J. Zool., Lond. (2004) **262**, 327–338 © 2004 The Zoological Society of London Printed in the United Kingdom DOI:10.1017/S0952836903004710

Survey of the slender loris (Primates, Lorisidae Gray, 1821: *Loris tardigradus* Linnaeus, 1758 and *Loris lydekkerianus* Cabrera, 1908) in Sri Lanka

K. A. I. Nekaris[1] and J. Jayewardene[2]

[1] Oxford Brookes University, School of Social Sciences and Law, Department of Anthropology, Nocturnal Primate Research Group, Oxford OX3 0BP, U.K.
[2] Biodiversity and Elephant Conservation Trust of Sri Lanka, 615/32 Rajagiriya Gardens, Nawala Road, Rajagiriya, Sri Lanka

(Accepted 26 August 2003)

Abstract

In 2001 and 2002, surveys of slender lorises were carried out in Sri Lanka, providing the first recent information on four taxa (*Loris lydekkerianus nordicus*, *L. l. grandis*, *L. tardigradus tardigradus*, and *L. t. nycticeboides*) endemic to the island. Thirty-one sites across five ecological zones were surveyed. Approximately 766 km were covered in 17 areas where no lorises were found; 192 km were walked or motored in 14 sites yielding 185 sightings of *Loris*: *L. l. nordicus* ($n = 111$), *L. t. tardigradus* ($n = 69$), *L. l. grandis* ($n = 4$), and *L. t. nycticeboides* ($n = 1$). Density estimates, based on sightings of animals/km, were: *L. t. tardigradus* (0.86–13 animals/km) and *L. l. nordicus* (0.33–50 animals/km). Significantly fewer sightings occurred within protected areas than were made outside of them. Animal densities varied across habitat type with the highest density of lorises occurring in the dry zone in monsoon forests. Presence of *Loris* is positively associated with insect presence, and negatively associated with primary forest with little undergrowth; taxa differ in their ability to thrive on the edge of human habitations. Human-induced threats include habitat loss, electrocution on live wires, road accidents, the pet trade, and use in traditional medicine. Further behavioural and ecological studies are needed to estimate the habitat requirements for the different taxa of slender loris.

Key words: population density, endangered species, prosimian conservation, *Loris*

INTRODUCTION

Slender lorises are small (85–385 g) nocturnal prosimian primates endemic to India and Sri Lanka. Two species (*Loris lydekkerianus* and *Loris tardigradus*), with six subspecies, have recently been recognized using the phylogenetic species concept (Groves, 2001). Though this assessment was made from museum specimens, accumulating behavioural and morphological evidence from wild populations reinforces this view (e.g. Coultas, 2002; Nekaris, 2002; Nekaris & Jayewardene, 2002). Recognition of a new species of slender loris makes studies and population surveys of these little-known primates even more crucial for their conservation.

Severe habitat loss in Sri Lanka has led to a rating of 'endangered' for the four slender loris taxa found there (Hilton-Taylor, 2002). Despite this assessment of the conservation status of these unique Sri Lankan primates, few studies are available regarding their distribution and ecology in the wild (but see Petter & Hladik, 1970; Nekaris, 2002; Nekaris & Jayewardene, 2002).

E-mail: anekaris@brookes.ac.uk

Owing to a high number of endemic species found on Sri Lanka, the island has been declared a biodiversity hotspot (Myers *et al*., 2000). Of the total mammalian taxa of Sri Lanka, 14% are endemic, including two species with at least four subspecies of slender loris (*L. tardigradus tardigradus*, *L. t. nycticeboides*, *L. lydekkerianus grandis*, and *L. l. nordicus*) (Groombridge & Jenkins, 1994; Esperance & Corea, 2001). Despite a recent surge of interest in Indian slender lorises (e.g. Kar Gupta, 1995; Nekaris, 1997, 2001; Nekaris & Rasmussen, 2003; Radhakrishna, 2001), information on the distribution and behaviour of the Sri Lankan forms is either scanty or was collected > 50 years ago (Osman Hill, 1953). This study provides the first recent systematic data on the distribution and population density of Sri Lankan slender lorises in their natural habitat. Some strategies are proposed for their conservation, as well as plans for further study.

MATERIALS AND METHODS

Study area

Research was conducted in Sri Lanka, a 66 000 km^2 island situated south-east of India across the Palk Strait

