Habitat quality and availability of the Sri Lanka Red Slender Loris *Loris tardigradus tardigradus* (Mammalia: Primates: Lorisidae) in the Kottawa Arboretum

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Abstract: The Red Slender Loris (*Loris tardigradus)* is one of the three primate species endemic to Sri Lanka. Currently there are two recognized subspecies of the Red Slender Loris, the Sri Lanka Red Slender Loris (*L. t. tardigradus)* and the Sri Lanka Montane Slender Loris (*L. t. nycticeboides)*. Of these, *L. t. tardigradus* inhabits rainforests in the southwestern region of the island while *L. t. nycticeboides* is restricted to the montane zone. Kottawa Arboretum harbors one of the few remaining *L. t. tardigradus* populations in the country. This study was conducted to determine the population density, habitat selection criteria and to asses the habitat availability of *L. t. tardigradus* in the Kottawa Arboretum. Using the line transect method, 34 sightings were made over a period of 21 months. Based on these observations the density of *L. t. tardigradus* in the Kottawa Arboretum and habitat selection criteria was ascertained. The calculated density of *L. t. tardigradus* in the Kottawa Arboretum is 41 animals/ km2. The average height of trees preferred by *L. t. tardigradus* is 13.97 m ± 6.02. Most of the time lorises were observed at a height range of 3.5-15 m above the ground level. Average height from the ground level where *L. t. tardigradus* were observed to occupy the tree was 8.64 m ± 5.00. Of the 50 tree species recorded in the Kottawa Arboretum, *L. t. tardigradus* was found to utilize only 16 species.

Keywords: Kottawa Arboretum, *Loris tardigradus tardigradus*, Sri Lanka Red Slender Loris

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Singhala Abstract:
රතු දණහපුළුවාණී *Loris tardigradus* වනාහි ශ්‍රී ලංකාවේ සිටින තැන්වැති වානර රටාසමයන් තුන් දෙනාගෙන් එකෙකි" මේ වන විට *L. t. tardigradus* සහ *L. t. nycticeboides* වශයෙන් රතු දණහපුළු උප රටාසමයන් දෙදෙනෙකු හඳුනා ගෙන ඇත" මොවුන් අතුරින් ශ්‍රී ලංකා රතු දණහපුළුවාණී *L. t. tardigradus* දිවයිනේ නිරිත දිග වැසි වනාන්තර තුළ වාසය කරන අතරණී ශ්‍රී ලංකා කඳුකර දණහපුළුවාණී *L. t. nycticeboides* දිවයිනේ කඳුකර ප්‍රදේශයට පමණක් සීමාවී ඇත" ශ්‍රී ලංකාවේ දැනට ඉතිරි වී සිටින සීමිත සංඛ්‍යාවක් වන ශ්‍රී ලංකා රතු දණහපුළුවන්ණී *L. t. tardigradus* ගහනයන්ගෙන් එකක් කොටිටව ශාකාගාරය තුළ වාසය කරයි" කොටිටව ශාකාගාරය තුළ වෙසෙන ශ්‍රී ලංකා රතු දණහපුළුවන් ගේණී *L. t. tardigradus* ගහන ඝනත්වයණී විසුම් බිම් තෝරා ගන්නා ආකාරය සහ පවත්නා විසුම් බිම් ඇගැයීම මෙම අධ්‍යයනය මඟින් සිදු කර ඇත" රේඩිය අනුවිජද, ක්‍රමවේදය මඟින් මාස 21 ක කාලයක් තුළ දී දණහපුළුවන් 34 ක් නිරීක්ෂණය කරන ලදි" මෙම නිරීක්ෂණ මත පදනම්ව කොටිටව ශාකාගාරය තුළ වාසය කරන ශ්‍රී ලංකා රතු දණහපුළුවන් ගේ ගහන ඝනත්වය සහ විසුම් බිම් තෝරා ගන්නා ආකාරය ගණනය කරන ලදි" කොටිටව ශාකාගාරය තුළ වාසය කරන ශ්‍රී ලංකා රතු දණහපුළුවන් ගේ ගණනය කරන ලද ගහන ඝනත්වය වර්ග කිලෝ මීටරයට සතුන් 41 කි" *L. t. tardigradus* දැකිය හැකි වූ ගස්වල සාමාන්‍ය උස මීටර් 13.97 ± 6.02 කි" බොහෝ විට පොළොව මට්ටමේ සිට මීටර් 3.5-15 අතර උසකදි දණහපුළුවන් නිරීක්ෂණය කරන ලදි" එම සාමාන්‍ය උස මීටර් 8.64 ± 5.00 කි" කොටිටව ශාකාගාරය තුළ ඇති රුක් රටා සමයන් 50 න් *L. t. tardigradus* භාවිතා කරන රුක් රටා සමයන් 16 ක් ලෙස නිරීක්ෂණය විය"

