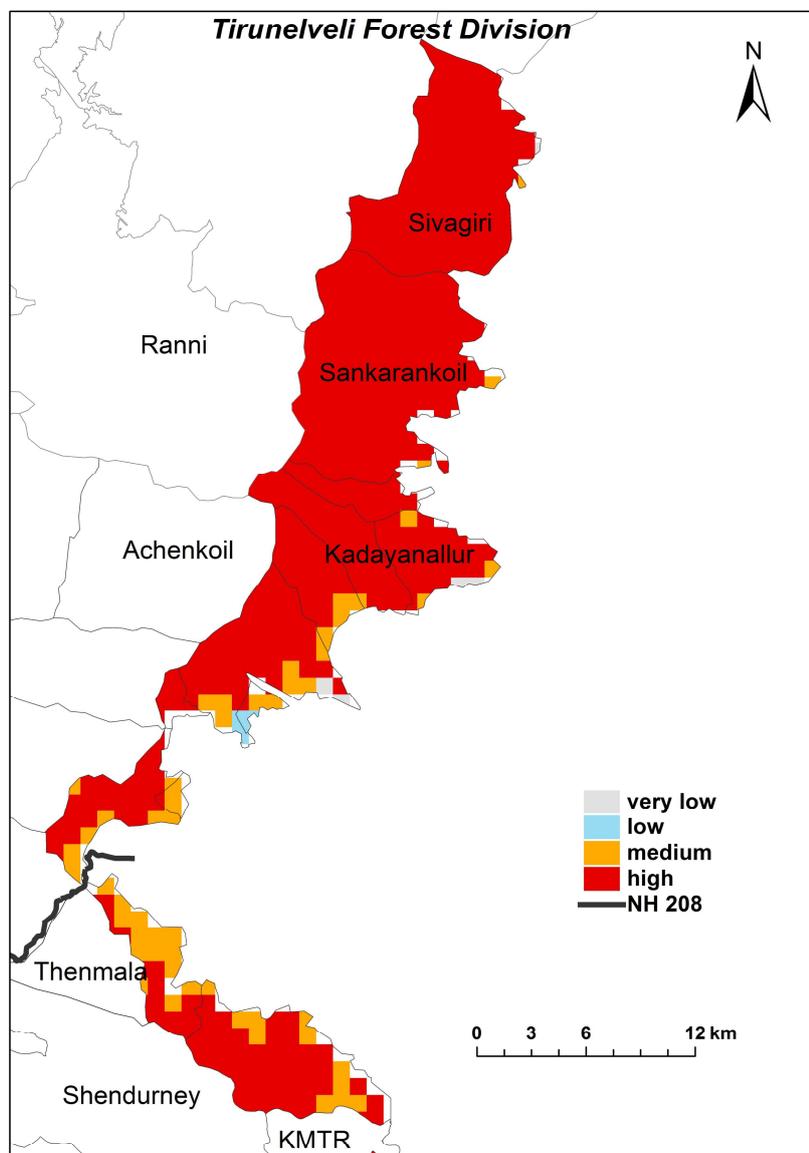
Srivilliputhur Grizzled Giant Squirrel Wildlife Sanctuary

This sanctuary was established primarily for the conservation of grizzled giant squirrel in 1988. All six study species occur in this sanctuary. This sanctuary is also an important site for the tufted gray langur. Our results indicate that 445km^2 of the sanctuary consists of high priority sites (Table 4). The evergreen forests in the sanctuary are contiguous with Periyar Tiger Reserve. There are numerous privately owned plantations inside the sanctuary which occur as enclosures. This sanctuary harbors a viable population of the threatened grizzled giant squirrel (Joshua et al. 2008). Our survey indicates presence of GGS on private lands adjoining all the four ranges. This population however remains vulnerable to various threats on these private farms.

Threats

Fuelwood collection within the sanctuary limits leading to habitat degradation, pilgrimage, land use change on private farms which have GGS, human-animal conflict, presence of domestic predators such as dogs.