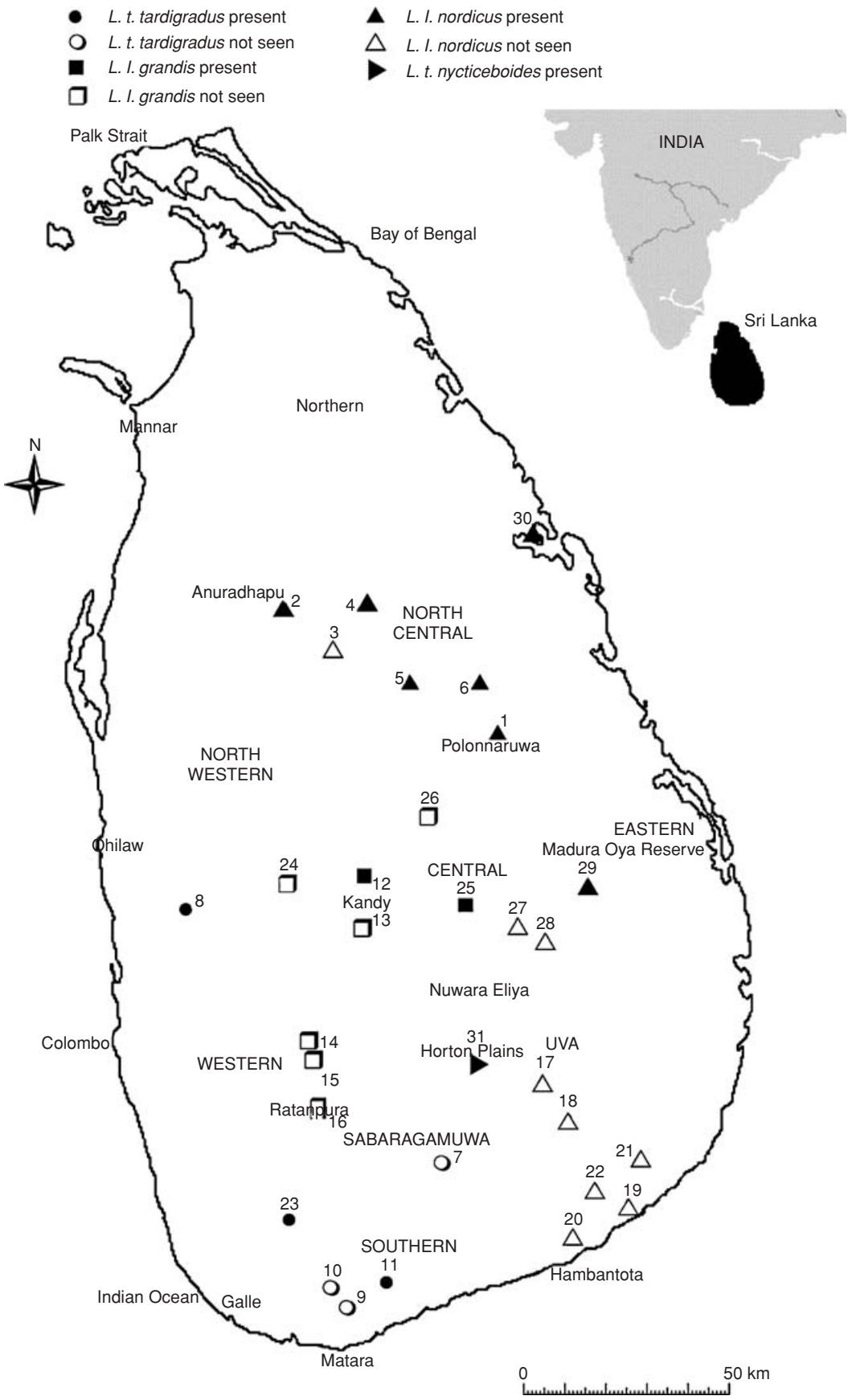

Fig. 1. The areas surveyed. Numbers correspond to those on Table 1. Major cities and provinces also are indicated.

and the Gulf of Mannar (5°55′–9°51′N, 79°41′–81°54′E). Sri Lanka is bordered on its western side by the Indian Ocean and on the eastern side by the Bay of Bengal. The island is characterized by 3 unique climatic zones: the dry zone (65% of the island), the intermediate zone, (12% of the island), and the south-western wet zone (23% of the island). Within these zones, several forest types and subtypes have been classified including desert, monsoon scrub jungle, monsoon forest and grassland, inter-monsoon forest, and rainforest interspersed with grassland. Surveys were conducted for slender lorises in each climatic zone and in each forest type. Average temperatures range from 11.4 to 30.8 °C. Rainfall averages *c*. 94–732 cm annually (Ashton *et al*., 1997; Esperance & Corea, 2001).

Thirty-one areas were surveyed during this study (Fig. 1, Table 1). Five of these fell within the range of *L. t. tardigradus*, 10 fell within the range of *L. l. nordicus*, 7 fell within the range of *L. l. grandis*, 1 is considered an intermediate zone between *L. l. grandis* and *L. l. nordicus*, and 1 fell within the range of *L. t. nycticeboides*. Seven additional sites were surveyed in the south-east, from which no subspecies has been described. Taxa were distinguished during this survey principally following the descriptions of Osman Hill (1933, 1953) and their distribution as reviewed by Schulze & Meier (1995). Table 1 lists each study site, subspecies presumed to inhabit that site, and primary vegetation type at the site (see also Fig. 1).

Survey techniques

Surveys were carried out over 3 periods from 27 May to 18 August 2001, 9 March to 19 April 2002 and 20 August to 19 September 2002 by Nekaris. During this time, a behavioural study also was undertaken (Nekaris, 2002, 2003*a*; Nekaris & Jayewardene, 2003). Because of time constraints and the large area covered, broad reconnaissance survey techniques were used to estimate population densities of animals at each site following the method of White & Edwards (2000). In particular, the index used for estimating relative abundance was animal encounter rate, or 'sightings' per km (Anonymous, 1981; Sutherland, 2002). Other researchers have successfully used this method for other species of prosimian (Ganzhorn, 1995), and for slender loris surveys in India (Rao, 1994; Nekaris, 1997; Singh, Lindburg *et al*., 1999; Singh, Anand Kumar *et al*., 2000). It is also increasingly used for surveys of mammals when a wide area is covered over a short time (White & Edwards, 2000).

The presence of lorises was scored as an actual sighting of 1 or more individuals. The distinct loud call of the loris was noted each time it occurred. This was given equal weight to actual sightings, unless a loris was seen at the same moment that it was calling (Anonymous, 1981; White & Edwards, 2000; Sutherland, 2002).

Nekaris and a team of 2–8 researchers conducted most surveys on foot. Vehicles were used in areas where walking was prohibited, particularly in national parks. Walking pace was *c*. 500 m/h. Vehicles were driven at 1–15 km/h, and 2–4 individuals directed lights out of the vehicle towards the vegetation. Even in a vehicle, the dazzling reflection from a slender loris' eyes, easily distinguishable from other animals, could be seen from up to 300 m (Singh, Anand Kumar *et al*., 2000; Nekaris, 2001). Home ranges of *L. l. lydekkerianus* in South India were estimated to measure 1.59 ha (females) to 3.6 ha (males) (Nekaris, 2003*b*). Thus whenever possible, a transect length was covered to accommodate the potential ranges of several lorises.

Data relevant to the survey included: transect length, distance travelled along transect, animal transect distance, animal observer distance, vegetation type, and vegetation height. Data pertaining to the weather, external noise, temperature, and presence or absence of the moon also were recorded. Slender lorises in 1 site in India were shown to be almost exclusively insectivorous; therefore, we felt presence or absence of insects might also influence loris density (Nekaris & Rasmussen, 2003). During dusk surveys of each site, the leaves of trees were checked for arthropod damage, and for colonies of ants or termites. As insects not consumed by *Loris* might also consume leaves, and as all species of ants and termites are not consumed by *Loris*, these observations were used only as a general index. At night, the number of insects attracted by lights and hand-held torches was descriptively noted. Finally, presence or absence of potential predators and records of human interference for each site were noted. Local villagers and park workers were also asked if they were aware of lorises in the area. Data were analysed using SPSS 11.0 for Windows. Probability is set at the $P \leq 0.05$ level.

RESULTS

General survey results

A total distance of 765.5 km, which included 17 sites, yielded negative results (see Tables 3 & 4). Owing to time constraints, if lorises were not seen in an area on one night, a new sight was surveyed. In almost all areas where lorises were observed, they were heard or seen again on subsequent nights (see below). Therefore probability is high that lorises are indeed absent from these areas, have migrated for the time being, or that their densities are low.

