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ACKNOWLEDGEMENTS. We thank the Head, Centre of Advanced Study in Geology, Lucknow University, for providing facilities. A.A. thanks the Head, CAS in Geology, Banaras Hindu University, Varanasi for help and encouragement. We also thank Dr R. Bali, Lucknow University for his critical suggestions and Prof. N. C. Pant, Delhi University and Prof. Santosh Kumar, Nainital University for help in the petrography of thin sections.

Received 11 March 2011; accepted 24 June 2011

Decline of suitable habitats and conservation of the endangered lion-tailed macaque: land-cover change at a proposed protected area in Sirsi–Honnavara, Western Ghats, India

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Habitat fragmentation, loss of habitat and other anthropogenic activities have caused a population decline in many species, caused restriction in their distribution or even led to their local extinction. We attempted to understand the impact of such pressures on the newly identified and possibly the largest population of the endangered lion-tailed macaque, *Macaca silenus* in the Reserve Forests of Sirsi and Honnavara, Karnataka, using a temporal series of satellite images. Classified images showed a major increase in open area with a rapid decline in vegetation cover of about 11.5% in the wet evergreen forests over the last decade, amounting to a loss at the rate of 1.9% per year. We thus consider habitat protection and restoration of evergreen forest as the top priority along with the enforcement of conservation steps, including legal action against encroachment, extraction of timber and further fragmentation, to protect this critically important habitat of the lion-tailed macaque.

Keywords: Habitat loss, fragmentation, *Macaca silenus*, satellite imagery, wet evergreen forest.

THE primary forests of Asia, particularly those of the Western Ghats in southwestern peninsular India, are disappearing at an alarming rate due to anthropogenic activities and are undergoing a change in land-use patterns, including being replaced by forests comprising inferior secondary species[1]. The hill ranges of the Western Ghats are rich in biodiversity and display high endemism, and have thus been considered as one of the biodiversity hotspots of the world[2]. The Western Ghats, however, also has a high human density[3]. Although these hills have been inhabited for several thousands of years[4], the forests of the Western Ghats are declining drastically and have undergone severe fragmentation in recent years due to a