Recommendations

- Forests adjoining the reserve boundary remain vulnerable to habitat degradation due to fuelwood collection as there are human settlements and agricultural fields adjoining the boundary. Alternatives such as use of LPG in these settlements need to be explored.

- Population surveys of all the study species need to be undertaken to establish baseline population information.

- In-situ conservation efforts to protect and enhance GGS populations need to be initiated. Populations of GGS on private land need to be protected and this can be achieved with a well designed incentive program, where farmers are actively involved in protecting squirrels and in maintaining squirrel-friendly habitat. Such an demonstration can be linked to other ongoing efforts in the landscape which include buffer zone management, Green India Mission and Tamil Nadu Afforestation Program. The potential of agro/ farm forestry exists, however market linkages for such products needs to strengthened.

- Upper reaches of the sanctuary are contiguous with the forests of Theni Forest Division,

Periyar tiger Reserve and Tirunelveli Forest Division in the south. However, there are also many private estates located within these forests. The survey reports occurrence of LTM and NL in forests adjoining these estates. For long term conservation of arboreal mammals in the landscape, it is important these estates are acquired.

Fig. 16. Conservation priority sites in Srivilliputhur grizzled giant squirrel Wildlife Sanctuary
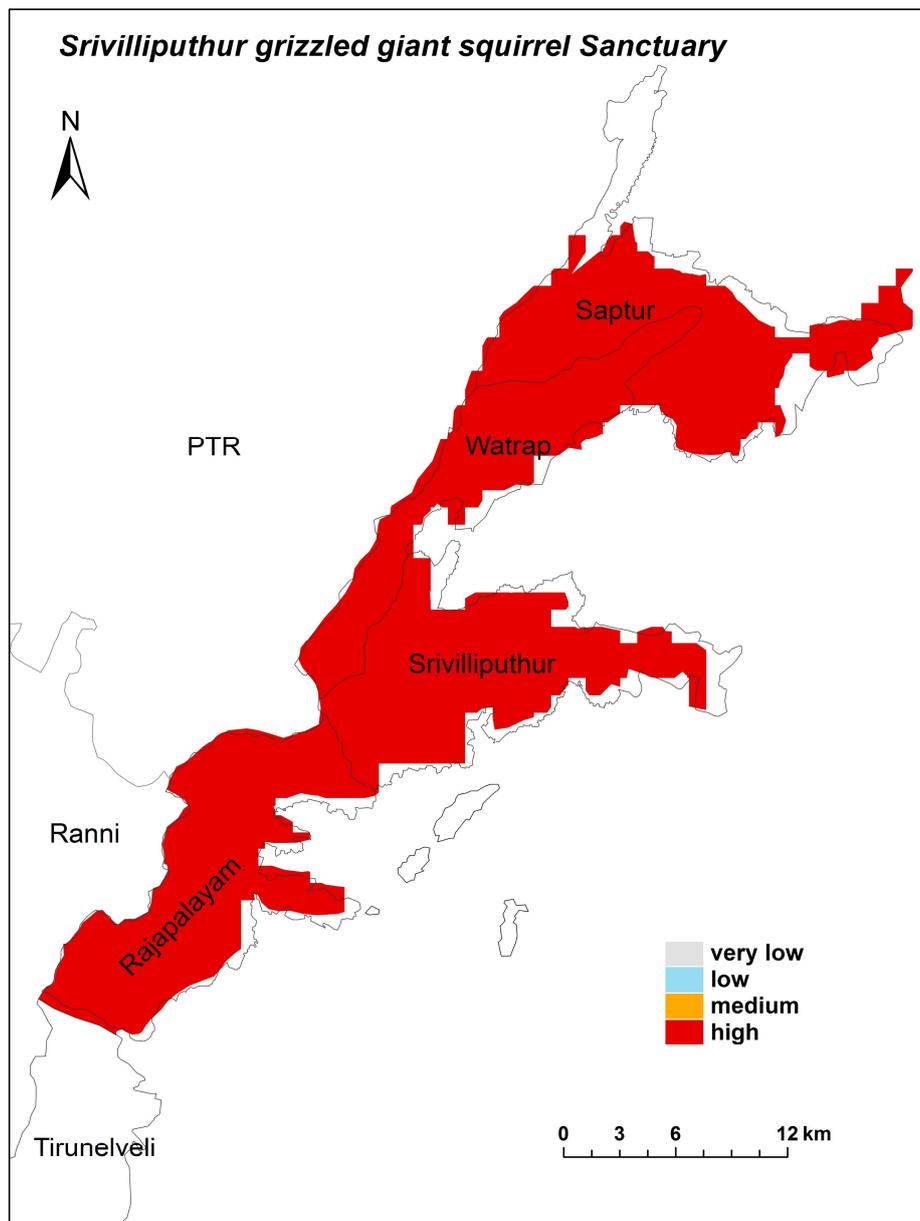
Kanyakumari Wildlife Sanctuary