Introduction

Sri Lanka, with a total land area of 65,610km^2 is a tropical island situated in the Indian Ocean. The southwestern region of Sri Lanka, encompassing approximately 20,000km^2, is the only aseasonal ever-wet region in the whole of South Asia (Ashton & Gunatilleke 1987; Gunatilleke et al. 2005). This region is referred to as the wet zone of Sri Lanka and receives up to 3000mm of rainfall annually. This area of Sri Lanka along with the Western Ghats of India is designated as one of the world's 11 biodiversity "hyper-hot" hotspots, in demand of extensive conservation investment (Myers et al. 2000; Brookes et al. 2002). However, agroecosystems and human settlement cover most of the land area in the wet-zone of Sri Lanka (Pemadasa 1996; Ashton et al. 1997; Gamage 2005). A burgeoning human population, demand for subsistence land, and a high proportion of endangered and endemic species within Sri Lanka's wet zone have resulted in its being declared a critically endangered eco-region (Mill 1995; Nekaris et al. 2005).

The Slender Loris (*Loris* spp.) is a small nocturnal prosimian primate endemic to Sri Lanka and southern India. The forests of Sri Lanka are home to two species of Slender Loris, *Loris tardigradus* and *L. lydekkerianus*, with four currently recognized subspecies, *L. t. tardigradus*, *L. t. nycticeboides*, *L. l. nordicus*, and *L. l. grandis* (Osman Hill 1953; Groves 2001; Nekaris & Jayewardene 2003). The Red Slender Loris (*Loris tardigradus)* is endemic

to Sri Lanka (Groves 2001; Nekaris & Jayewardene 2003; Nekaris et al. 2005). The conservation status of *L. tardigradus* has since been elevated to the Endangered category (Nekaris 2008).

The Sri Lanka Red Slender Loris, *L.t. tardigradus*, is the smallest of the slender lorises, weighing 85-172g (Nekaris et al. 2005). On the basis of museum specimens, Groves (2001) recently distinguished it from other slender lorises. According to current studies *L. t. tardigradus*, only inhabits in the low land rainforest in southwestern region of the island while the other subspecies *L. t. nycticeboides* is restricted to the montane region above 1800m (Nekaris & Jayewardene 2003; Bernede & Gamage 2006). Preliminary abundance estimates of *L. t. tardigradus* showed that these lorises are patchily distributed, even within a single forest reserve (Nekaris & Jayewardene 2003; Nekaris et al. 2005).

The Kottawa Arboretum is a part of Kottawa-Kombala forest reserve and is classified as a lowland rainforest (Pemadasa 1996; Ashton et al. 1997). Kottawa Arboretum harbors one of the few remaining *L. t. tardigradus* populations in the country. Only one previous study has focused on the ecology of *L. t. tardigradus* (Nekaris et al. 2005; Bernede pers. com.). Thus, the overall aim of this study was to determine the density, habitat selection criteria, and habitat availability of *L. t. tardigradus* in the Kottawa Arboretum.

Material and Methods

The study site was the Kottawa Arboretum, part of the Kottawa-Kombala forest reserve situated in the southern region of Sri Lanka and belonging to Yakkalamulla Divisional Secretariat Division of Galle District (6°05'N & 80°18'E). The extent of the arboretum is approximately 20ha and it is classified as a lowland rainforest (Pemadasa 1996). Remnants of Dipterocarp forest occur in the site. Secondary forest occurs where the original forest cover has been removed due to logging. Some of the logged areas have been replanted with Pine Trees (*Pinus caribaea*) (Gamage 2005).

Population density: This study was carried out from August 2003 to April 2005, using the fixed line transect method. Five line transects, each 200m long separated by 50m, were marked in the study site. These transects were repeated 19 times during the sampling period. Along the transect distance to the animal was visually estimated and the angle between the animal and transect was measured using a compass. Density was calculated using the following equation. $D = f\Sigma n_i / 2L$ (Sutherland, 1996), where D is density, L is length of the transect; n_i is numbers of animals recorded in the recognized zones, and $f = a_1 + 1/ d_t$ where $a_1 = 2 (\Sigma \cos g_i / d_t \Sigma n_i)$ and d_t is distance beyond which data were truncated; $g_i = \pi n_i d_i / d_t$; and $d_i = z_i \sin \varnothing_i$, where z_i is distance of the *i*th animal when first observed, d_i is angle to *i*th animal when first observed, and di is perpendicular distance from transect line to *i*th animal.

Vegetation sampling: The plotless sampling technique (Sutherland 1996) was used to ascertain the density of tree species of the study sites. Thirty sampling points were chosen randomly in the study site. At each point two sticks were placed perpendicular to each other to demarcate four quadrates. In each quadrate the nearest tree (girth > 10cm) from the point and the nearest neighbor of the tree (girth > 10cm) in the same direction was identified. Then identity of the tree species, distance from the point to the tree, distance between tree and its nearest neighbor, circumference at breast height and the estimated tree height were recorded. Furthermore, the percentage arboreal continuity of each tree was measured using the following scale 0-1.5, 1.5-3.5, 3.5-5.0, 5.0-10.0, 10-15 & > 15 meters (Nekaris et al. 2005; Gamage 2005). In addition microhabitat characteristics of each of the following strata 0-1.5, 1.5-3.5, 3.5-5.0, 5.0-10.0, 10-15 & >15 meters, including nature, size, orientation and the presence or absence of vines and epiphytes, were recorded. In each quadrate percentage of saplings on the ground was determined using the Braun-Blanquet scale (Sutherland 1996).