Approximately 192 km was walked or motored in areas where lorises were located. The average length of transect was 1.2 km. A total of 185 sightings was made of the following taxa: *L. l. nordicus* ($n = 111$), *L. t. tardigradus* ($n = 69$), *L. l. grandis* ($n = 4$), and *L. t. nycticeboides* ($n = 1$). The average distance a loris was encountered from an observer was 9 m (range 0.05–50 m); only on 10 occasions were animals seen at distances > 20 m. The average distance from a transect was 6.2 m (range 0–38 m); only on seven occasions were lorises encountered at distances > 20 m. Animals were most

Table 1. Sites where surveys for *Loris* were conducted, presumed subspecies at each location, habitat type and ecological zone. Officially protected areas are bold. Number of study site corresponds to locations shown on Fig. 1

Study site	Province/district	Subspecies	Habitat type	Ecological zone/hectares (if known)
1. Smithsonian Primate Research Camp (Polonnaruwa)	North Central Province, Polonnaruwa DT	*L. l. nordicus*	Monsoon forest and grassland	Northern low country dry zone
2. Anuradhapura Town	North Central Province, Anuradhapura DT	*L. l. nordicus*	Monsoon forest and grassland	Northern low country dry zone
3. Turuwila and Nachchaduwa Tanks	North Central Province, Anuradhapura DT	*L. l. nordicus*	Monsoon forest and grassland	Northern low country dry zone (3500 ha)
4. Mihintale Sanctuary	North Central Province, Anuradhapura DT	*L. l. nordicus*	Monsoon forest and grassland	Northern low country dry zone (999.6 ha)
5. Ritigala Strict Nature Reserve	North Central Province, Anuradhapura DT	*L. l. nordicus*	Monsoon forest and grassland	Northern low country dry zone (1528 ha)
6. Minneriya-Giritale Sanctuary	North Central Province, Polonnaruwa DT	*L. l. nordicus*	Monsoon forest and grassland	Northern low country dry zone (7529 ha)
7. Udawalawe National Park	Sabaragamuwa/Uva Province, Moneragala DT	Unknown	Inter-monsoon forest	Intermediate zone (30821 ha)
8. Maimbulakanda Nature Reserve	Western Province, Gampaha DT	*L. t. tardigradus*	Inter-monsoon forest	Low country intermediate zone
9. Ruhuna Uni, Faculty of Agriculture Gardens	Southern Province, Matara DT	*L. t. tardigradus*	Rainforest	Low country wet zone
10. Oliyagankele Forest Reserve	Southern Province, Matara DT	*L. t. tardigradus*	Rainforest	Low country wet zone (481 ha)
11. Masmullah Proposed Forest Reserve	Southern Province, Matara DT	*L. t. tardigradus*	Rainforest	Low country wet zone (793 ha)
12. Udawattakele Sanctuary	Central Province, Kandy DT	*L. l. grandis*	Rainforest	Central Hill intermediate zone (104 ha)
13. Kandyan Home Gardens	Central Province, Kandy DT	*L. l. grandis*	Home gardens	Central Hill intermediate zone
14. Peak Wilderness (Samanala) Sanctuary	Sabaragamuwa Province, Ratnapura DT	*L. l. grandis*	Montane forest	Central Hill intermediate zone (22 379.9 ha)
15. Hapugestenna Tea Estate	Sabaragamuwa Province, Ratnapura DT	*L. l. grandis*	Montane forest/ home gardens	Central Hill intermediate zone
16. Ratnapura	Sabaragamuwa Province, Ratnapura DT	*L. l. grandis*	Home gardens	Central Hill intermediate zone
17. Wellawaya, Buttala RD; Rosebery Estate	Uva Province, Moneragala DT	Unknown	Monsoon forest and grassland	South-eastern dry zone
18. Handapanagala Tank & Pelwatta Sugar Cane Co.	Uva Province, Moneragala DT	Unknown	Monsoon forest and grassland	South-eastern dry zone
19. Yala (Ruhuna) National Park	Southern Province, Moneragala DT	Unknown	Monsoon scrub jungle	South-eastern dry zone (103882.9 ha)
20. Bundala Sanctuary	Southern Province, Moneragala DT	Unknown	Monsoon scrub jungle	South-eastern dry zone (6216 ha)
21. Kataragama Town and forest patches	Uva Province, Monaragala DT	Unknown	Monsoon scrub jungle	South-eastern dry zone (837.7 ha)
22. Nimalawa Sanctuary	Southern Province, Monaragala DT	Unknown	Monsoon scrub jungle	South-eastern dry zone
23. Kanneliya Forest Reserve	Southern Province, Galle DT	*L. t. tardigradus*	Lowland rainforest	Low country wet zone (6114 ha)
24. Private Land near Pinnawela Elephant Orphanage	North Central Province, Anuradhapura DT	*L. l. grandis*	Inter-monsoon forest	Intermediate zone
25. Knuckles Range	Central Province, Matale DT	*L. l. grandis*	Montane forest mixed with patana grassland	Unique zone (Knuckles Range)
26. Elahara	North Central Province, Polonnaruwa DT	*L. l. grandis/nordicus* intermediate	Inter-monsoon forest	Low country dry zone

Table 1. Continued

Study site	Province/district	Subspecies	Habitat type	Ecological zone/hectares (if known)
27. Wasgomuwa National Park	North Central/North-eastern Province,	*L. l. nordicus*	Monsoon forest and grassland	Low country dry zone (36948 ha)
28. Private land, Wilgamuwa	North Central Province, Matale Dt	*L. l. nordicus*	Monsoon forest and grassland	Northern low country dry zone (2 ha)
29. Maduru Oya National Park	North-eastern/Uva Province Batticaloa/Matara DTs	*L. l. nordicus*	Monsoon forest and grassland	Low country dry zone (58849.8)
30. Trincomalee	North-eastern Province, Trincomalee District	*L. l. nordicus*	Scrub forest and grassland; city gardens	Low country dry zone
31. Horton Plains National Park	Central Province, Nuwara Eliya Dt.	*L. t. nyticeboides*	Grassland patana	High country montane rain forest; 3160 ha

often seen in trees or on substrates (roads or fences composed of tangled branches) measuring 5.7 ± 3.64 m; maximum tree height was 20 m, and minimum substrate height was 0 m. Lorises were seen at a height of 3.2 ± 2.4 m. The minimum height at which animals were detected was 0 m (on the ground or crossing a road). The maximum height at which they were seen was 12 m. Further details of substrate use and behaviour between taxa are described elsewhere (Nekaris & Jayewardene, 2003).