Kanyakumari Wildlife Sanctuary was formed in the year 2007. About 402.39 km^2 was declared as Wildlife Sanctuary excluding 24 private estates, Kani settlements and the area leased to Arasu Rubber Corporation. Surveys for arboreal mammals were carried out in May 2012. All the ranges of the sanctuary were surveyed. The study confirms the presence of lion-tailed macaque, Nilgiri langur, Indian giant squirrel and bonnet macaque. Kanyakumari WLS is the southernmost distribution of the endemic lion-tailed macaque and the Nilgiri langur. Although we did not have direct sightings of tufted gray langur, secondary source of information points to occurrence of this species in Bhoothapandi range in areas adjoining Thirukurangudi range of KMTR.

Extent of high priority sites for arboreal mammals conservation is ~ 43 km^2 . Forest areas adjoining KMTR, contain high priority sites. These sites in Virapuli and Klamalai RFs have now been incorporated into the core and buffer areas of KMTR. There are a few high priority sites in the Azhagiapandipuram and Bhoothapandi ranges which fall within Ashambu and Mahendragiri RFs. There are also several private estates that occur adjoining these high priority sites.

Threats

No specific threats. However, potential threat of encroachment, habitat degradation due to fuel wood collection and illegal logging near these enclosures do exist.

Recommendations

- Baseline population estimates of primates are required since this a new PA.

- High priority sites adjoining private estates should be regularly monitored for habitat degradation and regular patrolling in these areas is required.

Fig. 17. Conservation priority sites in Kanyakumari Wildlife Sanctuary
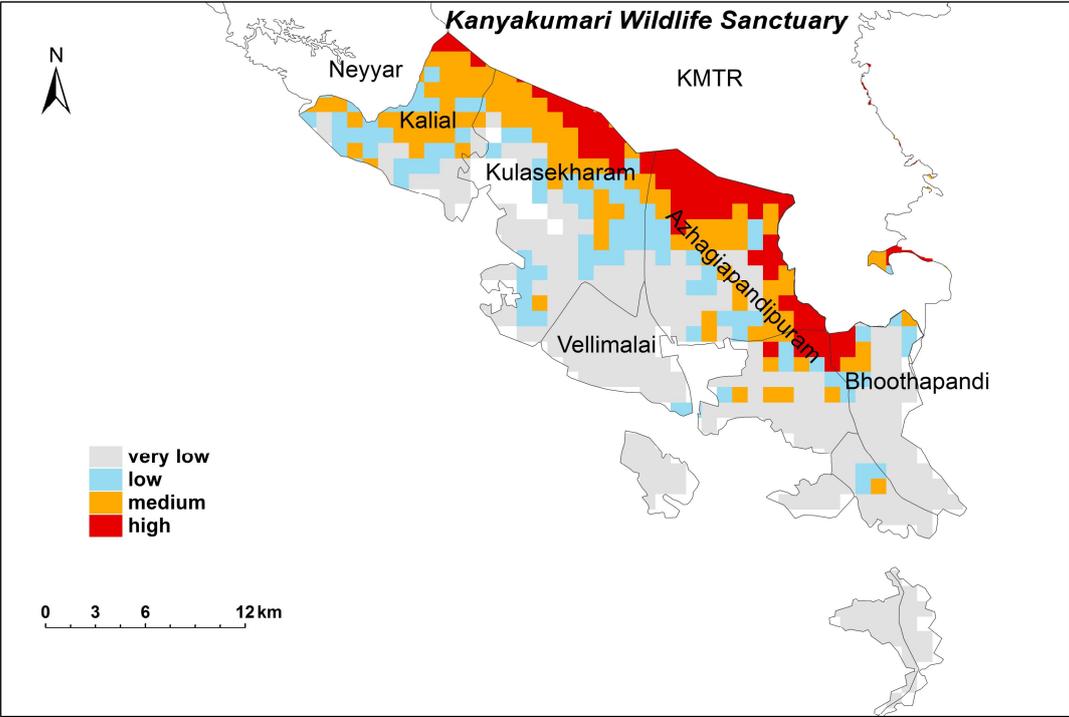
Conclusions