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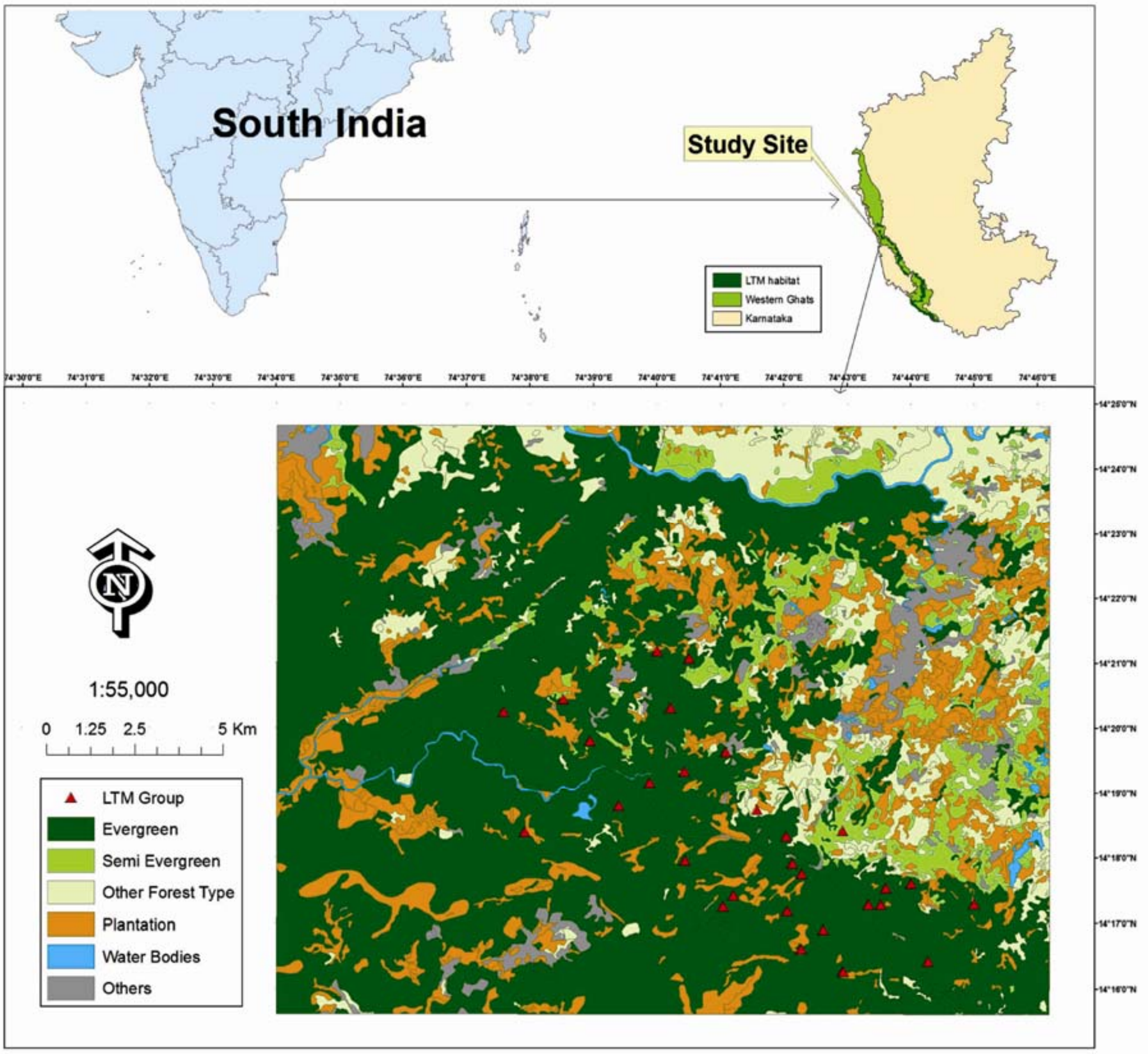

Figure 1. Vegetation map of the study area showing the location of lion-tailed macaque troops.

high degree of exploitation[5]. Such fragmentation or the complete loss of habitats and other anthropogenic activities have led to the local extinction of many species or caused them to be now restricted in their distribution to isolated and threatened patches.

The lion-tailed macaque, *Macaca silenus* is an endemic, highly endangered primate facing various threats in its last rainforest habitat patches[6–10]. These macaques, restricted to the evergreen forests of the Western Ghats in Karnataka, Tamil Nadu and Kerala, have been classified as endangered[11] because of their selective feeding habits, limited range of occupancy, delayed sexual maturity, long interbirth intervals, low population turnover and small remaining populations in the wild. Population surveys have suggested that there are less than 4000 individuals in the wild[12]. In the recent past there has been a drastic decline in the population of this species, the principal factors being habitat loss, habitat fragmentation and hunting[7–11,13–15]. In this dismal scenario, Kumara and Singh[8] identified a large population of this primate in the reserve forests of Sirsi–Honnavara, Karnataka, whereas Kumara and Sinha[10] have identified it as possibly the largest among the known populations of the species in the wild. To conserve this population, Kumara *et al.*[16] developed potential boundaries to protect and manage it and further proposed that this area be designated as a protected area. The region, however, is characterized by high human density with extensive areas under agriculture, posing high anthropogenic pressures on the forests. We attempted to evaluate the forest status in this proposed lion-tailed macaque conservation area using a temporal series of satellite images. Such satellite images are crucial in providing a temporal window on recent changes in the forest cover, particularly in an area where the difficult terrain prevents extensive ground-truthing of potential habitat loss and fragmentation.

