Advances in life science research

Spatial Primatology in India: Current trends and future perspectives

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ABSTRACT

Understanding spatial patterns and processes is critical for the conservation and management of several animal species, including primates, especially under the current rapid deforestation and climate change scenario. India is home to at least 24 species of primates and, in the past few decades, it has been observed that several of these species, and their habitats, have been drastically declining. It is, therefore, critical to understand how spatial processes and patterns affect primate populations. Here we review the current trends in the application of spatial ecological methods on primate populations and their habitats, and explore the future prospects of spatial primatology research in India. We searched for articles related to spatial perspectives on Primates in India using the keywords "Primate habitats India" "Primate habitat matrix India" Primate land use associations India" in Google Scholar. From the several papers appeared during the search in Google Scholar we filtered 99 papers based on the title and further selected 39 papers based on abstract and methods representing our topic. We observed that the spatial studies of some primates and habitats in India were rare in the literature. Further, studies incorporating large spatial scales, and focusing on habitat structure, human-animal conflict, climate change and disease spill over were rarely conducted. Several ecological and conservation prospects, and several primates and their habitats in India remain unexplored from a spatial perspective and hence such studies should be initiated in the future. The advancement of new remote sensing technologies and modelling techniques will open new opportunities for spatial primatology research in India.

KEYWORDS

Primate habitats, Remote sensing, Ecological modelling, Land use change, Climate change

Introduction

Habitat loss and fragmentation, and climate change, are the major drivers of global animal species extinctions (Thomas et al. 2004; Jetz et al. 2007; Silva et al.. 2019) and several species of mammals are severely affected by these processes (Cowlishaw 1999; Lister and Stuart 2008; Isaac 2009; Sharma et al. 2012; Morcatty et al. 2013). A detailed understanding of spatial processes and patterns is required to assess how species adapt to different type of landscapes, especially degraded and patchy landscapes. Such studies are necessary for conservation and management of several species including primates inhabiting such degraded and patchy habitats. The suitable habitats of several primate species have been found to decline in the recent past due to habitat loss (Cowlishaw 1999; Ocampo-Penuela et al. 2020) and marked decline in habitat quality and structure (Rosenbaum et al. 1998), and hence assessing the primate habitats is critical for conservation and management of several primate species.

To assess the suitable habitat of a primate species, the first step is to determine the associations of primates to different land use types. Primates can have varied relationships to a land use based on the functionalities that a land use provides for performing different activities, such as feeding, resting and locomotion, and understanding it can have conservation implications (Hamilton 1982; Thomas 1991; Bryson-Morrison et al. 2017; Rahman et al. 2019). For example, some rainforest dwelling primates such as lion-tailed macaques *(Macaca silenus)* can use coffee plantations with native trees as fall-back habitats and it is important to identify these plantations for their conservation (Erinjery et al. 2015). In addition to the land use associations, the quality and structure of the preferred land uses are also important for assessing suitable habitats of primates (Arroyo-Rodriguez et al. 2007; Galan-Acedo et al. 2021). The landscape metrics including the size of a patch, the edge of a patch, the connectivity of a patch to other patches etc. are required to assess how fragmentation might affect the distribution and abundance of a primate species (Umapathy and Kumar 2000a). For example, the size of a patch can determine the population size and social structure in primates (Arce-Pena et al. 2019). The shape and the edge of a patch can determine whether edge habitats can be suitable for a primate species (Arroyo-Rodriguez et *al*. 2013). The connectivity information between patches can help in assessing whether there is a possibility of dispersal between different groups (Brooker et al. 1999). The distribution and abundance of specific trees, and their patchiness have been found to influence primate distribution, abundance, social structure and behaviour (Arroyo-Rodriguez et al. 2007; Pozo-Montuy et al. 2011; Vogel and Janson 2011). The structure of the trees has been found to affect habitat suitability of many primate species (Koops et al. 2012; Fitzgerald et al. 2018; Liu et al. 2020). For example, orang-utans *(Pongo pygmaeus)* has been found to prefer trees with specific height for their nest site selection (Davies et al. 2019). The anthropogenic activities have been found to alter both habitat quality and structure of primates in the recent past (Almeida-Rocha et al. 2017) and hence assessing habitat quality and structure is critical for metapopulation management of several primate species. Also, the information can help in assessing the behaviour of many primates, including the optimal foraging strategies adapted in a particular habitat. Although, a general consensus exists on what land characteristic a primate might use for performing its activities, a detailed mapping of such land use associations, their quality, structure and the metrics, based on different activities for different primates is rare, especially in tropical countries such as India. Here, we review the literature on the spatial ecological methods employed for primate research in India and discuss the potential of such methods for future re-search.

