

Nesting and feeding habits of the Indian giant squirrel (*Ratufa indica*) in Karlapat wildlife sanctuary, India

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Pradhan, A. K., Shrotriya, S., Rout, S. D. & Dash, P. K., 2017. Nesting and feeding habits of the Indian giant squirrel (*Ratufa indica*) in Karlapat wildlife sanctuary, India. *Animal Biodiversity and Conservation*, 40.1: 63–69.

Abstract

Nesting and feeding habits of the Indian giant squirrel (Ratufa indica) in Karlapat wildlife sanctuary, India.— The Indian giant squirrel (*Ratufa indica*) is one of four species of giant squirrels in the world. It is endemic to India and its populations are severely fragmented. The ecology of squirrels in Asia has been little studied, hindering conservation and management efforts. We studied the Indian giant squirrel's nesting and feeding habits during spring in the Karlapat Wildlife Sanctuary, India. We surveyed 122.5 km of natural trails for direct observation of these squirrels, their nests and feeding evidence, and we sampled plot-based quadrats to assess the availability of resources. We used Manly's resource selection function and log-likelihood test ratios to analyse the data for preference. The mean encounter rate of the Indian giant squirrel was 0.57 (\pm 0.18 SD) individuals/km. *Haldinia cordifolia* ($W_i = 4.899$, $p < 0.001$) and *Mangifera indica* ($W_i = 4.322$, $p = 0.001$) were the preferred tree for nesting, whereas *Xylia xylocarpa* (31.30%) and *Bauhinia vahlii* (28.24%) were the most commonly eaten plants. Nest site preference was for taller tree species. As current management practices directly damage the preferred nesting sites and food resources, our findings aim to promote effective conservation of the Indian giant squirrel.

Key words: Giant squirrel ecology, Forest management, Nest tree selection, Nest structure, Food preference, NTFP (non-timber forest products) collection

Resumen

Hábitos de nidificación y alimentación de la ardilla gigante hindú (Ratufa indica) en el refugio de vida silvestre de Karlapat, India.— La ardilla gigante hindú (*Ratufa indica*) es una de las cuatro especies de ardilla gigante del mundo. Se trata de una especie endémica de la India, pero sus poblaciones se encuentran muy fragmentadas. La ecología de las ardillas en Asia se ha estudiado poco, lo que ha entorpecido los esfuerzos de conservación y de gestión. Se estudiaron los hábitos de nidificación y alimentación de la ardilla gigante hindú durante la primavera en el refugio de vida silvestre de Karlapat, en la India. Se inspeccionaron 122,5 km de senderos naturales para la observación directa de estas ardillas, sus nidos e indicios de alimentación, y se muestrearon varios cuadrantes para evaluar la disponibilidad de recursos. Para analizar los datos sobre preferencias, se emplearon los índices de la función de selección de recursos de Manly y del logaritmo de la prueba de razón de verosimilitud. El promedio del índice de encuentros de la ardilla gigante hindú fue de 0,57 (\pm 0,18 DE) individuos/km. *Haldinia cordifolia* ($W_i = 4,899$; $p < 0,001$) y *Mangifera indica* ($W_i = 4,322$; $p = 0,001$) fueron los árboles preferidos para la nidificación, mientras que *Xylia xylocarpa* (31,30%) y *Bauhinia vahlii* (28,24%) fueron las plantas de las que se alimentaron en mayor medida. La preferencia del sitio de nido fue por especies arbóreas más altas. Como las actuales prácticas de gestión dañan directamente los sitios preferidos de nidificación y los recursos alimentarios, con nuestras conclusiones tratamos de promover la conservación eficaz de la ardilla gigante hindú.