With all taxa combined, the average density was 2.4 lorises/km^2. Significantly fewer sightings (24%) occurred within protected areas, than were made outside of them (76%) ($\chi^2 = 29.82$, d.f. $= 3$, $P < 0.001$). Loris densities varied across habitat type with the highest density of 4.9 animals/km^2 in dry zone monsoon forest. These differences were not significant ($F = 0.668$, d.f. $= 5$, $P = 0.651$). Similarly, loris densities varied across ecological zones, with the highest density of 3.9 animals/km^2 occurring in the dry zone. Again, density differences across ecological zones were not significant ($F = 0.819$, d.f. $= 3$, $P = 0.494$). Densities across habitat type and ecological zone are summarized in Table 2. Variation does indeed occur, and lack of significant difference may be the result of the small sample size.

The moon was present and not obscured by heavy clouds during 57.7% of sightings, and was absent the remaining 42.3%. Weather was clear 71.4% of sightings, cloudy 25.8%, and 2.7% of sightings occurred during the rain. Adults were seen 128 times, juveniles eight times, parked infants seven times, and age could not be determined 42 times. Observations of males were recorded 31 times, and of females 53 times; sex could not be determined for the remaining 101 observations.

Table 2. Density of all *Loris* taxa in different habitat types and ecological zones; although densities vary greatly between habitat types and ecological zones, differences were not significant

Habitat type	Average density/km^2	Standard deviation
Monsoon forest	4.87	9.47
Inter-monsoon forest	2.05	4.12
Rainforest	1.89	1.22
Home gardens	0.88	1.72
Montane forests	0.04	0.05
Scrub jungle	0	6.03
Ecological zone		
Dry zone	3.85	7.81
Intermediate zone	0.45	0.76
Wet zone	1.21	1.25
Montane	0.49	1.24

Loris lydekkerianus nordicus

Approximately 52 km was covered at seven sites containing populations of *L. l. nordicus* (Fig. 2). Loris densities ranged from 0.33 to 50 animals/km, with an overall density of 3.65 animals/km (Table 3). The densest populations of *L. l. nordicus* were located in the north-east at the Smithsonian Primate Research Camp near Polonnaruwa, the Minneriya-Giritale Sanctuary, Maduru Oya National Park, and in Trincomalee town and its outlying forests (Fig. 1).

Loris l. nordicus was more often associated with disturbed human habitation (68%) than with forest (32%) ($\chi^2 = 29.82$, d.f. $= 3$, $P < 0.001$). Densities seemed higher in non-protected areas (6.5/km^2) than in protected areas (0.8/km^2), although this was not significant ($F = 3.079$, d.f. $= 1$, $P = 0.096$). Even when lorises were associated with a forest reserve, they were commonly seen in areas bordering human settlements, including on human-built fences, and their calls were heard in gardens. *Loris lydekkerianus nordicus* was seen on average at heights of 2.1 ± 0.55 m (Trincomalee), 2.16 ± 0.29 m (Ritigala), 1.5 ± 0.5 m (Mihintale), and 2.6 ± 1.3 m (Giritale and Madura Oya). Lorises living within sanctuaries seemed to use slightly lower heights (2.5 ± 1.5 m) than those living outside protected areas (3.05 ± 1.8 m), although

Fig. 2. The recently recognized *Loris lydekkerianus nordicus* occurs at higher densities than other loris taxa.

these differences were not significant ($F = 0.808$, d.f. $= 1$, $P = 0.370$).

No lorises were detected at 10 sites where the habitat was suitable for *L. l. nordicus*. The south-eastern dry zone, east of the Walawe Ganga, yielded no lorises. Eleven nights were spent investigating six different areas, covering *c*. 317 km in vehicles and on foot. Despite the absence of lorises, flying insects were common at night, and arthropod damage to leaves was extensive. Vertical substrates were also qualitatively abundant.

Although lorises were not detected in the area around Nachchaduwa tank, it is part of the same forest complex as the Mihintale Sanctuary. R. Jayewardene (pers. comm.) reported sightings of lorises at this location within the last 2 years. Logistical difficulties prevented penetration deep into the forest, possibly explaining loris absence at this site.

No lorises were seen in Udawalawe National Park. Local rangers reported hearing their calls, but not any sightings. Only one night was spent in this park; *Loris* may prove to be here on further investigation.

Despite three nights surveying over 12 km, no lorises were found in Wasgomuwa National Park. Its dry scrub habitat is similar to that found in Minneriya-Giritale and Polonnaruwa. Three full nights were spent in this area

Table 3. Population density estimates for *Loris lydekkerianus*. ?, Questionable sighting where an animal was seen but not confirmed to be a loris (see text)

