Chapter 10
Forest Fragmentation Imperils Red Slender Lorises (*Loris tardigradus tardigradus*) in South-Western Sri Lanka

K. Anne-Isola Nekaris, Sarah M. Jaffe, and Giuseppe Donati

Abstract The red slender loris (*Loris tardigradus tardigradus*) is endemic to Sri Lanka's southern rainforests, where less than 2% of their habitat remains in small, fragmented patches. Because of continued encroachment on these small areas, the species is considered endangered. We present data on red slender loris abundance in nine of the last remaining forest patches in Sri Lanka's Wet Zone and examine the relationship between habitat characteristics and abundance. Slender lorises were present at 7 out of 9 patches, and 44 animals were encountered. Density estimates ranged from 3.4 to 28 lorises/km^2 with linear encounter rates of 0.1–1.1 lorises/km. Patch size heavily influenced encounter rate, with the largest patches containing more lorises. Removing the effect of patch size, we explored whether support size, undergrowth continuity, number of lianes/vines, and canopy continuity influenced loris density. We found slight evidence that increased numbers of lianes and vines were associated with decreased numbers of lorises. Although lorises rely on continuous substrates for movement, increased numbers of lianes and vines are also associated with the smallest and most disturbed habitats. In order to persist, red slender lorises require continuous forest. Unless forest encroachment can be halted and reforestation programmes started, their future in all but the largest of Sri Lanka's remaining forest patches is bleak.

Resume Le loris rouge (*Loris tardigradus tardigradus*) est endémique de la forêt pluviale du sud de Sri Lanka, où moins de 2% de son habitat subsiste sous forme de petits fragments isolés. Parce que ces fragments sont détruits continument, l'espèce est considérée en danger d'extinction. Nous présentons des estimations de l'abondance du loris rouge obtenues pour neuf des fragments de forêt subsistants dans la partie humide de Sri Lanka, et examinons les caractéristiques de ces habi-

K.A.-I. Nekaris (✉) • S.M. Jaffe • G. Donati
Nocturnal Primate Research Group, School of Social Sciences and Law,
Oxford Brookes University, Oxford OX3 0BP, UK
e-mail: anekaris@brookes.ac.uk; sarahmjaffe@gmail.com; gdonati@brookes.ac.uk

J. Masters et al. (eds.), *Leaping Ahead: Advances in Prosimian Biology*, Developments in Primatology: Progress and Prospects, DOI 10.1007/978-1-4614-4511-1_10,

tats. Des loris ont été trouvés dans 7 fragments sur 9, et 44 animaux ont été rencontrés. La densité estimée était de 3.4 à 28 loris/km2, avec un taux de rencontre linéaire de 0.1 à 1.1 loris/km. La taille des fragments avait une très forte influence sur le taux de rencontre, avec davantage de loris rencontrés dans les plus grands fragments. Nous avons exploré les effets possibles de la taille des supports, de la continuité du sous-bois et de la canopée, et la présence de lianes, indépendamment de la taille des fragments. La densité de loris tendait à diminuer légèrement quand le nombre de lianes augmentait. Bien que les loris aient besoin de supports continus, la présence de nombreuses lianes est souvent observée dans les plus petits et les plus dégradés des fragments. Les loris ont besoin, pour subsister, de forêt continue. A moins que la destruction de la forêt ne cesse, et qu'un programme de reforestation soit initié, leur avenir dans les forêts de Sri Lanka est compromis, à l'exception des plus grands fragments.

Introduction

Slender lorises (*Loris* spp.) are nocturnal primates known for their specialized, non-saltatory locomotion (Sellers 1996). Although originally thought to be so slow that their habitat requirements were minimal (Petter and Hladik 1970), we now know that slender lorises make regular use of home ranges comparable in size to other similarly sized nocturnal primates (Nekaris 2003). It has been suggested that, contrary to animals that can leap over large gaps, areas inhabited by lorises should contain continuous canopy (Kar-Gupta 1995; Singh et al. 1999; see also Chap. 38) so that lorises need not travel on open ground, where they are vulnerable to predation (Nekaris et al. 2007).