In the entire Western Ghats, the Periyar – Agasthyamalai landscape is one of the few sites which has retained vast stretches of intact forests despite numerous agro – forestry operations and infrastructure development. The forests of Periyar – Agasthyamalai landscape are therefore important for landscape level conservation of globally threatened arboreal mammals such as the lion-tailed macaque and Nilgiri langur. However, given the rapid rate of development, proliferation of human settlements and the concomitant pressures on the forests, this landscape is under an imminent threat of habitat fragmentation. Yet there is still scope for proactive conservation measures. Although in the past, there have been attempts to reserve specific areas for conservation, these efforts in establishing Protected Areas have largely been species centric and have tended to exclude adjoining forests without consideration of biodiversity values. This indicates that very little importance was given to landscape level conservation planning. Our gap analysis highlight sites within the landscape that need to be conserved for long term persistence of arboreal mammals in the landscape (Fig.18). Most of these potential conservation sites remain outside of the existing network of Protected Areas. Many of the high priority sites are devoid of human settlements and are adjacent to PA s. This offers an opportunity to extend PA boundary to incorporate these high priority sites as a pre-emptive measure against future human incursions into these forests. In order to broaden the scope of conservation in the landscape, results from the present study may be integrated with the results from the study on terrestrial large mammals.

Fig. 18. Conservation planning of Periyar – Agasthyamalai landscape based on high conservation priority sites for arboreal mammals (WLS – Wildlife Sanctuary; CR – conservation reserve; WLS_extension – areas to be incorporated into adjacent PAs; Nellai WLS (proposed) – the proposed Nellai Wildlife Sanctuary
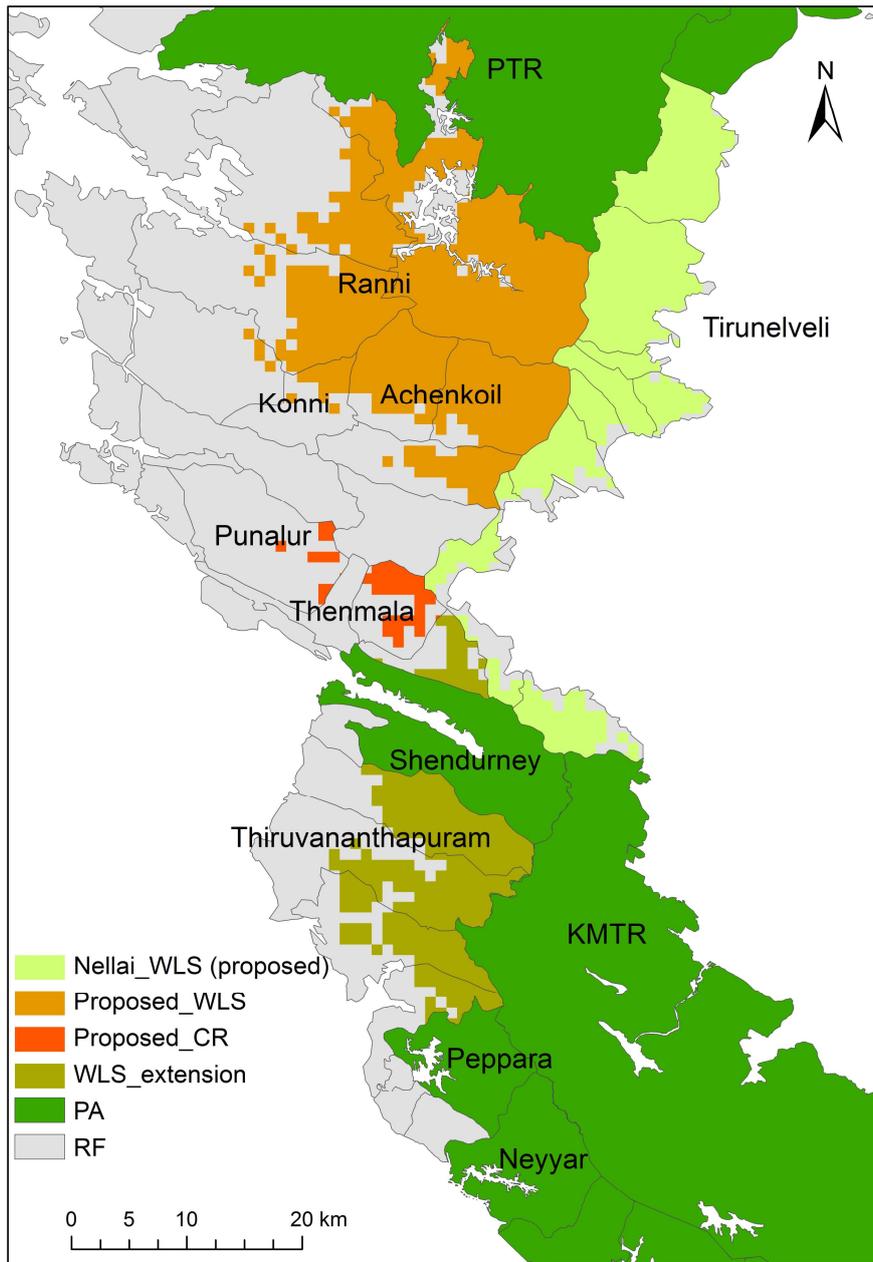
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Appendix 1.