India is home to at least 24 species of primates which includes strepsirrhine primates such as lorises, Old World primates such as langurs and macaques, and apes such as gibbons {Singh et al. 2020). The primates in India inhabit a variety of habitats ranging from rainforest to cities (Sinha 2001). Many of the primate species in India are habitat specialist species and survive only in specific habitats such as rainforests, and many of them are found in the vulnerable habitats in the Western Ghats and Himalayas (Menon 2014). The habitats and populations of most of the primate species in India are drastically declining, which is also indicated by including them as endangered/threatened/vulnerable in the IUCN red list (Nameer 2015; Singh et al. 2020). Apart from habitat loss, several habitats of primates are severely fragmented and degraded, leading some of these primate species to invade human habitats, and to come into conflict with humans (Singh et al. 2001; Pebsworth et al. 2020; Pebsworth and Radhakrishna 2021). Considering this, there is a need to assess the spatial patterns and processes limiting the distribution, abundance and behaviour of primates in India. Both field methods and remote sensing techniques can be employed for assessing spatial patterns and processes affecting primates. Here, we review the past literature in Indian primatology related to land use metrics and land use associations of primates, and evaluate the current trends in Indian spatial primatology, and suggest future prospects in the advancement of spatial primatology.

Spatial primatology using field methods

Several field studies have been carried out on Indian primates since 1980's to assess their habitat quality and habitat suitability. Among them, several field surveys were conducted across India to assess the population and distribution of different primate species. Some of these surveys were utilized to predict the density and the occurrence of primate species using Distance and Occupancy modelling. For example, Kumara et al. (2014) used occupancy modelling to predict the habitats and factors affecting the lion-tailed macaque distribution in the Anamalai landscape in the Western Ghats and found that height of the tallest trees had a positive effect on the occupancy of lion-tailed macaques. Gnanaolivu et al. (2020) showed that habitat parameters such as tree species richness, basal area, and tree felling and branch lopping, positively determined the occupancy of the Malabar slender loris *(Loris lydekkerianus malabaricus).* Some other studies predicted the effect of different environmental factors and metrics on primate occurrence and abundance. Umapathy et al. (2011) used several habitat parameters such as tree density, forest fragment area, canopy cover, tree height and total basal area to assess the impact of these factors on the demography of lion-tailed macaques in the fragmented forests of Anamalai Hills and found that some of the metrics and environmental factors related to forest fragmentation had an effect on the demography of primates. Singh et al. (2002), Umapathy and Kumar (2000b), and Sridhar et al. {2008), from their surveys on communities of primates in Anamalai Hills, found that some primates do not occur in some fragments, probably due to unsuitable features of the forest fragments, which is an indicator of habitat quality and suitability for primates. Singh et al. (2002) also found that the mean group size of primates was smaller in contiguous forests than in the fragmented forests but standard deviation of group size was higher in forest fragments when compared to larger forest complexes. Sharma et al. (2012) assessed the occurrence of 6 primate species in the forest fragments of North East India using the local and landscape scale factors and found that the metrics affecting the occurrence of a primate species could be different from that of the other species. Other than the field surveys, spatial field based studies have been carried out to understand how different land uses provide habitats for primates with respect to their ecology and behaviour. Umapathy and Kumar (2000b) reported that the feeding time and ranging were more in the smaller fragments than in the larger fragments in lion-tailed macaques in the Anamalai Hills. Singh et al. (200I) and Dhawale et al. (2020) showed the changes in behavioural responses of lion-tailed macaques to habitat fragmentation due to anthropogenic interventions and observed that they tend to spend more time on ground and near human habitations in the forest fragments. Erinjery et al.(2015) showed that the lion-tailed macaques preferred forests during certain seasons, and preferred coffee plantations during others, for feeding and other activities. Singh et al (2011) observed that bonnet macaques *(Macaca radiata)* are declining in their preferred roadside habitats due to changes in land use, changes in attitude of people towards monkeys, and expansion of roads. They observed that small hillocks with places of Hindu worship and interspersed with dry or scrub forests with fruit bearing native plants were the potential sites for bonnet macaque conservation. As a continuation of this, Erinjery et al. (2017) showed that bonnet macaques are not found in high abundance in forest habitats, their distributional range is declining due to invasion by rhesus macaques *(Macaca mulatta),* and their populations in temples and tourist places have drastically declined due to trapping and translocations over the past few years. Singh et al (2000) showed that slender loris *(Loris lydekkerianus lydekkerianus*) in Andhra Pradesh usually prefers mixed dry-deciduous forests and farmlands adjoining these forests which have interspersed trees. It was also observed that irrespective of the forest type slender loris prefers riparian habitats in Andhra Pradesh. Sanna et al. (2015a) found that Eastern hoolock gibbon *(Hoolock leuconedys)* group size varied with number of standing trees, and distance to the nearest forest patch, with smaller groups occurring away from the forest patches. Vasudev and Fletcher (2015) assessed the resistance of several matrixes based on the movement behaviour of the Western hoolock gibbon *(Hoolock hoolock)* and found that conservation prioritization can be given for fragments based on their connectivity with other patches. Shil et al. (2020) showed that habitat conditions have an effect on group size and birth rate of golden langurs in North East India.