Red slender lorises (*L. tardigradus tardigradus*) are endemic to southern Sri Lanka, a region characterized by dramatic forest loss and fragmentation (Mill 1995). Habitat loss is identified as the greatest threat to red slender lorises, listed as Endangered by the IUCN (2008). Nekaris and Jayewardene (2004) found lorises to be rare at several sites within their range and to be absent from the smallest forests studied (Douglas et al. 2007). Few data are available, however, that quantify the relationship between microhabitat and loris abundance, findings crucial for determining conservation action plans (SAMD 2008).

We present data on slender loris abundance in nine of the last remaining forest patches in Sri Lanka's Wet Zone and examine the relationship between habitat characteristics and abundance. In particular, we explore whether the following features influence loris density: support size, undergrowth continuity, and canopy continuity.

Methods

Data were collected on 72 days from June to August 2005 at nine sites in Sri Lanka's Southern Province (Fig. 10.1, Table 10.1). With the exception of one site protected by a local land owner (Bangamukande), all sites are protected by the

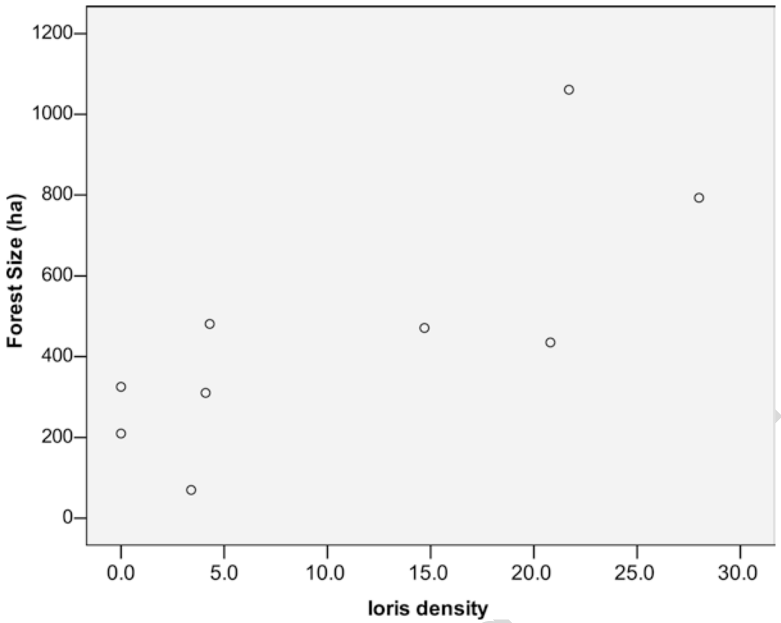

Fig. 10.1 Plot of the relationship between forest fragment size and red slender loris density

Table 10.1 Sizes of forest fragments at the time of the study, a representative geographic coordinate for each site, distance covered on foot, and density of animals at each site; sites listed in descending order of abundance

Study site (size in ha)	Representative geographic coordinates	Days	Distance walked (km)	Animals per km	Animals per km^2
Masmullah (793)	6°02′59.80″N 80°35′41.72″E	16	13.9	1.1	28.0
Kottawa (435)	6°4′59″N 80°20′8 ″E	8	14.7	0.7	20.8
Kakanadura (471)	5°59′13.89″N 80°35′42.23″E	7	13.2	0.5	14.7
Oliyagankele (481)	6°05′11.52″N 80°31′33.22″E	9	13.05	0.2	4.3
Wattahena (210)	6°0′0″N 80°27′0″E	5	6.75	0.1	4.1
Bangamukande (28)	6°21′00.97″N 80°13′16.25″E	14	8.29	0.1	3.4
Polgahaivalakande (325)	6°17′0″N 80°17′0″E	5	7.8	0	0
Welihena (310)	6°07′15.32″N 80°30′35.58″E	3	6.0	0	0
Total:		72	92.64	0.5 ± 0.4	10.8 ± SD 10.6