Palabras clave: Ecología de la ardilla gigante, Gestión forestal, Selección de árboles para la nidificación, Estructura de los nidos, Preferencia alimentaria, Recogida de productos forestales no madereros

Received: 15 II 15; Conditional acceptance: 17 IV 15; Final acceptance: 4 X 16

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Introduction

The Indian or Malabar giant squirrel (*Ratufa indica* Erxleben, 1777) is endemic to the Peninsular India (South India) (Corbet & Hill, 1992). Although it is widely distributed within its range, it occurs in severely fragmented populations (Molur et al., 2005). It has faced local extinction and range restriction in several areas due to hunting and habitat loss and suitable habitat is limited in the areas where it occurs (Molur, 2016). The Indian giant squirrel is currently listed in the 'Least Concern' category of IUCN Red List, Appendix II of CITES and Schedule II of the Wildlife (Protection) Act, 1972 of India (Favre, 1989; Molur, 2016).

The Indian giant squirrel occurs in the elevation range of 180 to 2,300 m and inhabits deciduous, mixed deciduous and moist evergreen forests (Prater, 1980). It is a large-bodied (90 to 100 cm), diurnal and arboreal squirrel (Hayssen, 2008). A solitary living species, it is seen in pairs only during the breeding season. It usually constructs more than one nest, or drey, within a single breeding season. The nests, which are made of leaves and twigs, are built in tall, profusely branched trees, in the higher canopy (Borges, 1989; Ramachandran, 1992). The species is omnivorous and feeds on fruits, flowers, nuts, bark, bird eggs and insects (Payne, 1979; Ramachandran, 1992). The ecology of squirrels from Asian countries has been little studied and published information is scarce (Pradhan et al., 2012). We studied the nesting and feeding preferences of the Indian giant squirrel in the Karlapat wildlife sanctuary, India, the easternmost limit of their distribution. We discuss threats to the species in our study area and envision that the information herein will contribute to the conservation of the Indian Giant Squirrel.

Material and methods

Study area

Karlapat wildlife sanctuary (19° 36' 50" to 19° 50' 51" North and 82° 56' 18" to 83° 19' 35" East) is located in Kalahandi district of Odisha, India (fig. 1). The sanctuary covers an area of 175.50 km² and altitude ranges from 400 to 996 m. According to the biogeographic classification of India, the sanctuary falls within the Deccan Peninsula Eastern highlands province close to the eastern coast (Rodgers et al., 2002). Geology of the region features patches of granite and bauxite rocks. The vegetation of the sanctuary is a mosaic of moist peninsular sal (*Shorea robusta*), moist mixed deciduous, dry deciduous and riparian semi-evergreen forests (Champion & Seth, 1968). The major fauna of the sanctuary are Leopard (*Panthera pardus*), Sloth bear (*Melursus ursinus*), Indian elephant (*Elephas maximus*), Indian bison (*Bos gaurus*), Sambar deer (*Rusa unicorn*), Barking deer (*Muntiacus muntjak*), Mouse deer (*Tragulus meminna*), Smooth-coated otter (*Lutra persipicillata*) and Indian Pangolin (*Manis crassicaudata*). The sanctuary is divided into six administrative blocks, and contains 17 villages.

Data collection

Data were collected from February 2009 to April 2009 (spring) when the squirrels are more active and easily seen. We searched for animals and their nests along the natural trails in the forest. The trails were selected using geographic information system (GIS) attempting to cover the entire sanctuary and keeping the trails spatially equidistant. A total distance of 122.5 km was walked over 55 trails of about 2 km each. The trails were walked in morning (06:00–10:00 hr) or evening (16:00–18:00 hr) hours when activity of the species is high. Feeding behaviour was recorded by direct observation and from food found in nests. Nest location was recorded using GPS. We also collected data on nesting tree species, height of the tree and height of the nest from the ground. Data on the nest building material and dimensions of the nest were collected only when nests were empty. Plot based random quadrat sampling was conducted to assess the availability of nesting tree species (Mishra, 1968). At least 20 plots (15 x 15 m²) were sampled for each of the six administrative blocks. Plants above 10 cm in girth at breast height were considered trees and categorised as dry deciduous, moist deciduous and semi-evergreen types.