Density was calculated using the T-square method (Sutherland 1996). The equation used was $D = m^2 / (2.828 \Sigma x_i \Sigma z_i)$, where D is tree density (trees/ha), m is number of sampling points, x_i is distance from the sampling point (m), and zi is distant to the nearest neighbor (m). A test of random distribution was determined using the equation 't' = $\{\Sigma [x_i^2 / (x_i^2 + z_i^2 / 2)] - m / 2\} (12/m)$ where a value greater than 1.96 indicates a non-random distribution (Sutherland 1996). Basal area was calculated using the equation, Ba = (2 x CBH/ 4) x D, where Ba is the basal area, CBH is circumference at breast height, and D is tree density (Sutherland 1996).

Habitat use: Focal animal instantaneous point sampling method was used to obtain behavior data (Charles-Dominique & Bearder 1979; Nekaris et al. 2005). Headlamps fitted with red filters were used to minimize disturbance to the animal. Data regarding habitat use was recorded upon first spotting an animal. The type of data collected included substrate size, substrate angle, height from the ground level, tree height, and tree type (Nekaris 2003; Nekaris et al. 2005).

Results

Population density: During the observation period a total of 34 sightings were recorded. The unit density of *L.t. tardigradus* at the Kottawa Arboretum was found to be 41 animals/km². Therefore the estimated population size of *L.t. tardigradus* in the Kottawa Arboretum (extent 20 ha) is approximately eight animals.

Vegetation sampling: The 240 trees surveyed during the vegetation study represents 50 species belonging to 25 families. Of these, 37 species (74%) are endemic to Sri Lanka while the remaining 13 (26%) can be defined as native species (Table 1) (Clarify/define the use of endemic and native here or in the table title for international readers. Does endemic mean to only the Arboretum, whereas natives are transplants from other areas of Sri Lanka and do not naturally occur in the study site). The most abundant tree species recorded was *Acronychia pedunculata* (n = 27; 11.3%). Other relatively common species included *Lijndenia capitellata* (n = 21; 8.8%), *Agrostistachys coriacea* (n = 11; 4.5%), and *Mangifera zeylanica* (n = 10; 4.2%). All other tree species were encountered less than 10 times during the survey period. The calculated density of trees in the sample (study site?) was 1917 trees/ha. The calculated 't' value for the test of random distribution was +21.48. The average height of trees in the sample was 8.19m ± 6.55, with a minimum of 2.5m and a maximum of 40m. The average CBH was 34.38cm ± 52.64; with a minimum of 10cm and a maximum of 305cm. The tallest tree (40m) recorded from the study site was *Dipterocarpus hispidus* with a CBH of 305cm. The most common

Table 1. Tree species (>10cm GBH) recorded using the plot-less sampling technique in the Kottawa Arboretum