The study area forms a part of the central Western Ghats in Uttara Kannada District, Karnataka, South India, and lies between 74.58°–74.78°E and 14.25°–14.42°N (Figure 1). The area includes five forest ranges, namely

Kyadagi and Siddapura in Sirsi Forest Division, and Kumta, Honnavara and Gersoppa in Honnavara Forest Division. The official status of the forest is that of a Reserve Forest, with interspersed revenue lands. The altitude varies from 300 to 800 m asl. The terrain, being a part of a ridge, is generally undulating and forms the primary watershed for the origin of many streams and rivers. The area is densely covered with southern tropical evergreen and southern tropical semi-evergreen forests, with many layers of vegetation. A number of villages with large tracts under cultivation of commercial crops (areca nut, *Areca catechu* and paddy, *Oryza sativa*) are scattered within the area.

A general land-use/land-cover map of the area was extracted by digitizing toposheet number 48 1/11 (ref. 17) to derive the vegetation cover of the area (Figure 1). Further verification was carried out by repeated field visits. The vegetation cover of the area could be classified into five thematic classes on the basis of a comparison with the classified images of the vegetation map produced by Pascal[18], and this classification was supported by the geo-coordinates directly obtained from the field. These thematic classes could be grouped and broadly categorized under evergreen forests, semi-evergreen forests, plantations (including *Acacia* species, *Casuarina* species, *Eucalyptus* species, bamboo and teak, *Tectona grandis*), other forest types (including scrub jungles and grasslands), water bodies, agricultural fields (including areca nut and paddy, the two major crops in the area) and other areas (including barren land and built-up areas).

We selected the Landsat 7 images of the year 1989 and 2000, given the preference of these images in the study of the environment[19], and selected subsets of the images to match our study area. The acquisition dates for the images were November 1989 and March 2000 respectively. The problem of differences being generated in vegetation cover on these acquisition dates due to varying climatic conditions was overcome by the geo-coordinates collected from the field during the classification process. A supervised classification was carried out, using the software ERDAS, to obtain a classified map of the land-use/land-cover over a span of 11 years from 1989 to 2000. Five distinct classes could be derived from homogeneous areas for which detailed descriptions on vegetation were available in the thematic map, and these were chosen for the supervised classification (Figure 1). These consisted of (i) evergreen forests (including evergreen and semi-evergreen forests); (ii) plantations (including those of areca nut, *Acacia*, *Casuarina*, bamboo, *Eucalyptus* and teak); (iii) paddy fields; (iv) *Byana* (grasslands, degraded forests, barren and built-up land), and (v) water bodies (rivers and streams). The parametric rule for the supervised classification used for all images was the maximum likelihood method, which exhibits sensitivity to variation in the quality of the training data[20]. A minimum of 40 and a maximum of 80 signature sets were collected from the field for each of the five thematic classes using a hand-held GPS (Garmin 76CSx). The chosen thematic classes were identified as relevant for quantifying the range of vegetation types and the associated habitat of the lion-tailed macaque across space and time.

The area under each thematic class was calculated to get the extent of change in the respective habitat type from 1989 to 2000. The areas (in sq. km) for all the classes were extracted for both the years and the same data were used to determine the intrinsic rate of change (r) in each forest type between the years using the formula:

$$N_t = N_0 e^{rt},$$

in which r is calculated from the available study years N, and t is the number of years between the study period.

Geo-coordinates were recorded for every sighting of lion-tailed macaque troops during the surveys in the study area. The data on group size and location details for the entire population are provided by Kumara and Singh[9]. These coordinates were then overlaid on the land-use/land-cover map to determine the habitat association of the species, and the classified images were visually interpreted to examine the qualitative changes and the magnitude of such change in the land-use patterns within the habitat of the lion-tailed macaque.

Our analysis of the habitat preference of the lion-tailed macaque population, obtained by mapping the observed troop locations on the vegetation cover map of the Sirsi–Honnavara area, indicated that virtually all troops, except three, were located in continuous evergreen forests (Figure 1). The three exceptional troops were mapped to the eastern limit of the population in areas that were richer in agricultural land, plantations and other forest types.