Data analysis

Preference for nesting trees was analysed using Manly's resource selection function (Manly et al., 2002). The data on nesting tree availability and use were obtained and treated in design I study framework of habitat use, where availability and use of the resource by individuals are not identified separately (Thomas & Taylor, 1990). Evidence for the non-random selection of food plants was tested using log-likelihood test ratios (Karanth & Sunquist, 2000). Summary statistics were calculated wherever appropriate. All statistical analysis were performed in the program 'R', version 3.3.0 and package 'adehabitatHS', version 0.3.12 (Calenge, 2006; R Core Team, 2016).

Results

We sighted a total of 70 Indian giant squirrels during the trail surveys, corresponding to a mean encounter rate of 0.57 (\pm 0.18 SD) individuals/km. We recorded 277 nests built in 37 tree species. The Indian giant squirrel built significantly more nests in dry deciduous trees (61.07%) than in semi-evergreen (30.15%) and moist deciduous trees (8.83%) ($X^2 = 12.584$, $df = 2$, $p = 0.002$; table 1). Resource selection function revealed a preferential selection for nesting tree species ($Khi2L = 199.288$, $df = 36$, $p < 0.001$). Analysis showed that *Haldinia cordifolia* ($Wi = 4.899$, $p < 0.001$) and *Mangifera indica* ($Wi = 4.322$, $p = 0.001$) were the most preferred nesting tree species whereas *Cassia fistula* ($Wi = 0.096$, $p < 0.001$) and *Mallotus philippensis* ($Wi = 0.137$, $p < 0.001$) were the least preferred species (fig. 2). Most nests were built on *Terminalia alata* (11.03%) and *Anogeissus latifolia*