Forest Department of Sri Lanka. Despite this, all showed signs of anthropogenic disturbance (including logging and agriculture) and closely bordered on villages and/or roads. To estimate loris abundance, we selected line transects at random at each site and walked them either from sunset to midnight or midnight to sunrise (Sutherland 2002). Two to three researchers walked at a pace of 500 m/h, using a halogen head lamp with a red filter to scan all levels of the vegetation (Nekaris et al. 2008). Line transect lengths were derived using a laser rangefinder and confirmed with GPS reference points. Upon spotting an animal, its perpendicular distance to the line was recorded using a measuring tape, and the tree on which it was located was flagged. Only confirmed visual sightings of slender lorises were used to estimate abundances, but we also recorded the loris' distinctive loud whistle whenever it was heard. Strip width was determined by eliminating the furthest 10% of observations on either side of the line. Density was estimated using the following formula: $D = n/2wl$, where n is the number of animals seen, w is the strip width, and l is the transect length (Sutherland 2002). In order to compare our data with other loris surveys (e.g., Singh et al. 1999), a linear encounter rate was estimated.

The point-quarter center method for vegetation sampling was adapted to record several characteristics of microhabitat (Southwood and Henderson 2000). Random plots were placed 15 m from areas where we spotted lorises following a randomly selected compass bearing; on transects where no lorises were encountered, plots were placed at a locality along the transect chosen with a random number table. The following variables were collected: canopy continuity and undergrowth continuity (measured by the ground cover of saplings and plants large enough to provide passage for a loris) between the point center and the nearest tree using the Braun-Blanquet scale; substrate size and angle at 3.5 m, the preferred height of red slender lorises; and number of vines connecting the closest tree to the point center to its nearest neighbor (Lacher and Cleber 2001; Nekaris et al. 2005). Normality of the data was confirmed using Kolmogorov–Smirnov tests, and parametric tests were used for the analyses. To test whether microhabitat variables have an effect on abundance independent of the effect of fragment size, we ran ANCOVA models between the variables using fragment size as a covariate, after transforming the original independent variables from numeric into categorical variables (Zar 1999).

Results

Nearly 100 km were walked during the survey. Slender lorises were present at seven out of nine patches (Table 10.1), and 44 animals were encountered in total. Density estimates ranged from 3.4 to 28 lorises/km^2 with linear encounter rates of 0.1–1.1 lorises/km. At all seven sites, presence was confirmed with clear visual sightings. The characteristic loud whistle of *Loris* was heard at all seven sites. Although lorises may still prove to be present at Welihena and Polgahaivalakande, absence of both sightings and whistles indicates that, if they are present, they occur at very low densities. Lorises were spotted exclusively within forest reserves; they were never seen along village roads or in gardens.

Table 10.2 Microhabitat features compared across sites represented by either the average and standard deviation, or the dominant habitat category

Study site	Tree height ***F	% Tree cover***χ	Canopy continuity***χ	No. vines ***F	Branch size***χ	Sub-strate angle***χ
Masmullah ($n=123$)	7.1 ± 5.7	0–25%	0–25%	0.8 ± 1.2	>30 cm	Vertical
Dandeniya ($n=75$)	4.7 ± 2.8	0–25%	26–50%	2.4 ± 1.6	1–5 cm	Oblique
Kottawa ($n=78$)	5.1 ± 3.4	26–50%	0–25%	0.9 ± 1.2	>30 cm	Vertical
Kakanadura ($n=93$)	6.8 ± 5.0	0–25%	2–50%	1.2 ± 1.6	>30 cm	Vertical
Oliyagankele ($n=126$)	6.3 ± 4.3	0–25%	0–25%	1.5 ± 1.4	>30 cm	Vertical
Wattahena ($n=80$)	4.9 ± 2.7	26–50%	26–50%	0.9 ± 1.3	1–5 cm	Vertical
Bangamukande ($n=50$)	12.0 ± 0.4	0–25%	0–25%	0.7 ± 1.4	>30 cm	Vertical
Polgahaivalakande ($n=80$)	5.6 ± 3.9	26–50%	0–25%	1.9 ± 1.8	1–5 cm	Vertical
Welihena ($n=80$)	5.4 ± 3.0	0–25%	0–25%	1.4 ± 1.5	1–5 cm	Vertical