Family	Species name	Common name	Count	%	Status
Anacardiaceae	*Campnosperma zeylanicum*	Aridda	8	3.33	Endemic
Anacardiaceae	*Mangifera zeylanica*	Atamba	10	4.17	Endemic
Anacardiaceae	*Semecarpus nigro-viridis*	Gatabadulla	6	2.50	Endemic
Anacardiaceae	*Semecarpus subpeitata*	Kabarabadulla	7	2.92	Endemic
Anacardiaceae	*Semecarpus walkeri*	Badulla	6	2.50	Endemic
Annonaceae	*Xylopia chamionii*	Dathketiya	1	0.42	Endemic
Arecaceae	*Caryota urens*	Kithul	1	0.42	Native
Burseraceae	*Canarium zeylanicum*	Kekuna	3	1.25	Endemic
Celastraceae	*Bhesa ceylanica*	Pelan	4	1.67	Endemic
Celastraceae	*Kokkoona zeylanica*	Kokum	2	0.83	Endemic
Clusiaceae	*Calophyllum bracteatum*	Walukeena	3	1.25	Endemic
Clusiaceae	*Calophyllum moonii*	Dombakeena	2	0.83	Endemic
Clusiaceae	*Calophyllum thwaitesii*	Batukeen	8	3.33	Endemic
Clusiaceae	*Garcinia quaesita*	Goraka	5	2.08	Endemic
Clusiaceae	*Mesua thwaitesii*	Diyana	5	2.08	Endemic
Dilleniaceae	*Dillenia retusa*	Godapara	7	2.92	Endemic
Dilleniaceae	*Schumacheria alnifolia*	Kakiriwara	8	3.33	Endemic
Dipterocarpaceae	*Dipterocarpus glandulosus*	Dorana	2	0.83	Endemic
Dipterocarpaceae	*Dipterocarpus hispidus*	Buhora	3	1.25	Endemic
Dipterocarpaceae	*Dipterocarpus zeylanicus*	Hora	7	2.92	Endemic
Dipterocarpaceae	*Shorea affinis*	Beraliya	4	1.67	Endemic
Dipterocarpaceae	*Stemonoporus canalicuculatus*	Mandora	3	1.25	Endemic
Dipterocarpaceae	*Vateria copallifera*	Hal	2	0.83	Endemic
Euphorbiaceae	*Agrostistachys coriacea*	Beru	11	4.58	Endemic
Euphorbiaceae	*Bridelia moonii*	Pathkela	6	2.50	Endemic
Euphorbiaceae	*Chaetocarpus castanocarpus*	Hedawaka	5	2.08	Native
Flacourtiaceae	*Homalium zeylanicum*	Liyan	2	0.83	Native
Flacourtiaceae	*Hydnocarpus octandra*	Waldeul	1	0.42	Endemic
Icacinaceae	*Stemonurus apicalis*	Uruhonda	4	1.67	Endemic
Lauraceae	*Cryptocarya wightiana*	Gulmora	1	0.42	Native
Lauraceae	*Lisea gardneri*	Thalan	1	0.42	Endemic
Melastomataceae	*Lijndenia capitellata*	Pinibaru	21	8.75	Endemic
Melastomataceae	*Memecylon capitellatum*	Velikaha	3	1.25	Endemic
Moraceae	*Artocarpus nobilis*	Badidel	2	0.83	Endemic
Myrataceae	*Syzygium makul*	Aluboo	3	1.25	Endemic
Myrataceae	*Syzygium neesianum*	Panukera	2	0.83	Endemic
Myristicaceae	*Horsfieldia irya*	Eriya	9	3.75	Native
Myristicaceae	*Horsfieldia iryaghedhi*	Ruk	7	2.93	Native
Myristicaceae	*Myristica dactyloides*	Malaboda	3	1.25	Native
Ochnaceae	*Ochna lanceolata*	Bokera	2	0.83	Native
Oleaceae	*Chionanthus zeylanica*	Gerieta	1	0.42	Native
Rhizophoraceae	*Anisophyllea cinnamomoides*	Velipenna	2	0.83	Endemic
Rhizophoraceae	*Carallia brachiata*	Dawata	4	1.67	Native
Rubiaceae	*Timonius flavescens*	Angana	1	0.42	Endemic
Rutaceae	*Acronychia pedunculata*	Ankenda	27	11.25	Native
Sapotaceae	*Palaquium grande*	Kiripedda	2	0.83	Endemic
Sapotaceae	*Palaquium petiolare*	Kirihambiliya	2	0.83	Endemic
Symplocaceae	*Symplocos coronata*	Uguduhal	2	0.83	Endemic
Thymelaeaceae	*Gyrinops walla*	Walla	5	2.08	Native
Verbenaceae	*Vitex altissima*	Milla	4	1.67	Native

Table 2. Frequency and percentage at which Slender Lorises were encountered on different plant species (n = 34)

Species	Common name	Frequency of usage	Average height	
			Tree	Occupied
Dillenia retusa	Godapara	6	13.8 ±3.5	9.0 ±2.8
Chaetocarpus castanocarpus	Hedawake	4	14.0 ±4.9	8.2 ±3.3
Mesua thwaitesii	Diyanaa	3	14.3 ±4.0	8.0 ±2.0
Horsfieldia iryaghedhi	Ruck	3	11.3 ±3.1	6.0 ±1.0
Artocarpus nobelis	Bedidel	2	20.5 ±6.4	14.0 ±8.5
Vitex altissima	Milla	2	13.5 ±2.1	9.5 ±2.1
Homalium zeylanicum	Liyan	2	12.0 ±2.8	6.5 ±0.7
Lijndenia capitellata	Pinibaru	2	3.0 ±0.0	1.5 ±0.7
Mangifera zeylanica	Etamba	2	17.0 ±11.3	9.0 ±7.1
Bhesa ceylanica	Pelen	2	9.0 ±1.4	4.5 ±0.7
Campnosperma zeylanicum	Aridda	1	15	15
Xylopia chamionii	Dathketiya	1	7	3
Kokkoona zeylanica	Kokum	1	26	18
Calophyllum thwaitesii	Batukeena	1	17	12
Calophyllum moonii	Dombakeena	1	28	22
Vateria copallifera	Hal	1	16	14

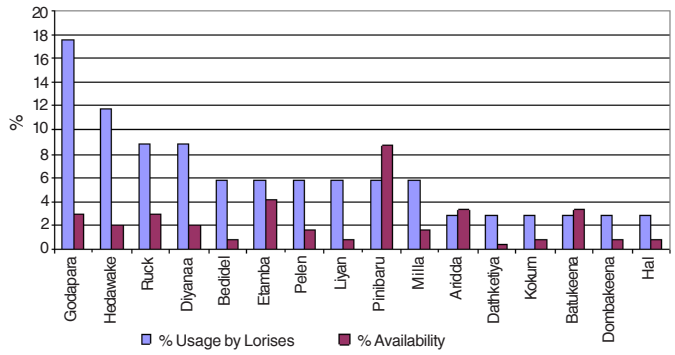


Figure 1. Tree availability at Kottawa Arboretum and frequency of utilization by *L.t. tardigradus* (n = 34)