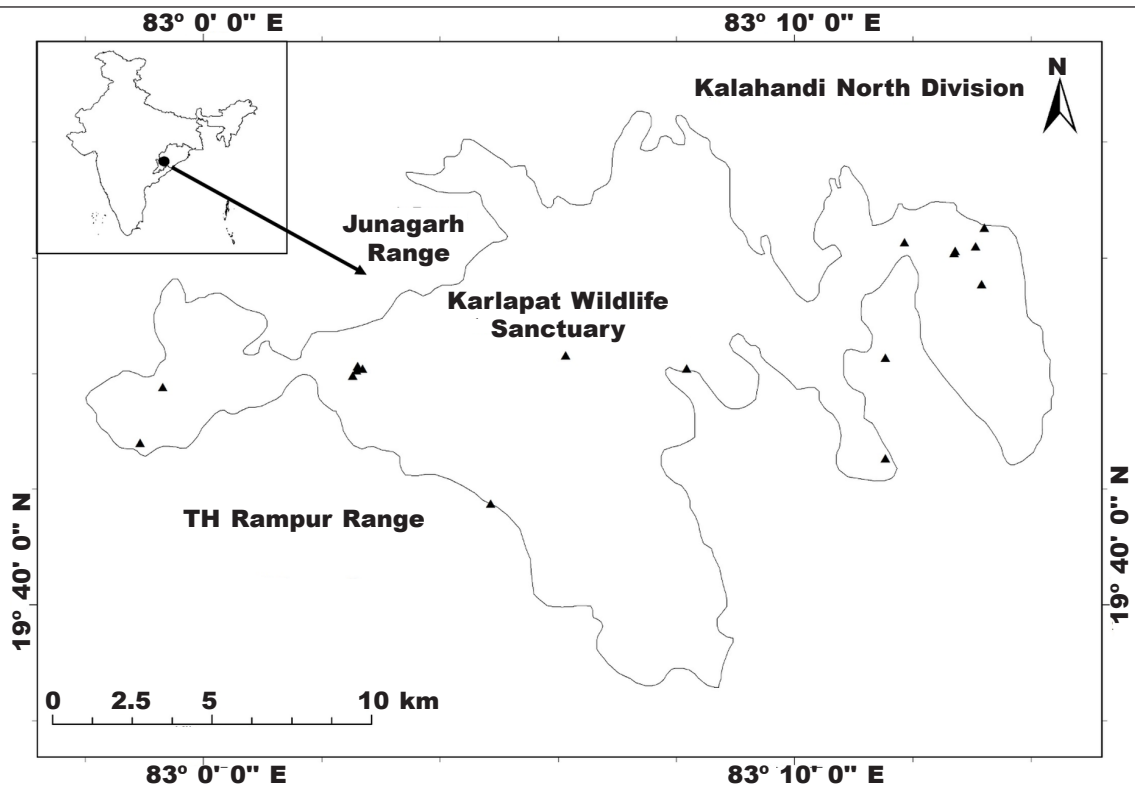


Fig. 1. Location and map of Karlapat wildlife sanctuary, Odisha, India. Black triangles represent villages inside the sanctuary.

Fig. 1. Ubicación y mapa del refugio de vida silvestre de Karlapat, en Odisha, la India. Los triángulos negros representan las aldeas dentro del refugio.

(8.82%) trees, which were also among the preferred nesting trees ($W_i = 1.925$ and 2.073 , $p = 0.004$ and 0.008 , respectively). The mean height of nesting trees was $11.08 (\pm 2.11 \text{ SD})$ m, and an average height of the nests from the ground was $9.64 (\pm 2.04 \text{ SD})$ m.

We observed that about 80% of the nesting trees had an association with climber plants species such as *Bauhinia vahlii*, *Combretum decandrum*, *Entada rheedii* and *Calycopteris floribunda*. The squirrels picked most of the nesting materials from the nes-

Table 1. Availability and use of nesting trees and height of nesting trees and nests in different tree types of Karlapat wildlife sanctuary.

Tabla 1. Disponibilidad y uso de árboles para la nidificación y altura de los mismos y de los nidos en distintos tipos de árbol del refugio de vida silvestre.

Tree type	Dry deciduous	Moist deciduous	Semi-evergreen
No. of species	20	5	12
Availability of trees (%)	54.07	16.46	29.47
Use for nesting (%)	60.65	8.66	30.69
No. of nests	168	24	85
Tree height (m \pm SD)	11.26 ± 2.26	10.66 ± 1.75	10.81 ± 1.86
Nest height (m \pm SD)	9.8 ± 2.18	9.29 ± 1.70	9.42 ± 1.81

Table 2. Preferred food plants of the Indian giant squirrel in Karlapat wildlife sanctuary: Fr. Feeding records (%); * Used for nesting.

Tabla 2. Alimentos vegetales preferidos de la ardilla gigante hindú en el refugio de vida silvestre de Karlapat: Fr. Registros de alimentación; * Utilizado para anidar.

Food species	Fr (%)		Food species	Fr (%)	
<i>Xylia xylocarpa</i>	31.30	*	<i>Cleistanthus collinus</i>	0.76	*
<i>Bauhinia vahlii</i>	28.24		<i>Madhuca indica</i>	0.76	*
<i>Terminalia alata</i>	9.92	*	<i>Mitragyna parvifolia</i>	0.76	*
<i>Shorea robusta</i>	9.16	*	<i>Zanthoxylum armatum</i>	0.76	
<i>Mangifera indica</i>	6.87	*	<i>Schleichera oleosa</i>	0.76	*
<i>Albizia lebbek</i>	3.05	*	<i>Stereospermum suaveolens</i>	0.76	*
<i>Butea monosperma</i>	1.53		<i>Syzygium cuminii</i>	0.76	*
<i>Garuga pinnata</i>	1.53	*	<i>Tamarindus indica</i>	0.76	*
<i>Terminalia arjuna</i>	1.53	*	<i>Terminalia belerica</i>	0.76	*

ting tree and associated climber species. Stem and leaves of *B. vahlii* were used in 86% of the nests. We measured the dimensions of 14 intact and abandoned nests. The mean length, width and depth of the nests were 27.35 (\pm 4.87 SD), 17.24 (\pm 3.40 SD) and 17.44 (\pm 3.33 SD) cm, respectively. Circular opening of the nests had a diameter of 5.09 (\pm 0.48 SD) cm.