Information on occurrence in the landscape, secondary data source, data type and data used in the distribution modeling

Division	Existing data type / information	Secondary source	Data gaps	Data obtained under present study	Data used for distribution modelling
1) Srivilliputhur grizzled giant squirrel sanctuary	Information only on grizzled giant squirrel from Alagarkoil valley and adjoining areas	Joshua (1992); Joshua and Johnsingh (1995)	Yes.	Surveys carried out. Point occurrences of the all study species obtained	Present study - LTM, NL,TGL, IGS, GGS, BM Ram and Vaidyanathan (2012) – NL, TGL
2) Theni Forest Division	Information on occurrence of LTM, NL, TGL, IGS and GGS with geo-coordinates	Kumara et al. (2011)	No	No surveys were carried out	Kumara et al. (2011) – LTM, NL, BM, TGL, GGS
3) Tirunelveli Forest Division	Information on occurrence of LTM, BM, IGS, NL and TGL with geo-coordinates	Gangadharan et al. (2011)	No	No surveys were carried out	Gangadharan et al. (2011) - LTM, NL, TGL, BM, IGS
4) Periyar Tiger Reserve	Information on occurrence of arboreal mammals with site names only.	Ramachandran et al. (1985); Balasubramanian (2007)	Yes	No surveys were carried out	Ram and Vaidyanathan (2012) – NL
5) Ranni Forest Division	Information on occurrence LTM only from Goodrical range with geo-coordinates;	Balasubramanian (2007)	Yes	Surveys were carried out in Goodrical and Vadasserikara ranges. Point records of LTM, IGS, NL and BM obtained	Present study – LTM, BM, IGS; Balasubramanian (2007) – LTM; Ram and Vaidyanathan (2012) – NL
6) Konni Forest Division	At division level presence of arboreal mammals; however no point occurrence records	Easa et al. (2002)	Yes	No surveys carried out	None