Some studies also showed that land use associations maybe related to larger risk of diseases in the case of primates. These studies show that there could be a sharing of parasites between humans and primates in regions where there is human-primate conflict. Hussain et al. (2013) showed that there is a higher prevalence of gastro- intestinal parasites in lion-tailed macaques living in close proximity to human settlements. Kumar et al. (2019) showed that relocation of bonnet macaques from human settlements to forests might increase parasite loads in other primate species such as lion-tailed macaques. Further, Kumar et al. (2018) showed that provisioned bonnet macaques had more probability of endoparasitic load than the non-provisioned macaques.

Although, several field based spatial ecological studies explored various aspects on how spatial patterns and processes might affect the primate distribution, occurrence, behaviour, ecology and conservation, most of them are limited to small spatial scales. The spatial extent to be covered, the time consumed for ecological and behavioural studies, the terrain, and the complexity of habitats is a potential limitation for field based studies, especially in tropical habitats such as India. The spatial modelling methods using remotely sensed data and GIS, using the field data as a baseline data has a huge potential in primatological studies since they can cover a larger spatial scale with lesser field effort.

Spatial primatology using remotely sensed data and GIS

Of the major factors affecting primate decline globally, the habitat loss and habitat quality play a substantial role (Peres 1997; Cowlishaw 1999; Srivastava et al. 2001). The habitat loss and quality can be estimated over years by observing land use change and land use metrics of primate habitats using satellite remote sensing data. Erinjery et al. (2017) showed that the loss of vegetation and canopy cover on the roadsides due to road expansion, between 2003 and 2015 (using Landsat satellite data and Google Earth images), led to the drastic decline of bonnet macaque populations in and around Mysore. Velanker et al. (2016) showed that the inundation of coastal area after tsunami in Nicobar Islands (using Landsat derived NDWI) led to an altered group structure in long tailed macaques *(Macaca fascicularis umbrosus).* These studies show how land use change across years can be a major factor affecting primate populations.