The supervised classified images of 1989 and 2000 (Figure 2) clearly depict a significant increase in open areas over the 11 years; these images, however, indicate a greater degree of change shown by the thematic vegetation cover map (Figure 1). The wet evergreen forests in this region exhibit a major decline of about 11.5% in these intervening years (Figure 3), a change at a rate of about 1.9% per year (intrinsic rate of change, $r = -0.019$; Figure 4). The area under all other forest types appears to have slightly increased during the same period, although it is significant that the maximum increase has been in grasslands/degraded forests (Figure 3). The evergreen forests, preferred by lion-tailed macaques, are still continuous in their distribution in the western part of the region, but there have been major changes in the eastern parts which now appear as a narrow strip covered principally by other forest types.

The rate of deforestation in the Western Ghats has been estimated to be about 0.57% annually during the period 1920–1990 (ref. 5). The estimate of annual decline in natural forest cover in different regions of the Western

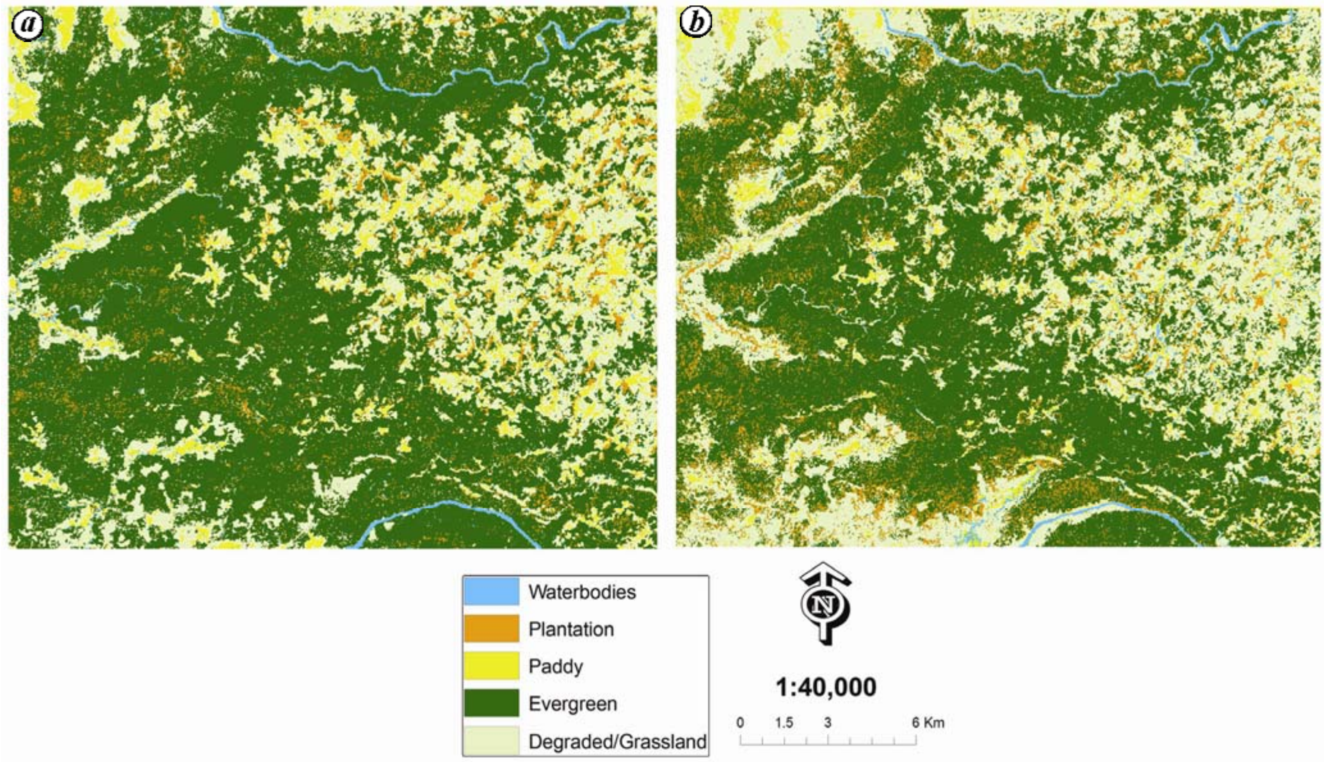

Figure 2. Classified images of the study area from (***a***) 1989 and (***b***) 2000.