7) Achenkoil Forest Division	Information on occurrence of LTM, BM, IGS and NL with geo-coordinates-coordinates	Gangadharan et al. (2011)	No	No surveys carried out	Gangadharan et al. (2011) – LTM, NL, BM, IGS
8) Punalur Forest Division	No information	--	Yes	Surveys carried out in Pathanapuram range. Point occurrences of LTM, BM, NL and IGS obtained	Present study – LTM, BM, IGS
9) Thenmala Forest Division	Information on occurrence of LTM, BM, IGS and NL with geo-coordinates	Gangadharan et al. (2011)	No	No surveys were carried out	Gangadharan et al. (2011) – LTM, NL, BM, IGS
10) Shendurney WLS	Information with geo-coordinates only from few of the sites	Gangadharan et al. (2011)	Yes	Surveys carried out. Point occurrences of LTM, NL, BM and IGS obtained	Gangadharan et al. (2011) – LTM, NL, BM, IGS
11) Thiruvananthapuram Forest Division	At division level presence of arboreal mammals; however no point occurrence	Easa et al. (2002)	Yes	Surveys were carried out in all the three ranges. Point occurrences of LTM, NL, BM and IGS obtained	Present study – LTM, BM, IGS Ram and Vaidyanathan (2012) – NL
12) Neyyar WLS	At division level presence of arboreal mammals; however no point occurrence	Easa et al. (2002)	Yes	Surveys were carried out. Point occurrences of LTM, NL, BM and IGS obtained	Present study – LTM, BM, IGS Ram and Vaidyanathan (2012) – NL
13) Peppara WLS	Information available from incidental sightings with site names only	Jayson et al. (1998)	Yes	Surveys were carried out. Point occurrences of LTM, NL, BM and IGS obtained	Present study – LTM, BM, IGS Ram and Vaidyanathan (2012) – NL
14) Kanyakumari WLS	No information		Yes	Surveys were carried out. Point occurrences of LTM, NL, BM and IGS obtained	Present study – LTM, BM, IGS
15) Kalakad-Mundanthurai Tiger Reserve	Information with geo-coordinates	Sushma et al. (2010)	No	No surveys were carried out	Sushma et al. (2010) – LTM, NL, BM, IGS Ram and Vaidyanathan (2012) – NL, TGL

Appendix 2

List of participants for the consultative workshop on site specific recommendations for arboreal mammals conservation in the Periyar – Agasthyamalai landscape, 25-2-2013, Forest Headquarters, Thiruvananthapuram.

The PCCF (Wildlife) and Chief Wildlife Warden Shri V. Gopinathan presided over the workshop. The workshop began with a presentation on the findings on species distribution and prioritization of the landscape for arboreal mammal conservation by Dr H.S Sushma, Prinicipal Investigator of the project "Gap analysis of the Periyar – Agasthyamalai landscape for arboreal mammal conservation". The participants of the workshop included managers from the Kerala Forest Department working in the study area, scientists, researchers from FERAL. The list of participants who attended the workshop are given below:

1. Shri V. Gopinathan, IFS, PCCF (Wildlife) and Chief Wildlife Warden, Kerala Forest Department
2. Shri T. Pradeep Kumar, DFO, Konni Forest Division
3. Shri S. Mohanan Pillai, DFO, Thiruvananthapuram Forest Division
4. Shri D. Rathish, Wildlife Warden, Thiruvananthapuram Wildlife Division
5. Shri K.I. Pradeep Kumar, ACF O/o PCCF (Wildlife) and CWLW, Thiruvananthapuram
6. Shri S. Janardhanan, DFO, Ranni, Forest Division
7. Shri K.N. Syam Mohan Lal, DCF (Wildlife), O/o Chief Wildlife Warden, Thiruvananthapuram
8. Shri Sunil Sahodaran, DFO, Achenkoil Forest Division
9. Shri S.V. Vinod, RFO, Themala Range, Thenmala Forest Division
10. Shri S. Radhakrishnan, DD, Agasthyavanam Biological Park range
11. Ms. Reney R. Pillai, Sr Wildlife Assistant, O/o, PCCF (Wildlife) and CWLW
12. Smt R. Lekshmi, Wildlife Warden, Shendurney Wildlife Sanctuary
13. Dr. M. Balasubramanium, Periyar Tiger Conservation Foundation
14. Dr. H.N. Kumara, Scientist, Salim Ali Centre for Ornithology and Natural History,