Study area	Distance walked (w) or motored (m) each transect	No. of times transect was covered	Animals/km (average)
L. l. nordicus			
1. Smithsonian Primate Research Camp (Polonnaruwa)	I: 205 m (w) II: 150 m (w) III: 168 m (w) IV: 100 m (w)	I: 12 II: 2 III: 3 IV: 3	I: 38 II: 20 III: 11.9 IV: 30
2. Anuradhapura	12 km (m)	1	0.33
3. Nachchaduwa Turuwila Tanks	I: 28 km (m) II: 1.2 km (w)	I: 1 II: 1	I: 0 II: 0
4. Mihintale Sanctuary	I: 550 m (w) II: 750 m (w)	I: 1 II: 1	I: 0 II: 5.3
5. Ritigala Strict Natural Reserve	I: 2 km (w) II: 4 km (m)	I: 1 II: 1	I: 1.5 II: 0
6. Minneriya-Giritale Sanctuary	I: 800 m (w) II: 2.3 km (w) III: 1.7 km (w) IV: 3.4 km (w) V: 2.7 km (w)	I: 1 II: 1 III: 1 IV: 1 V: 1	I: 2.5 II: 0.43 III: 1.2 IV: 0.88 V: 1.5
7. Udawalawe National Park	I: 500 m (w) II: 28 km (m)	I: 1 II: 1	I: 0 II: 0
17. Wellawaya, Buttala RD; Rosebery Estate	I: 28 km (m) II: 3.5 km (w)	I: 1 II: 1	0
18. Handapanagala Tank & Pelwatta	I: 4.5 km (w) II: 18 km (m)	I: 1 II: 1	0
19. Yala (Ruhuna) National Park	I: 115 km (m) II: 400 m (w)	I: 2 II: 2	0
20. Bundala Sanctuary	I: 46 km (m) II: 1.5 km (w)	I: 2 II: 2	0
21. Kataragama and forest patches	I: 1.2 km (w) II: 84 km (m)	I: 1 II: 2	0
22. Nimalawa Sanctuary	I: 4.5 km (w) II: 32 km (m)	I: 3 II: 2	0
27. Wasgomuwa National Park	I: 500 m (w) II: 4 km (m) III: 4 km (m) IV: 2 km (m)	I: 4 II: 1 III: 1 IV: 1	I: 1 (?) II: 0 III: 0 IV: 0
28. Wilgamuwa, Matale	500 m (w)	3	0
30. Trincomalee: Petroleum Corp Rd	I: 700 m (w)	I: 1	I: 4.3
30. Trincomalee: Fort Grounds	I: 750 m (w)	I: 1	I: 1
30. Trincomalee: banana chena	I: 1.8 km (w) II: 250 m (w)	I: 1 II: 1	I: 2.8 II: 16
L. l. nordicus/grandis intermediate			
26. Elahara	I: 500 m (w) II: 1.5 km (m) III: 25 km (m)	1 1 1	I: 2/4 (?) II: 0 III: 0
L. l. grandis			
12. Udawattakele Sanctuary	I: 1.2 km (w)	I: 1	I: 3.3
25. Knuckles Range	I: 5.5 km (w) II: 26 km (m)	I: 1 II: 1	I: 0 II: 0.11
13. Kandyan Home Gardens	2.3 km (w)	1	0
14. Peak Wilderness Sanctuary	I: 28 km (m) II: 2.5 km (w)	I: 1 II: 1	0
15. Hapugestenna Tea Estate	1.5 km (w)	4	0
16. Ratnapura	1.25 km (w)	2	0
24. Pinnawela	1.5 km (w)	1	0

attempting to record the loris loud whistle, also without success. As lorises in general call nightly, absence of this call is a strong indicator that population density is low or absent (Bearder, Nekaris & Buzzell, 2002; Coultas, 2002). Lorises are not included on the mammal checklist for this park.

No lorises were found in a patch of dry scrub jungle in Wilgamuwa, Matale District, *c*. 10 km from the Wasgomuwa National Park. At one time, a corridor connected this forest patch to the park itself. Paddy fields have replaced this corridor, making connection to other forest patches nearly impossible for the small-bodied loris.

Loris sightings at Elahara were questionable. Osman Hill (1933) identified a loris from this area as an intermediate form between *L. l. grandis* and *L. l. nordicus*. Two animals were observed, loris-like in their movements, in vegetation along a river edge, though their distance and lack of appropriate lighting prevented further affirmation. We saw no other animals in 27 km of surveys.

Loris lydekkerianus grandis

Thirty-three km were travelled in two areas containing low numbers of lorises, which fell in the historic range of *L. l. grandis*. The animals could not be seen clearly enough to confirm this designation. Loris densities ranged from 0.11 to 3.3 animals/km, with an overall density of 0.42 animals/km (Table 3). Sample size was too small to compare animal densities in protected *vs*. unprotected areas.

Two lorises were seen at heights of 18 m at Udawattakele Forest Reserve. They were difficult to see, and are referred to as *L. l. grandis* based on a brief early study (Petter & Hladik, 1970). One individual and one pair of lorises were spotted in the Knuckles Range. Despite the low density, indicated in Table 3, of 0.11 animals/km, all three animals were seen within 2 km, making the estimate within this area much higher (1.5 animals/km). Although tall trees (< 15 m) were present, all three animals were seen at heights of 2 m or below.

No animals were seen at five sites, over which 42.5-km were covered. These included forests in the central hill zone around Ratnapura, Peak Wilderness Sanctuary, Kandyan home gardens, private land near the Pinnawela Elephant Orphanage and the Hapugestenna Tea Estate. *Loris l. grandis* was reported from these areas before 1933 (Osman Hill, 1933). Local people, including elderly tea estate workers, reported never having seen them in the areas near Ratnapura, Peak Wilderness Sanctuary, Pinnawela Elephant Orphanage and Hapugestenna. Residents of Kandy reported not having seen lorises in the home gardens, although Petter & Hladik (1970) studied them at this location 30 years ago.

Loris tardigradus tardigradus

Forty-eight km were covered in four sites yielding *L. t. tardigradus* (Fig. 3). Loris densities ranged from 0.86 to 13 animals/km, with an overall density of 1.02/km^2 (Table 3). *Loris t. tardigradus* was seen significantly more in areas away from villages, and was never seen near any large human settlement ($\chi^2 = 101.72$, d.f. $= 1$, $P < 0.0001$). More sightings occurred in forested areas that are not legally protected (53.4%) than in those that were (46.6%) ($\chi^2 = 14.44$, d.f. $= 1$, $P < 0.0001$). Densities were similar in non-protected areas (0.91/km^2) and in protected areas (1.1/km^2).

The site of highest density (2.10 animals/km^2) was the Kanneliya Forest Reserve, which is part of a larger complex of forests (called KDN forest complex) consisting of the Nakiyadeniya Proposed Reserve in Galle District and Dediyagala Forest Reserve in Matara District. These forests form a continuous block of natural forest covering 11 146 ha in the south-west lowland hills (Mill, 1995; W. K. D. D. Liyanage, pers. comm.). Kanneliya is a unique lowland rainforest habitat, with 78% of plant species endemic. Both primary and secondary growth forest are found in this reserve. No subspecies of slender loris has yet been described from this forest, though its appearance complies with that of *L. t. tardigradus*.

Three nights were spent in the reserve, and lorises were seen each night. They were seen in secondary growth habitat only, possibly because of the lack of undergrowth and fine branches in the primary growth forest. All lorises were seen in association with the vine *Coscinium fenestratum*. They moved in the undergrowth (0.5 m) as well as high in the trees (7 m). Lorises were seen higher on average at Kanneliya than at any other site (4.6 ± 2.0 m).

A second site, the Masmullah Proposed Forest Reserve, was visited during all three study periods, and each time yielded loris sightings. Although this forest is reported to consist of 793 ha, local villagers estimate that perhaps more than half has been exploited for rice paddy or *Pinus* plantations. Two transects were covered in secondary growth, yielding loris densities of 2.6–5.1 animals/km^2. Three transects in primary growth forest resulted in only one sighting. Lorises were rarely seen on the edges of rice paddies, nor were they ever seen entering *Pinus* plantations. The most commonly used tree species at this sight was *Humboldtia laurifolia* (Fabaceae), a tree heavily associated with ants, the preferred food of *Loris*. Animals were seen at an average of 3 ± 2.4 m, on the ground and as high as 8 m.