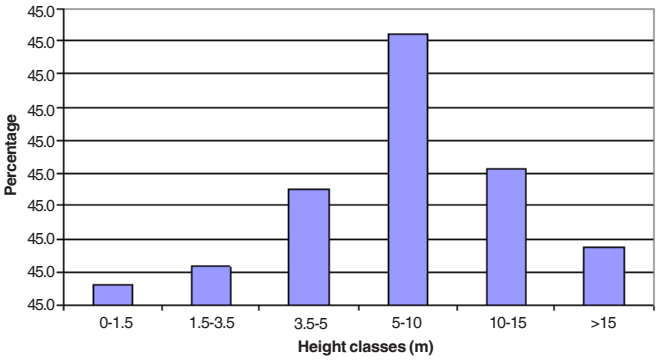


Figure 2. Vertical distribution of *L.t. tardigradus*

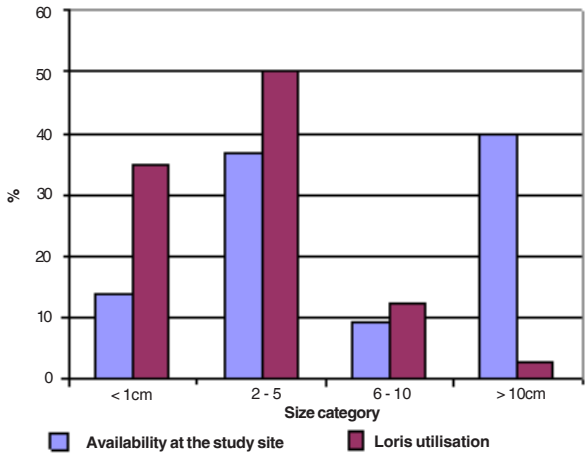


Figure 3. Percentage substrate size availability and usage by *L.t. tardigradus*

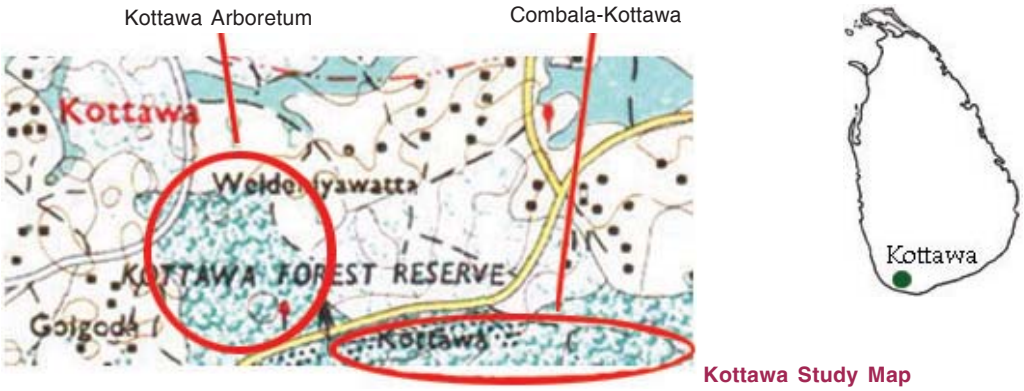
tree species, *Acronychia pedunculata*, had an average height of 4.96m ± 0.84, and a CBH of 17.48cm ± 4.03. The average basal area of the trees was 94.0 ± 220.4m2/ha. Density of ground cover between nearest neighbor trees was determined 120 times using the Braun-Blanquet scale. The average density was 2.1 ± 1.8%.

A total of 28 climbers were identified. They were as follows: *Dalbergia lattifolia* (Fabaceae) (n = 6; 21.4%), *Salacia reticulata* (Hippocrateaceae) (n =4; 14.3%), *Pandanus* sp. (Pandanaceae) (n = 4; 14.3%), *Dalbergia pseudo-sisoo* (Fabaceae) (n = 3; 10.7%), *Tetracera sarmentosa* (Dilleniaceae) (n = 3; 10.7%), *Coscinium penistratum* (Menispermaceae) (n = 3; 10.7%), *Gyrinops walla* (Thymelaeaceae) (n = 3; 10.7%), *Smilax zelanica* (Smilacaceae) (n = 1; 3.6%) and *Entada phaseoloides* (Fabaceae) (n = 1; 3.6%).

Habitat use: Of the 50 tree species recorded in the Kottawa Arboretum, *L. t. tardigradus* was found to utilize only 16 species (Fig. 1). Among the trees species preferred most were *Dillenia retusa*, *Chaetocarpus castanocarpus*, *Horsfieldia iryaghedhi* and *Mesua thwaitesii*. Of the four most abundant tree species, *Acronychia pedunculata*, *Lijndenia capitellata*, *Agrostistachys coriacea* and *Mangifera zeylanica*, only two species, *L. capitellata*, and *M. zeylanica*, were used by *L. t. tardigradus* and even these were used sparsely. A detailed description of the trees on which *L. t. tardigradus* was seen is given in Table 2.