Coimbatore

15. Dr. A.J.T. Johnsingh, Scientist, Nature Conservation Foundation, Mysore, WWF, India

16. Dr. R. Prabhakar, Strand Life Sciences, Bangalore

17. Dr. Bhaskar Acharya, Coordinator, CEPF-ATREE, Bangalore

18. Shri Adithya Gangadharan, JRF, FERAL, Pondicherry

19. Shri Rajat R. Nayak, JRF, FERAL, Pondicherry

20. Shri Srinivas Vaidyanathan, Head, Wildlife Biology and Conservation, FERAL, Pondicherry

21. Ms Sunita Ram, Managing Director, FERAL, Pondicherry

22. Shri Saravanan, FERAL, Pondicherry

23. Dr. H.S. Sushma, Research Associate, FERAL, Pondicherry

Appendix 3.

Questionnaire used for the workshop exercises

Arboreal Mammal conservation: Group exercise

Species Distribution

- Are any of the restricted range species (lion tailed macaque, Nilgiri langur, grizzled giant squirrel, tufted langur) found outside the high priority area for conservation? if so, indicate those areas with numbered polygons and indicate the species.
- In which of these locations do you think the population of each species is good (for example, more than 5 groups seen in the area)? Please provide details of populations used to define them as good populations.
- Are there sites where these species were known to occur previously, but now do not occur in these sites or rarely seen in these areas? If, yes, which are those sites? (please mark on the map)

Table indicating presence of restricted range species outside high priority area

Location number	Species	Populations size, if available

Table indicating absence of arboreal species from the landscape. Provide information for all arboreal mammals used in the prioritization process.

Location number	Species	Populations size, if available

Prioritization process

- Can you mark on the map, areas that have been left out of the high priority zone that should be prioritized for arboreal mammal conservation? Please indicate these areas. And also a brief justification why these areas need to be considered
- Additional high priority areas that need to be considered

Location number and name	Justification to include the area

- As a manager/researcher, please indicate the legal designation that can be assigned to these high priority sites. These can include National Park, Wildlife Sanctuary, Conservation Reserve, Community Reserve. Also consider extension of existing boundaries when these high priority sites occur adjoining existing protected areas.

Please provide a description of the rationale used to assign them to the designated category

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- Identify areas within the landscape that need to be notified as "critical wildlife habitat" "eco-sensitive zones" "corridors" and "no go zones". Along with these areas please provide details of the rationale behind the decision. Also indicate if this decision was accepted by all members of the group, else indicate alternatives that were suggested.

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Human settlements and production landscapes

- Are there any settlements within the areas that have been prioritized? Can you mark these on a map?
- Are there any cultivated areas within the areas that have been prioritized? Can you provide a brief description of crops, number of years since establishment, number of cultivators and area under cultivation?

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Threats within the landscape

- On the map, indicate locations of threats within the landscape. In the following table, do indicate which of these threats needs to be addressed immediately, in the next 1-2 years and 3-5 years.

Threats	Priority
Irrigation Projects	
Hydel Projects	
Wind energy farms	
Mining	
Power/ Telecom lines	
Pipeline projects	
Railroads	
Roads/ Highways	
Enclosures	
Landuse change	
Encroachment	
Hunting / Poaching	
Livestock grazing	
Exotics/ Invasives	
NTFP Extraction	
Logging	
Illegal logging	
Illegal quarrying	
Fuelwood collection	
Fodder removal	
Leaf litter removal	
Micro-hydel projects	
Fire	
Conflict with large wildlife & retaliation	