We collected data on feeding through 131 direct and indirect records. Log-likelihood test ratio showed that evidence for non-random selection of food plants was significant ($G^2 = 236.98$, $df = 17$, $p < 0.001$). *Xylia xylocarpa* (31.30%) and *B. vahlii* (28.24%) were the most frequently used feeding plants, implying their importance (table 2). We observed the squirrels eating new leaves of *Tamarindus indica*, ripe fruits of *X. xylocarpa*, *Ficus recimosa*, *B. vahlii*, *Schleichera oleosa*, *M. indica* and *T. alata* and flowers of *Butea monosperma*. We also found other food materials nibbled upon by the squirrels inside the nests (fig. 3).

Discussion

The encounter rate or direct observations of the Indian giant squirrel varied little across the sanctuary area. However, the encounter rate was high in the pristine forest patches with dense canopy cover. Preference for nesting trees could depend on factors such as access to nesting material and food, nest safety and the branching pattern of the tree species. Our data showed that tree height was a major factor governing nesting tree selection. The Indian giant squirrel consistently selected tall trees with a mean height of 11.08 (\pm 2.11 SD) m. A nesting preference for dry deciduous trees could also be attributed to tree height (table 1). The nesting trees with high selection ratios were comparatively taller species with a long main trunk topped by a large crown

with many branches. Tree squirrels are known to build nests on trees with interlinking crowns, allowing easy access and movement in the canopy (Patton, 1975; Hall, 1981; Ramachandran, 1992). Datta & Goyal (1996) also observed that the Indian giant squirrel preferred large trees as nesting sites, probably to avoid predators. Kumara & Singh (2006) sighted the Indian giant squirrel mostly at a height of 16 to 20 m in moist forests and 11 to 15 m in dry forests. We observed the Indian giant squirrel nesting on a large variety of the tree species ($n = 37$) in Karlapat wildlife sanctuary. Kanoje (2008) also reported the use of a large variety of tree species ($n = 30$) for nesting in Sitanadi wildlife sanctuary, India.

Some of the preferred nesting trees, such as *M. indica*, *Albizia lebbek*, *Syzygium cumini* and *T. alata*, also provided food material (table 2). An association with climber plants, which provide nest building resources, could influence the selection of nesting trees. *B. vahlii* was a crucial climber species as it was the most frequently used nesting material and also a preferred plant food (table 2). The squirrels constructed their nests on a forked branch by interweaving climber plant stems and twigs and padding it with the leaves. Entrance to the globular (or oval) shaped nest was horizontal. Size and shape of the nests varied from nest to nest, but the diameter of the entry was consistent at 5.09 (\pm 0.48 SD) cm. The height of the nest from the ground depended on the height of the tree, which is evident from the similar standard deviation for both (table 1). However, it is interesting to note that the distance of the nest from the top of the tree was averaged at 1.185 (\pm 0.48 SD) m. The nests were not built on the highest possible branch, as the squirrels sought cover above the nest. Such cover might help avoid direct heat from the sun and serve as a hiding-place from birds of prey (Pradhan et al., 2012).