The average height of the trees used by L.t. tardigradus was 13.97 m ± 6.02 (range 3-28m). Average height from the ground level where *L. t. tardigradus* were observed to occupy the tree was 8.64 m ± 5.00 (range 1-22m). Most of the time (n = 27; 79%) lorises were seen to occupy a position in the range of 3.5-15 m above the ground level (Fig. 2). Only on 2 occasions w***as a*** loris seen at a height greater than 20 m from ground level. The available substrate was grouped into four categories according to their diameter as twigs (≤ 1cm), small branches (2-5cm), medium sized branches (6-10cm) or large branches (≥ 10cm). *L. t. tardigradus* showed a higher preference for branches or twigs (n = 27; 76 %) followed by vines (n = 6; 15%). *L. t. tardigradus* were seen rarely on tree trunks (Fig. 3). We also grouped the substrate into three categories according to the orientation as either vertical, horizontal or oblique. *L.t. tardigradus* showed a higher preference to oblique and horizontally oriented substrates compared to vertical oriented substrates (Fig. 4).

The vertical axis of the Kottawa Arboretum was divided into six height classes and the tree availability, substrate continuity, substrate availability and the nature of the available substrate within each of these height classes was investigated



Kottawa Study Map

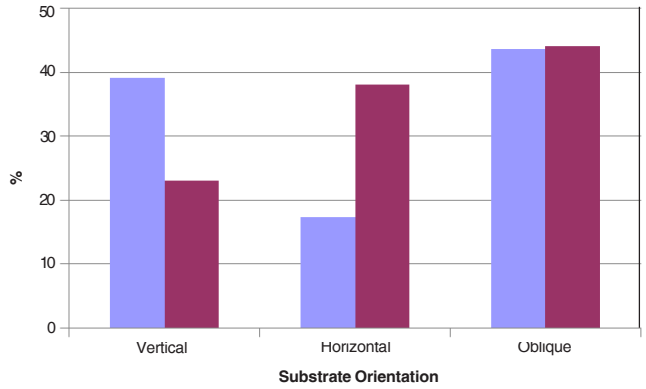


Figure 4. Orientation of the available substrate and percentage usage by *L.t. tardigradus*

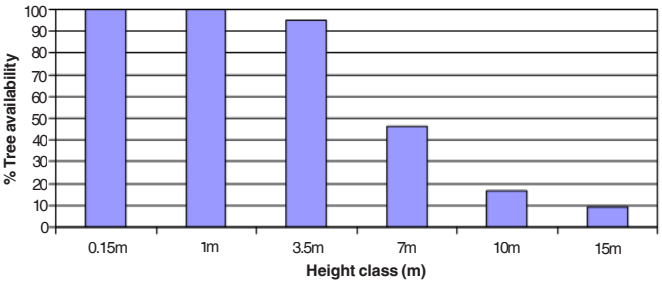


Figure 5. Percent tree availability at different height classes in the Kottawa Arboretum

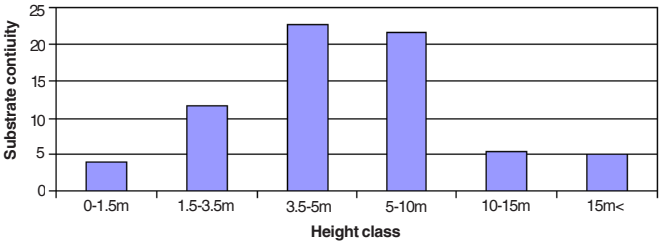


Figure 6. Percent substrate continuity at different height classes in the Kottawa Arboretum

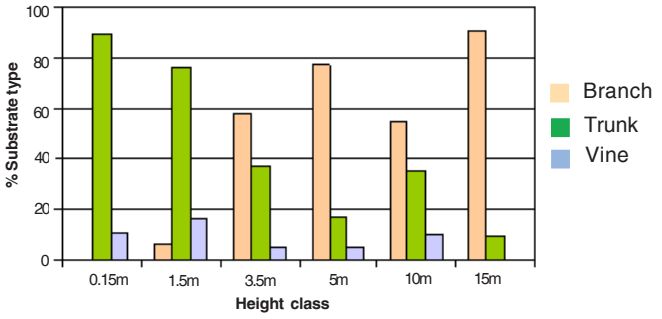


Figure 7. Percentage availability of different substrate types at the different heights of the vertical axis at Kottawa Arboretum

to ascertain the habitat availability of *L. t. tardigradus* within the Kottawa Arboretum. Percentage of trees that reach the maximum height of each of the six height classes was determined to asses the density of the available substrate. All the trees studied were taller than 1m. After 1m the number of