Recommendation at the site level/division level

Keeping the threats and conflicts in mind, can you suggest management actions
that need to be enforced to ensure greater conservation success.
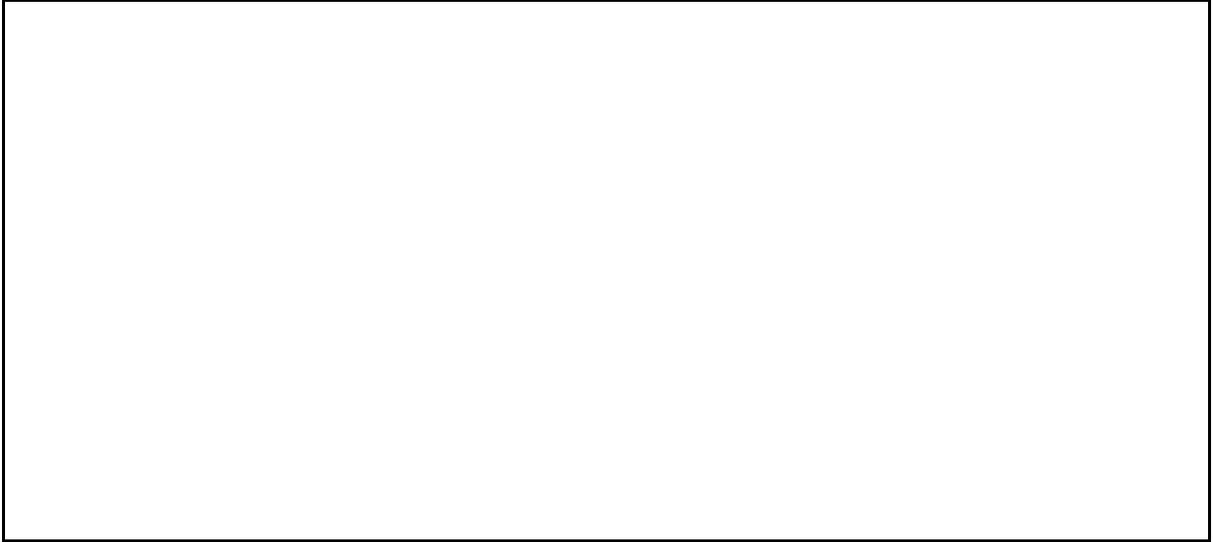
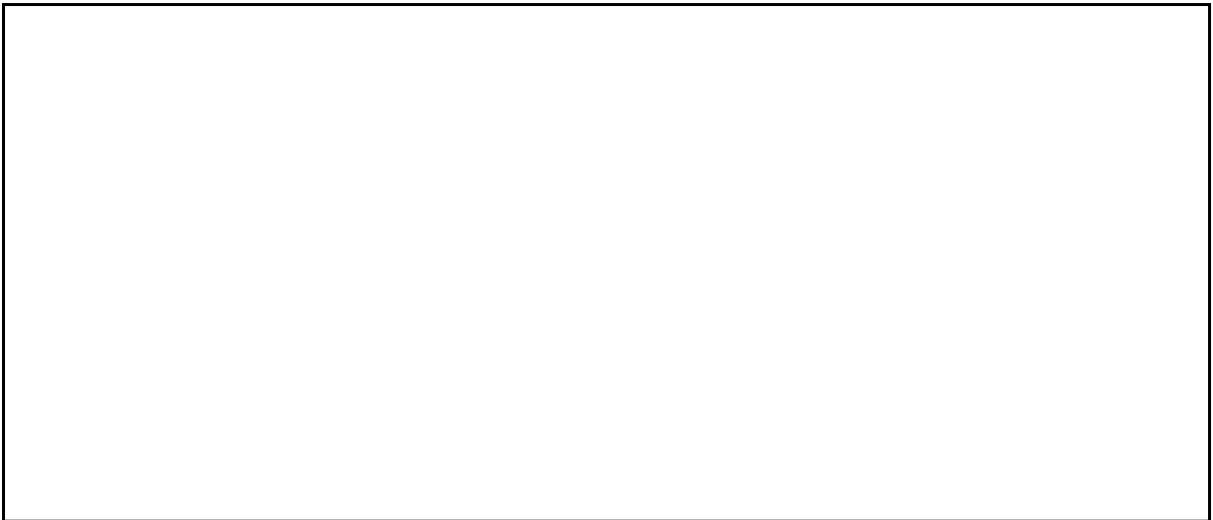What additional recommendations can the group come up with for your area?