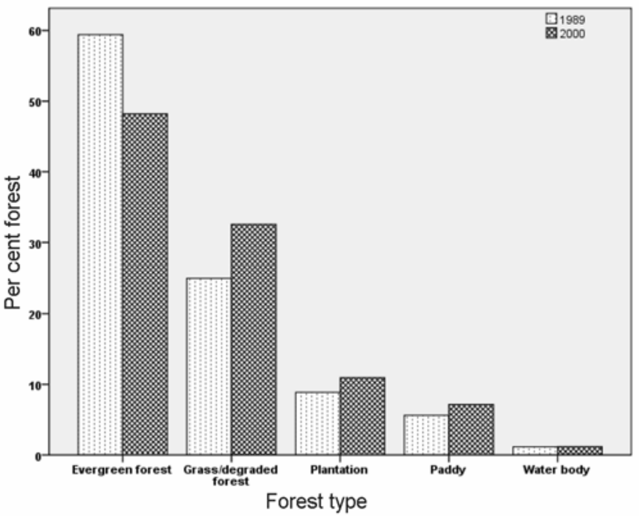

Figure 3. Status of different forest types during 1989 and 2000.

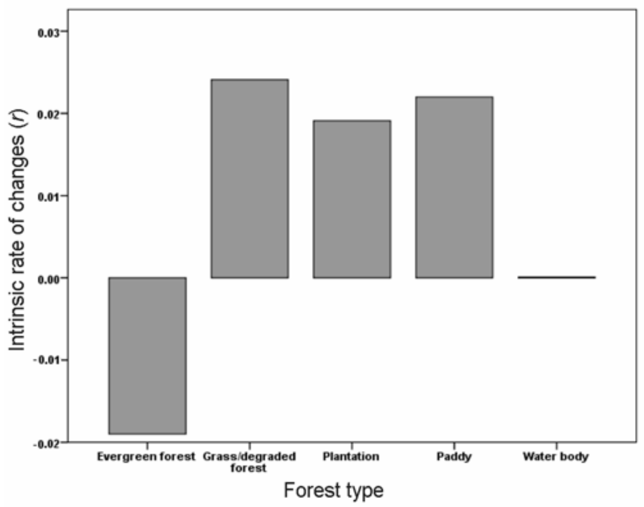

Figure 4. Intrinsic rate of change (r) in the area under different forest types between 1989 and 2000.

Ghats, however, remains highly variable, as, for example, 0.90% in some parts of Kerala and 0.28% in others between 1961 and 1988 (ref. 21); 0.33% in the Agastya-malai region from 1920 to 1990 (ref. 22), and up to 1.84% in some districts of Tamil Nadu and Kerala[23]. In our estimate, the annual loss of evergreen forests in Sirsi–Honnavara was about 1.9%, which is on par with the highest decline reported for any part of the Western Ghats[23]. An important reason for this may be the fact that the forests of Sirsi–Honnavara do not fall under the Indian protected area network, and further there is a high density of humans (~46 people/km^2) spread out in about 29 villages[9]. Most of the local people in the study area are agriculturists and the expansion of agricultural land is almost invariably mediated by the illegal encroachment of forestland. Although the collection of non-timber forest produce by the local people is legal, uncontrolled timber and firewood extraction continues unabated in these forests. Leaf litter is regularly collected from the forest floor during the dry season, whereas green manure is made by extracting the foliage from the undergrowth and also by lopping tree branches during the wet season. The collected leaf litter and green manure are then mixed with cow dung and used as manure for agriculture. As such activities keep escalating in an ever-increasing human population, the already threatened forests near human settlements are made even more fragile[24]. These anthropogenic factors have collectively contributed to the rapid loss of evergreen forests and the concomitant increase in degraded forests or grasslands over the last decades.