The Oliyagankele Forest Reserve was visited during the first field season, yielding no loris sightings. In the third field season, a pair of lorises was spotted on one night, but no lorises were seen on a second night. No calls of the loris were heard over several hours within the forest, suggesting low population densities, as is indicated by the overall density of 0.33 animals/km^2.

The final locality for *L. t. tardigradus* was Maimbulakanda Nature Reserve. Only one loris and her twin offspring were observed and no vocalizations were heard (Table 4).

No *L. t. tardigradus* were found in the gardens of the Ruhuna University Faculty of Agriculture. Students, however, reported seeing a loris in 2000. As this garden is connected via corridors to the Masmullah Proposed Forest Reserve, lorises may visit it occasionally.

Loris tardigradus nycticeboides

A total of 59.7 km was travelled over three nights in the Horton Plains National Park (Table 4). One loris was

Fig. 3. *Loris tardigradus tardigradus* occurs at relatively low densities in isolated patches of the remnant south-western rainforests of Sri Lanka.

located in a 2-m high tree (*Neolitsea cassia*). We could see only the eyeshine of a second small mammal along another road in the park. Though the eyes were characteristic of a loris in size, shape, and colour, we cannot confirm with certainty that this animal was a loris. The former of these sightings is the first confirmed sighting of a slender loris in the Horton Plains National Park since 1937 (Nicholls, 1939), and is described in detail elsewhere (Nekaris, 2003*c*).

Threats to lorises from humans

Throughout this survey, notes were made of additional threats to *Loris*, either by direct observation or through informal interviews with local villagers and park officials. Pet lorises were seen on three occasions, although we never came across markets selling lorises. Two animals were injured or killed in road accidents (V. B. P. Perera, pers. comm.), a death commonly reported by villagers. In the area around Trincomalee, lorises were observed inhabiting forest interspersed with landmines. Though lorises themselves may not set off these land mines, elephants and spotted deer do so (Jayewardene, 1994). Such explosions could certainly affect the lorises. The most commonly seen and reported threat was death by electrocution, which apparently takes the lives of numerous lorises each month. If the lorises do not die, they may be maimed (Nekaris, 2000). As well as numerous

Table 4. Population density estimates for *Loris tardigradus*. ?, Questionable sighting where an animal was seen but not confirmed to be a loris (see text)

Study area	Distance walked (w) or motored (m) on each transect	No. of times transect was covered	Animals/km (average)
L. t. tardigradus			
8. Maimbula-kanda Nature Reserve	I: 3.5 km (w)	I: 1	I: 0.86
9. Ruhuna Uni, Fac. Agriculture Gardens	2.5 km (w)	1	0
10. Oliyagankele Forest Reserve	I: 6 km (m)	I: 2	I: 0
	II: 3 km (w)	II: 2	II: 0.67
11. Masmullah Proposed Forest Reserve	I: 275 m (w)	I: 7	I: 2.6
	II: 1.2 km (w)	II: 11	II: 5.1
	III:2.25 km (w)	III: 1	III: 0
	IV: 3 km (w)	IV: 1	IV: 0
	V: 700 m (w)	V: 1	V: 1.4
23. Kanneliya Forest Reserve	I: 1.3 km (w)	I: 1	I: 2.3
	II: 2 km (w)	II: 2	II: 2.5
			III: 1.5
L. t. nycticeboides			
31. Horton Plains National Park	I: 16 km (m)	I: 1	I: 0
	II: 6.2 km (w)	II: 2	II: 0.16
	III: 5.32 (w)	III: 2	III: 0
	IV: 4.6 (m)	IV: 1	IV: 0
	V: 9 km (w)	V: 1	V: 0
	VI: 1 km (w)	VI: 1	VI: 0
	VII: 12.3 km (m)	VII: 1	VII: 0.08 (?)

reports, seven deaths were witnessed. In one instance, a lactating female was found dead on a power line (V. B. P. Perera, pers. comm.). Presumably, this also resulted in the death of her infant(s).

Some superstitions regarding the lorises also affect their well-being. Villagers throughout Sri Lanka anecdotally reported the continued use of loris eyes in medicine and for religious practices. A guard at Anuradhapura reported that people who believe that lorises are witches because of their cry, stone them to death. He also reported the deaths of many lorises by domestic cats (S. G. Nandesana, pers. comm.).

DISCUSSION

Populations of slender lorises were found in only 20% of *c*. 960 km of surveyed transects. Distribution of lorises in Sri Lanka seems to be influenced by several factors. Undergrowth and secondary growth forest are common when lorises are present. Densities of *L. tardigradus*, in particular, were lower in primary growth forest with little or no undergrowth. Both taxa occurred more often in forested areas that were not legally protected. Despite this, *Loris tardigradus* was not found within human settlements, whereas *Loris lydekkerianus* was able to survive even in home gardens.

In India, dry forest forms seem to thrive near areas of human disturbance whereas wet forest forms seem to suffer (Kar Gupta, 1995; Singh, Lindburg *et al*., 1999). Indian and Sri Lankan slender lorises may share this ecological trait. Higher population densities of dry zone *vs.* wet zone lorises further evidence this trend. Singh, Anand Kumar *et al*. (2000) suggested that fences and groves around farmlands might provide corridors for isolated populations of Indian *L. l. lydekkerianus*. The regular use of such man-made features by *L. l. nordicus* suggests this as a possible alternative for them too. Clearly, separate conservation strategies need to be developed for the two Sri Lanka species.

Seasonality and forest types may bias animal densities as visibility is greater in dry forests. Many of the driest sites, however, yielded the lowest abundance or no lorises (e.g. the south-eastern dry zone containing Yala National Park).

The complete absence of slender lorises from the south-eastern dry zone was striking, as it is highly protected. Osman Hill (1953) reported that *Loris* was absent from this area. Despite this evidence, several forest rangers, as well as a local guidebook, reported lorises in the area, although no one interviewed had seen them. Local villagers near Wellawaya also said they had seen *Loris* in and around this town in previous years, although we neither saw nor heard them.