The modelling approaches using field data can be used to predict the habitat suitability of primates over a large spatial scale. The land use and its metrics, climate data, vegetation indices, the anthropogenic factors, the forest structure etc. can be used for modelling habitat suitability of primates. Erinjery et al. (2018) showed that highly precise land cover data and its metrics for mapping the habitats of arboreal animals can be produced using a combination of Sentinel-2 and Sentinel-I satellite data. Several other local and global datasets of land use and land cover are available for mapping the habitat suitability of primates (Amarnath et al. 2003; Lardeux et al. 2011; Reddy et al. 2015). Present and future climate data is available from Worldclim database and this data can be used for mapping the furure habitats of primates (https: //www.worldclim.org/). Using this data, Subrahmanyam et al. (2021) showed that the suitable habitats of *Loris lydekkerianus malabaricus* will potentially expand in the central Western Ghats and the habitat of *Loris lydekkerianus lydekkerianus* will potentially shrink in the Eastern Ghats under the future climate change scenario. The data on vegetation indices and several other potential environmental factors are available in LPDAAC database of USGS and NASA (https://lpdaac.usgs.gov/), and several other similar databases, and a few modelling studies have utilised this for modelling habitat suitability and occupancy of primates. Although forest structure data can be derived from recent missions such as GEDI (Global Ecosystem Dynamics Investigation), and other aerial and terrestrial Lidar's, none of the primatological studies in lndia have utilised this data for mapping habitat suitability of primates.

A few studies have utilised some of the above mentioned data to model the potential suitable habitats of primates in India. Chetan et al. (2014) mapped the niche of various langur species in south India using Maxent modelling and observed that different species of langurs have different geographical distributions. Sanna et al. (2015b), and Sarania et al. (2017) mapped the potential distribution of Hoolock gibbons and Arunachal macaques respectively, in Arunachal Pradesh and suggested strategies for the conservation and management of the species. Sarma et al. (Sarma et al. 2021) mapped the distribution of Western Hoolock Gibbons in Assam and did fragment and conservation priority analysis. Erinjery et al. (2019) mapped the potential suitable habitats of lion-tailed macaque and Nilgiri langur groups and solitary males, and observed that folivorous Nilgiri langur solitary males have more suitable habitats than frugivorous lion-tailed macaques. Although, the above mentioned studies have utilized environmental factors for mapping the potential suitable habitats of several primates, only rarely have they considered the use of biological interactions and animal dispersal strategies for mapping habitat suitability (Sober6n and Peterson 2005). Also, studies testing specific ecological theories and conservation aspects such as metapopulation management, habitat connectivity etc. are rarely conducted on Indian primates. Hence, the future studies potentially can map the potential habitats of primates using these components and emerge with more accurate predictive habitat suitability models of primates.

Conclusion

This review highlights the current trends in spatial primatology in India and shows that studies dealing with spatial aspects are limited, especially at a large spatial scale, and need to be conducted in several habitats of primates across India. Although, the studies till now have explored various aspects regarding spatial primatology, there are still some aspects which are not explored at all in primates of India. For example, studies have not explored how forest fires may impact the habitats of primates (and studies exploring climate change are also rare). Also, rarely have studies explored the human-primate conflict and disease spill over from a spatial perspective. Several models such as agent based modelling and infectious disease modelling can be employed for conducting such studies. Further, the advancement of remote sensing technologies and advancement in statistical modelling can offer new opportunities in spatial primatology.

Acknowledgement: We thank the members of Ecological parasitology and Tropical biodiversity laboratory and faculties of Department of Zoology, Kannur University, Mananthavady Campus for their valuable suggestion during the writing of this review. Mewa Singh acknowledges Science and Engineering Research Board, Government of India for the award of SERB Distinguished Fellowship (Award No. SB/S9NSCP/ SERB-DF/2018(1)). Muhammed Sabith K M acknowledges the University Grant Commission for the fellowship (Ugc-Ref. No.: 515/(CSIR-UGC NET JUNE 2018). Joseph J Erinjery acknowledges Science and Engineering Research Board, Government of India startup research grant (SRG/2021/001098)

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