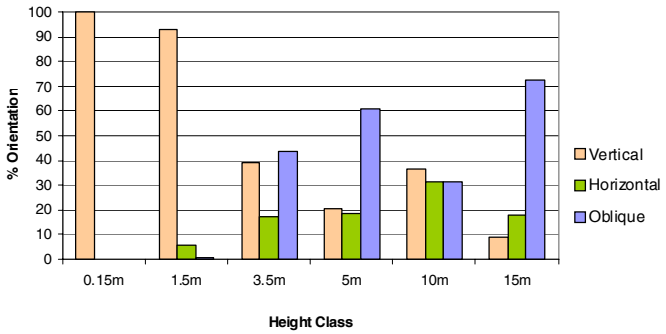


Figure 8. Percentage orientation of substrate types in the different heights of the vertical axis at Kottawa Arboretum

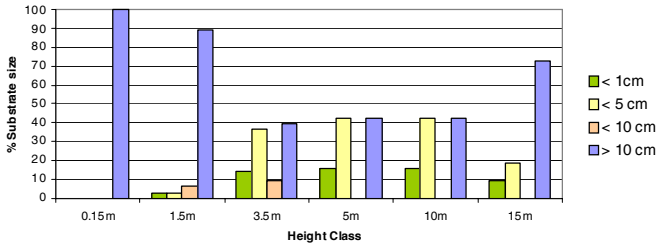


Figure 9. Available substrate size at different heights of the vertical axis at Kottawa Arboretum

trees reaching the maximum height of the height class decreased gradually. A significant reduction occurred after 3.5m (Fig. 5). Substrate continuity was present in all of the height classes. The height classes 3.5-5m (23%) and 5-10m (22%) had the highest percentage of substrate continuity (Fig. 6). The habitat quality of Kottawa Arboretum was analyzed based on the habitat selection criteria (type of substrate, orientation and the girth) observed in this study for *L.t. tardigradus*. The habitat quality for lorises was found to be highest between 3.5m-10m height range (Figs. 7, 8, 9). However, the habitat quality between 10 to 15m was also found to be suitable for lorises.

Discussion

Population density of *L.t. tardigradus* recorded in the Kottawa Arboretum during this study (41 animals/km^2) is three times greater than the population density recorded at Massmulla Proposed Forest Reserve (13 animals/km^2) by Nekaris & Jayewardene (2004) who note that it is the highest population density of *L.t. tardigradus* recorded in Sri Lanka. This indicates that the habitat quality of Kottawa Arboretum is much better than Masmulla Proposed Forest Reserve even though the arboretum is smaller in size. Therefore, a detailed investigation of the habitat selection criteria of slender lorises was conducted at the site. Based on these observations, habitat quality and availability in the Kottawa Arboretum were also evaluated.

The vegetation sampling results show that the Kottawa Arboretum has high species diversity. Climbers, which provide good substrate for lorises (Nekaris et al. 2005) were associated with more than 10% of the trees sampled in the study site. However, increased number of climbers indicates that the forest has been subjected to disturbance (Ashton et al. 2001). Furthermore, the basal area values recorded are lower than the

Sri Lanka Red Slender Loris *Loris tardigradus tardigradus* in Kottawa Arboretum

values expected from a primary forest which once again indicates that the area has been selectively logged (Bhuyan et al. 2003). However, compared to Massmulla Proposed Forest Reserve, Kottawa Arboretum appears to be less disturbed for to two reasons. First, the basal area value is higher than the values recorded for Massmulla Proposed Forest Reserve (Nekaris et al. 2005). Second, no introduced plant species were recorded in the tree sample (n = 240) of Kottawa Arboretum.

Based on the tree usage by *L.t. tardigradus* it can be concluded that they show a higher preference towards trees such as *Chaetocarpus castanocarpus* and *Dillenia retusa* which generally grow in disturbed forests. Analysis of habitat preferences of *L. t. tardigradus* showed a higher preference for small branches and twigs that are obliquely or horizontally oriented.

Nekaris (2001) and Demes et al. (1990) argue that continuity of arboreal substrate is important for slender loris locomotion. An analysis of the three dimensional structure of the Kottawa Arboretum in terms of continuity of habitat and habitat characters such as type, orientation, and girth of the available substrate indicates that the highest habitat quality and availability is in the height range 3.5 to 15m. This is consistent with the field observations where the highest number of loris sightings were made at this height range with the average height from the ground level where *L.t. tardigradus* were observed to occupy was 8.64m ± 5.00.

The potential predators that were observed at the study site were Golden Palm Cat (*Paradoxurus zeylonensis*), Rusty Spotted Cat (*Prionailurus rubiginosus*), Fishing Cat (*Prionailurus viverrinus*), Brown Fish Owl (*Ketupa zeylonensis*), Forest Eagle Owl (*Bubo nipalensis*), and Indian Python (*Python molurus*).

Even though the size of the estimated population of *L.t. tardigradus* at Kottawa Arboretum is small, the high density observed indicates that the habitat quality is very good. Thus Kottawa Arboretum should be considered as an important site for conservation of this species. However, at present Kottawa Arboretum exists as a small isolated forest patch as the Galle-Udugama road separates it from closest large forest track, the Kanneliya-Nakiyadeniya-Dediyagala (KND) complex. Thus long term conservation of this population may require linking Kottawa Arboretum with the KND complex through a suitable land use practice.