One factor potentially influencing the lack of lorises, or their exceedingly low densities, in the south-east of Sri Lanka may be the predominance of trees with vertical to near vertical substrates. *Loris lydekkerianus* in India infrequently used vertical substrates (Nekaris, 2001). In a behavioural study corresponding to this survey, *L. lydekkerianus* almost never chose vertical substrates, whereas *L. tardigradus* preferred them (Nekaris & Jayewardene, 2003). Availability of oblique and horizontal substrates may be an essential ecological component for supporting a population of *Loris lydekkerianus*, whereas the presence of vertical substrates, including vines, may be essential to *L. tardigradus*.

Lorises occurred most often at heights of 3.2 m. This is similar to *L. l. lydekkerianus* in Tamil Nadu, India which was most often seen at 3.4 m (Nekaris, 2001), and to lorises in Andhra Pradesh, India, which were most often seen at 3 m (Singh, Anand Kumar *et al*., 2000). Trees without suitable substrates at these heights rarely contained lorises. This is further evidence of their reliance on secondary growth forests. Animals such as golden palm civets were regularly seen at heights up to 18 m. Thus, the low height preferred by lorises does not seem to be the result of poor visibility.

Slender lorises are almost exclusively insectivorous (Nekaris & Rasmussen, 2003). Leaves with heavy orthopteran damage and trees associated with ant colonies, both preferred foods of lorises, are common when lorises are present. Singh and colleagues (Singh, Lindburg *et al*., 1999; Singh, Anand Kumar *et al*., 2000) also suggested that insects, including those associated with farmers' crops, are probably beneficial to populations of *Loris*. During a long-term study in India, even group size was related to insect density within a single study area (Nekaris, 2000). In the Masmullah Forest, centres of high loris density were clustered around trees heavily associated with the lorises' preferred food of ants (A. Nekaris, pers. obs.).

It has been suggested that some insect populations in the south-east have recently been decimated due to increased pesticide use for crops (S. Weerderwardene, pers. comm). This certainly could influence loris densities and is worthy of further investigation.

Several human-induced constraints on loris populations were witnessed, which are also reported historically. Their body parts, especially their eyes, are used for traditional medicine (e.g. Senanayake, 1967). Valuable material from the eyes is extracted by holding a loris above a fire until the eyes burst. Some people fear their cry as an ill omen (Lewis, 1917). The mournful tone of the cry is thought to bring misfortune, usually resulting in their being stoned to death.

The most severe threat to lorises from humans is habitat destruction. In one field season, habitat loss of both primary and secondary forest was noted for the Masmullah Forest, which is subjected to severe human encroachment (A. Nekaris, pers. obs.). Although several forest patches exist in the Southern and Western Provinces, they are small, isolated and diminishing, with only 3% of original forest cover remaining (Erdelen, 1988; Mill, 1995). Most museum specimens of slender lorises come from the Western Province, especially in areas such as Kesbewa, Matugama and Bandaragama where forest cover has been nearly completely eliminated because of urban expansion (Erdelen, 1988). Protection of these forest patches is a key to the survival of *L. t. tardigradus*, for whom this habitat is particularly important.

In the north-eastern dry zone, lorises face increased habitat loss as a result of the Mahaweli Ganga Project. Through this project, 24% of the dry zone is in the process of being converted into arable land (Erdelen, 1988). As the land is increasingly deforested for agriculture by cutting and burning, even *L. l. nordicus*, which currently seems to be the least endangered of the lorises, will be severely pressed.

Cutting of forest occurs for other reasons. For example, the Pinnawela Elephant Orphanage receives plant material each week to feed orphaned elephants. Workers at the orphanage reported that individuals collecting this plant material sometimes find lorises among it, which may have come from hundreds of kilometres away. Workers then release these animals into forest patches. This re-release of lorises into random forest patches should be considered during any taxonomic assessment of the animals.

The key to survival of slender lorises is reduction of habitat loss, as well as establishment of corridors between heavily fragmented forest patches. Implementation of such programmes for larger 'flagship' species including elephants and leopards would have important implications for lorises as well. Furthermore, the education of local people to dispel the myths regarding lorises may help to reduce deaths caused by superstitious beliefs or their use in traditional medicines (Nekaris, 2002).

This report has been generated as part of an ongoing comprehensive study of the behaviour, ecology and distribution of slender lorises in Sri Lanka. Further research plans include surveys for montane forms, detailed behavioural studies of each species, as well as analysis of microhabitat-use related to forest type and level of disturbance. Although many of the results presented in this paper are preliminary, we hope they are a first step towards a better understanding of this little known and unique group of primates.

Acknowledgements

We thank the Department of Wildlife Conservation for authorizing this study and providing aid, including the directors Mr. A. P. A. Gunasekera and Mr Kariyawasam, as well as Messrs H. D. Ratnayake G. Samarakoon, C. Suraweera, and S. Weerdawardene. Logistical support was provided at various sites by: W. Dittus, S. N. Gamage, A. Gunawardene, S. Illangacoon, W. K. D. D. Liyanage, A. Perera, R. Perera, V. B. P. Perera, and T. Ramanadan. H. Schulze, S. K. Bearder and C. P. Groves provided literature, invaluable advice, and support. Lastly, Nekaris thanks her field assistants, Nallaka, K. R. Hart, D. S. Coultas, and E. R. Pimley. Two anonymous reviewers greatly improved the quality of this manuscript. This project was funded by grants to Nekaris from Margot Marsh Primate Biodiversity Fund, Columbus Zoo, Primate Conservation Inc., the People's Trust for Endangered Species, One With Nature of the Philadelphia Zoo, the Petzl Headlamp Company, NHK Films, and the Department of Biology and the Nocturnal Primate Research Group of Oxford Brookes University. We also thank P. Lemelin and D. Schmitt who contributed videotapes funded by an NSF grant (BCS-9904401), and H. Schulze who provided other essential aid and equipment.

REFERENCES

Anonymous (1981). *Techniques for the study of primate population ecology*. Washington, DC: National Academy Press.

Anonymous (2002). Opinion 1995 (Case 3004). Lorisidae Gray, 1821, Galagidae Gray, 1825 and Indriidae Burnett, 1828 (Mammalia, Primates): Conserved as the correct original spellings. *Bull. Zool. Nomencl*. **59**(1): 65–67.

Ashton, M., Gunatilleke, S., de Zoysa, N., Dassanayake, M. D., Gunatilleke, N. & Wijesundera, S. (1997). *A field guide to the common trees and shrubs of Sri Lanka*. Colombo: WHT Publications.

Bearder, S. K., Nekaris, K. A. I. & Buzzell, C. A. (2002). Are some nocturnal primates afraid of the dark? In *Eat or be eaten: predator sensitive foraging in primates*: 21–40. Miller, L. (Ed.). Cambridge: Cambridge University Press.