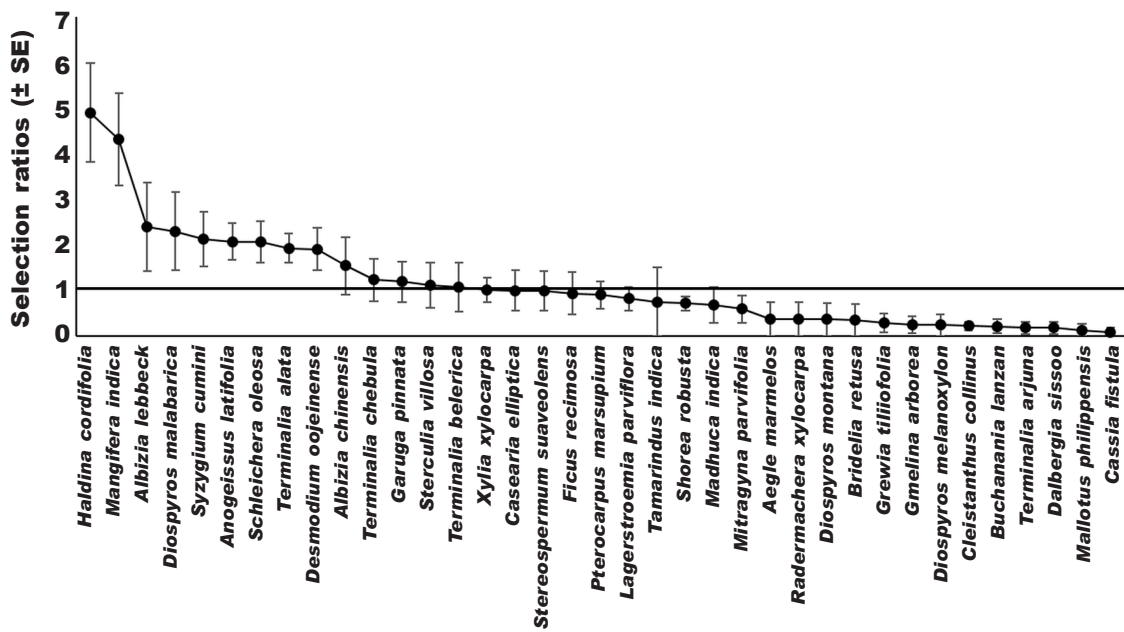


Fig. 2. Manly's resource selection function for nesting tree preference of the Indian giant squirrel. Plant species above selection ratio one are preferred for nest building.

Fig. 2. Función de selección de recursos de Manly para las preferencias de árboles para la nidificación de la ardilla gigante hindú. Las especies vegetales cuyo cociente de selección es superior a uno son las preferidas para la construcción del nido.

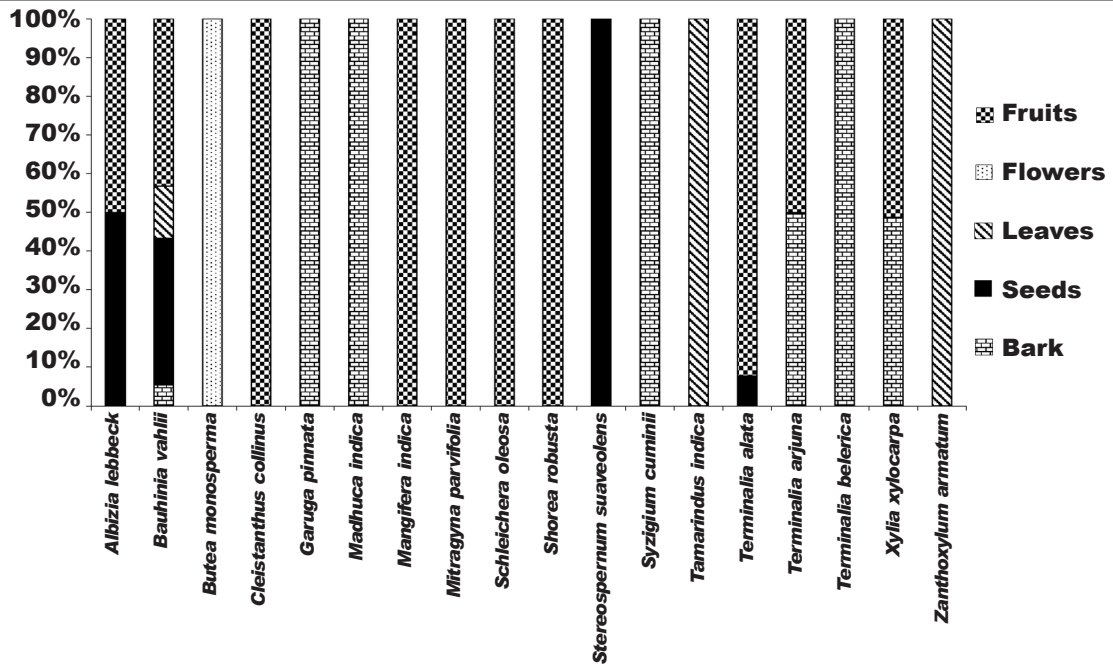


Fig. 3. Plant species and their parts used as food by the Indian giant squirrel.