References

Ashton, P.S. & C.V.S. Gunatilleke (1987). New light on the plant geography of Ceylon I. Historical plant geography. *Journal of Biogeography* 14: 249-285.

Bernede, L. & S.N. Gamage (2006). A Guide to the Slender Loris of Sri Lanka. *Primate Conservation Society of Sri Lanka*, No. 610, Arachchikanda, Wackwella, Sri Lanka. 12pp.

Bhuyan, P., M.L. Khan & R.S. Tripathi (2003). Tree diversity and population structure in undisturbed and human-impacted stands of tropical wet evergreen forest in Arunachal pradesh, Eastern Himalyas, India. *Biodiversity and Conservation* 12: 1753-1773.

Brookes, T.M., R.A. Mittermeier, C.G., Mittermeier, G.A.B. Da Fonseca, A.B. Rylands, W.R. Konstant, P. Flick, J. Pilgrim, S. Oldfield, G. Magin & C. Hilton-Taylor (2002). Habitat loss and extinction in the hotspots of biodiversity. *Conservation Biology* 16: 909-923.

Charles-Dominique, P. & S.K. Bearder (1979). Field studies of lorisid behavior: Methodological aspects, pp. 5629-5667. In: Doyle *et al.* (eds.). *The Study of Prosimian Behavior*. Academic Press, New York.

Demes B., W.L. Jungers & U. Nieschalk (1990). Size and speed related aspects of quadrupedal walking in lorises: a comparison of gait characteristics and locomotor stresses in *Loris tardigradus* and *Nycticebus coucang*, pp.175-197. In: Jouffroy *et al.* (eds.). *Gravity, Posture and Locomotion in Primates II*. Sedicesimo Publishers, Florence.

Groves, P.C. (2001). *Primate Taxonomy*. Smithsonian Institution Press, Washington D.C.

Gamage, S.N. (2005). *A comparative study on Biodiversity of selected manmade and Natural habitats in low country wet zone of Sri Lanka*. M.Phil. thesis. Faculty of Agriculture, University of Ruhuna. Kamburupitiya Sri Lanka.

Gunatilleke, I.A.U.N., C.V.S. Gunatilleke & M.A.A.B. Dilhan (2005). Plant biogeography and conservation of the southwestern hill forests of Sri Lanka. *The Raffles Bulletin of Zoology*, supplement no. 12: 9-22.

Myers, N., R.A. Mittermeier, C.G., Mittermeier, G.A.B. Da Fonseca & J. Kent (2000). Biodiversity hot spots for Conservation Priorities. *Nature* 403: 853-858.

Nekaris, K.A.I. (2003). Observations on mating, birthing and parental care in three subspecies of slender loris in the wild (*Loris tardigradus* and *Loris lydekkerianus*) *Folia Primatologica* 72: 228-241.

Nekaris, K.A.I. (2008). *Loris tardigradus ssp. tardigradus*. In: IUCN 2008. 2008 IUCN Red List of Threatened Species. <www.iucnredlist.org>. Downloaded on 25 February 2009.

Nekaris, K.A.I. & J. Jayawardena (2003). Pilot study and conservation status of the slender loris (*Loris tardigradus* and *Loris lydekkerianus*) in Sri Lanka. *Primate Conservation* 19: 83-90.

Nekaris, K.A.I. & J. Jayawardena (2004). Survey of slender loris (Primates, Lorisidae Grey, 1821: *Loris tardigradus* Linnaeus, 1758 and *Loris lydekkerianus* Cabrera, 1908) in Sri Lanka. *Journal of Zoology* 262: 327-338.

Nekaris, K.A.I., W.K.D.D. Liyanage & S.N. Gamage (2005). Influence of forest structure and composition on population density of the red slender loris *Loris tardigradus tardigradus* in Masmullah proposed forest reserve, Sri Lanka. *Mammalia* 69(2): 201-210.

Mill, R.R. (1995). Regional overview: Indian Subcontinent, in Davis *et al.* (eds), *Center of Plant Diversity: a Guide to Strategy for their Conservation. Volume 2: Asia, Australia and the Pacific*. World Wildlife Fund for Nature and the IUCN Press, Cambridge, 62-135.

Osman Hill, W.C. (1953). *Primates - Comparative Anatomy and Taxonomy. I. Strepsirrhini*. Edinburgh University Press, Edinburgh.

Pemadasa, A. (1996). *The Green Mantle of SriLanka*. Tharanjee Prints, Nawinna, Maharagama, Sri Lanka, 242pp.

Sutherland, J.W. (1996). *Ecological Census Techniques*. Cambridge University Press. UK, 336pp.

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S.N.G. in research designing and field work, and in writing the paper; W.K.D.D.L. in research designing and field work; D.K.W. in research designing, supervising and writing; A.G. in supervising and logistical support.