Coultas, D. S. (2002). *Bioacoustic analysis of the loud call of two species of slender loris (**Loris tardigradus** and **L. lydekkerianus nordicus**) from Sri Lanka*. MSc thesis, Oxford Brookes University.

Erdelen, W. (1988). Forest ecosystems and nature conservation in Sri Lanka. *Biol. Conserv*. **43**: 115–135.

Esperance, C. & Corea, C. (2001). Sri Lankan Wildlife Conservation Society web site. http://www.benthic.com/sri_lanka/ (Accessed 29 September 2002.)

Ganzhorn, J. U. (1995). Low level disturbance effects on primary production, leaf chemistry and lemur populations. *Ecology* **76**: 2084–2096.

Groombridge, B. & Jenkins, P. (Eds) (1994). *Biodiversity data sourcebook*. Compiled by the World Conservation Monitoring Centre. Cambridge: World Conservation Press.

Groves, C. P. (2001). *Primate taxonomy*. Washington, DC: Smithsonian Institution Press.

Hilton-Taylor, C. (2002). *2002 IUCN red list of threatened species*. Gland, Switzerland: World Conservation Union (IUCN), Species Survival Commission (SSC). www.redlist.org

Jayewardene, J. (1994). *The elephant in Sri Lanka*. Colombo: Aitken Spence.

Kar-Gupta, K. (1995). Slender loris, *Loris tardigradus*, distribution and habitat use in Kalakad-Mundanthurai Tiger Reserve, India. *Folia Primatol*. **69**(Suppl.): 401–402.

Lewis, J. P. (1917). The folklore of animals among Sinhalese and Tamils. *Ceylon Antiquary* **II**(IV): 236–238.

Mill, R. R. (1995). Regional overview: Indian subcontinent. In *Centres of plant diversity: a guide to strategy for their conservation* **2**: *Asia, Australia and the Pacific*: 62–135. Davis, S. D., Heywood, V. H. & Hamilton, A. C. (Eds). Cambridge: World Wildlife Fund for Nature and the IUCN Press.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B. & Kent, J. (2000). Biodiversity hot spots for conservation priorities. *Nature (Lond.)* **403**: 853–858.

Nekaris, K. A. I. (1997). A preliminary survey of the slender loris (*Loris tardigradus*) in South India. *Am. J. Physiol. Anthropol. Suppl*. **24**: 176–177.

Nekaris, K. A. I. (2000). *The socioecology of the Mysore slender loris (**Loris tardigradus lydekkerianus**) in Dindigul, Tamil Nadu, South India*. PhD thesis, Washington University, St. Louis, MO.

Nekaris, K. A. I. (2001). Activity budget and positional behaviour of the Mysore slender loris: implications for slow climbing locomotion. *Folia Primatol*. **72**: 228–241.

Nekaris, K. A. I. (2002). Slender in the night. *Nat. Hist*. **2**(2): 54–59.

Nekaris, K. A. I. (2003*a*). Observations on mating, birthing and parental care in three subspecies of slender loris in the wild (*Loris tardigradus* and *Loris lydekkerianus*). *Folia Primatol*. *Suppl*. **74**: 312–336.

Nekaris, K. A. I. (2003*b*). Spacing system of the Mysore slender loris. *Am. J. Physiol. Anthropol*. **121**: 86–96.

Nekaris, K. A. I. (2003*c*). Rediscovery of the slender loris in Horton Plains National Park, Sri Lanka. *Asian Primates* **8**(3): 1–7.

Nekaris, K. A. I. & Jayewardene, J. (2002). Status survey and pilot study of the slender loris in Sri Lanka. In *Caring for primates,* abstract No. 0453: 340. *Abstracts of the XIXth Congress. The International Primatological Society*. Beijing: Mammalogical Society of China.

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

Nekaris, K. A. I. & Rasmussen, D. T. (2003). The diet of the Mysore slender loris (*Loris lydekkerianus lydekkerianus*). *Int. J. Primatol*. **24**(1): 33–46.

Nicholls, L. (1939). Period of gestation in *Loris. Nature (Lond.)* **143**(1): 246.

Osman Hill, W. C. (1933). A monograph on the genus *Loris* with an account of the external, cranial and dental characters of the genus: a revision of the known forms; and the description of a new form from Northern Ceylon. *Ceylon J. Sci*. **18**: 89–132.

Osman Hill, W. C. (1953). *Primates: comparative anatomy and taxonomy* **I**, *Strepsirhini*. Edinburgh: Edinburgh University Press.

Petter, J. J. & Hladik, C. M. (1970). Observations sur le domaine vital et la densité de population de Loris tardigradus dans les forêts de Ceylon. *Mammalia* **34**: 394–409.

Rao, P. (1994). Occurrence of the slender loris *Loris tardigradus* in South Coastal Andhra Pradesh, India. *J. Bombay nat. Hist. Soc*. **91**(2): 303.

Rhadakrishna, S. (2001). *The social behavior of the Mysore slender loris (**Loris tardigradus lydekkerianus**)*. PhD thesis, University of Mysore.

Schulze, H. & Meier, B. (1995). The subspecies of *Loris tardigradus* and their conservation status: a review. In *Creatures of the dark: the nocturnal prosimians*: 193–209. Alterman, L., Doyle, G. A. & Izard, M. K. (Eds). New York: Plenum Press.

Senanayake, R. (1967). All for a pair of eyes. *Loris* **9**(2): 80–81.

Singh, M., Anand Kumar, M., Kumara, H. N. & Mohnot, S. M. (2000). Distribution and conservation of slender lorises (*Loris tardigradus lydekkerianus*) in Southern Andhra Pradesh, South India. *Int. J. Primatol*. **21**(4): 721–730.

Singh, M., Lindburg, D. G., Udhayan, A., Anand Kumar, M. & Kumara, H. N. (1999). Status survey of slender loris *Loris tardigradus lydekkerianus* in Dindigul, Tamil Nadu, India. *Oryx* **33**(1): 31–37.

Sutherland, W. J. (2002). Mammals. In *Ecological censusing techniques*: 260–278. Sutherland, W. J. (Ed.). Cambridge: Cambridge University Press.

White, L. & Edwards, A. (2000). Methods for assessing the status of animal populations. In *Conservation research in the African rain forests: a technical handbook*: 191–201. White, L. & Edwards, A. (Eds). New York: Wildlife Conservation Society.