Fig. 3. Especies vegetales y sus partes utilizadas como alimento por la ardilla gigante hindú.

We observed that the Indian giant squirrel depended on *X. xylocarpa* (31.30%) and *B. vahlii* (28.24%) for the bulk of its diet (table 2). This finding could be the result of the higher availability of these plants in the forest and the fact that the survey season matched with the fruiting of both species. Baskaran et al. (2011) found that the principal food source of the Indian giant squirrel was *Tectona grandis* (41%) in Mudumalai wildlife sanctuary, southern India. Nevertheless, it could be inferred that *X. xylocarpa* and *B. vahlii* are valuable food sources of the Indian giant squirrel in spring. *B. vahlii* also provided a greater variety of food items than other species (fig. 3). The Indian giant squirrel depends on a variety of plant species and their different parts to meet its nutritional needs. Similar dietary patterns of consuming different plant parts are reported from other parts of its range as well (Borges et al., 1992; Kanoje, 2008; Baskaran et al., 2011).

Karlapat wildlife sanctuary faces severe pressure from the collection of non-timber forest products (NTFP) collection and demands for wood in Kalahandi district. Fruits of *M. indica* and *S. cumini* and leaves of *Diospyros melanoxylon* are among the top NTFP collections, which are also the preferred nesting trees of the Indian giant squirrel (fig. 2). Leaves of *B. vahlii* and *S. robusta*, seeds and latex of *S. robusta*, and flowers and fruits of *Madhuca indica*, which are also extracted heavily, are all central to the diet of the Indian giant squirrel (table 2). Each month, 500 to 1,000 large, old trees are cut down to sell as part of crop management by the forest department in the surrounding areas (Kalahandi Forest Department, pers. comm.). Heavy grazing also hinders forest regeneration within the sanctuary. The wood industry requires quality timber from tall, mature trees, trees that the Indian giant squirrel specifically need for nesting. Datta & Goyal (1996) also found that the Indian giant squirrel depends mainly on large, mature trees for feeding. Another issue of concern is the increased hunting of the Indian giant squirrel for meat consumption by locals in Karlapat wildlife sanctuary (Pradhan et al., 2012). The threats to this squirrel population in Karlapat wildlife sanctuary are immediate and visible. The results of this study support the need to implement the following conservation measures for the Indian giant squirrel: prevention of lopping and felling of mature, tall trees of the preferred nesting species; prevention of forest fires and mitigation of heavy grazing to allow regeneration of trees; regular monitoring of NTFPs; conservation of food plants such as *X. xylocarpa* and *B. vahlii*, and strict implementation of the law to minimise hunting of the squirrel. Karlapat wildlife sanctuary holds one of the easternmost populations of this endemic mammalian species in India. The sanctuary is a natural mosaic of different forest types and effective conservation management could have a positive, long-lasting impact on the population of the Indian giant squirrel.

Acknowledgements

We are thankful to the Principal Chief Conservator of Forest, PCCF (wildlife), Odisha for granting research

permission. Dr. Susil Kumar Dutta and Dr. H. K. Sahoo, Department of Zoology, North Orissa University, and Dr. L. A. K. Singh, Senior Research Officer, Forest Department, Odisha are acknowledged for their input during field surveys. Dr. Prautush Mahapatra and Rupa Majhi, forest department officials, were a great support for logistics. We also thank the anonymous reviewers for their suggestions and improvement of the article.

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