Land-cover change and habitat loss can have drastic impacts on any species. Habitat specialists, such as many arboreal mammalian species, are usually more severely affected by such changes than are more resilient species that are able to adapt and survive better under these adverse conditions. Fragmented habitats, particularly evergreen forests, usually tend to be biologically impoverished and, in general, support a relatively lesser number of habitat specialists[25]. The lion-tailed macaque is one such habitat specialist found in this region and the Sirsi–Honnavara population marks the northernmost limit of its distribution range. Although the macaque population of Sirsi–Honnavara does not face much hunting pressure, the extensive habitat loss documented in this study can lead to severe population fragmentation. Kumara and Sinha[10] have pointed out that most lion-tailed macaque populations in the wild, including those in southern Karnataka, are depleted in troops, and many troops have highly skewed sex ratios. The Sirsi–Honnavara population has thus been considered as one of the largest and most important populations of the species over its entire distribution range. We thus consider habitat protection and restoration of the evergreen forest to be of highest priority in this region and additionally advocate the enforcement of conservation action, particularly through legal action against forest encroachment and extraction of timber to restrain further loss of evergreen forests. Any developmental activities like dam construction or road development should also be carefully considered as they can significantly enhance habitat fragmentation.

The forests of Sirsi–Honnavara are a treasury of the endemic flora and fauna of the Western Ghats, many of which are today severely endangered, though the official status of the region is that of a Reserve Forest. A new species of frog, *Philautus neelanethrus*, has been recently discovered[26], and a few critically endangered tree species are also reported from this region[27]. This area is also characterized by *Myristica* swamps, a unique habitat for many endemic plant species, including the recently discovered tree, *Semecarpus kathlekanensis*[27,28]. The conservation, restoration and management of the evergreen forests of Sirsi–Honnavara are of critical importance in order to protect the biodiversity of the region and ensure the continued survival of several unique endemic species, including the lion-tailed macaque.

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ACKNOWLEDGEMENTS. We are grateful to the Chief Wildlife Warden and the officials of the Karnataka Forest Department for research permission. This study was funded in part by a Rufford Small Grant, UK; Primate Action Fund (Conservation International), USA; Primate Conservation Inc, USA; Sirsi Forest Division (Karnataka Forest Department), India, and a Critical Ecosystem Partnership Fund–Small Grant. We acknowledge the support of Lakshminarayana and Shanthala Kumar in the field and during data analyses. We thank Josh Cole, Jane Raymonds, Noel Rowe, Anthony B. Rylands, Mewa Singh, Werner Kaumanns, Ajith Kumar, Surendra Mal Mohnot, Thomas T. Struhsaker and Mohammad Irfan-Ullah for their inputs and continued support. We also thank the anonymous referee for critical comments that helped improve the manuscript.

Received 24 January 2011; revised accepted 16 June 2011

Erratum

First evidence of brain surgery in Bronze Age Harappa

A. R. Sankhyan and G. R. Schug
[*Curr. Sci.*, 2011, **100**, 1621–1622]

1. In the caption to Figure 1 *a*, ‘left’ lateral view should read as ‘right’ lateral view.
2. The first author’s name should read as Anek Ram Sankhyan. The second author’s name and affiliation should read as

Gwen Robbins Schug
Department of Anthropology
Appalachian State University
Boone, NC 28608, USA

3. The acknowledgement should read as follows:

ACKNOWLEDGEMENT. G.R.S. was funded by the United States India Educational Foundation, Fulbright–Nehru Senior Fellowship. She thanks Kelsey Gray for assistance. The study was conducted at Kolkata (India) in the Palaeoanthropology Laboratory. A.R.S. thanks Prof. K. K. Misra, Director, Anthropological Survey of India, Kolkata for facilities and Rana Chakrabarty for assistance.

Note of clarification: The author A. R. Sankhyan is responsible for the text, references and figures. He feels that further study based on CT scans may clarify the extent of osteogenesis and osteosclerosis. The co-author Gwen Robbins Schug shares the views expressed, and in addition, clarifies that trepanation is lacking in the Kalibangan skulls.