Both analysis of variance (F) and chi-squared cross tabulation tests (χ) revealed that sites differed significantly in microhabitat components ($p \leq 0.001$)

Although a low percentage of canopy continuity and ground covered by saplings characterized all sites, they differed significantly from one another for all microhabitat variables measured (Table 10.2). A single factor, forest patch size, correlated strongly with loris abundance (Pearson's $r=0.778$, $p \leq 0.01$) (Fig. 10.2). Given this correlation, we removed the effect of fragment size to explore the effects of microhabitat variables on loris abundance. The only significant effect observed was a negative relationship between number of vines and lianas and loris abundance (ANCOVA: $F=18.65$, df$=2$, $n=9$, $p \leq 0.005$). Indeed, the total model that accounted for the effect of the number of vines, taking fragment size into account, explained 93% of the variance in loris abundance. The only other variable that approached significance was branch size (ANCOVA: $F=4.96$, df$=1$, $n=9$, $p=0.067$).

Discussion

Most previous studies of slender lorises have estimated their abundance linearly. The linear results obtained in this study ranged from 0.1 to 1.0 animals/km. These figures are comparable to the lower end of estimates for slender lorises in previous studies in India and Sri Lanka (Singh et al. 1999, 2000; Nekaris and Jayewardene [AU1] 2004; Kumara et al. 2006; Chap. 38). They are also comparable to the generally low abundance estimates of Southeast Asian slow lorises (Nekaris et al. 2008). At two sites (Wattahena and Bangamukande), only one animal was seen in 19 days of survey. Indeed, at Bangamukande, the smallest site in the sample, encounter rates may even be lower, as only two others were ever seen during three other field seasons,

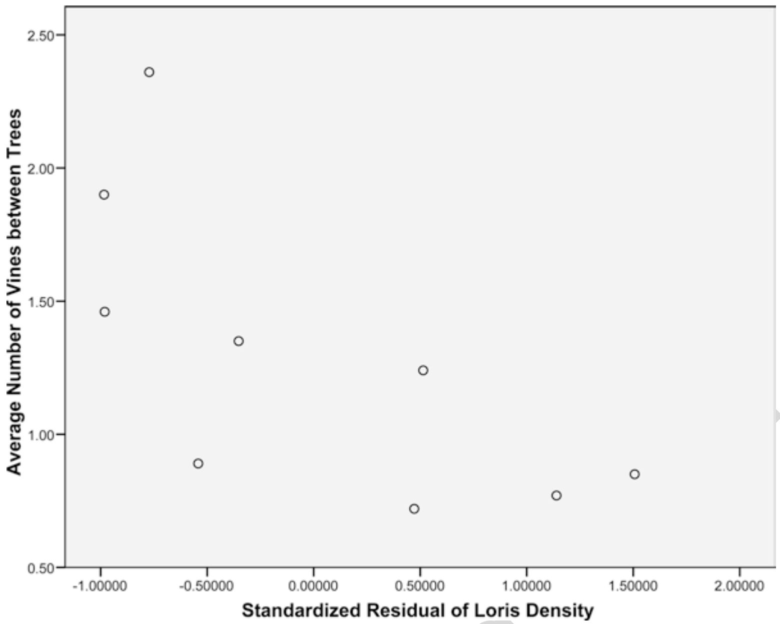

Fig. 10.2 Even when the effect of forest size is taken into account, a significant negative relationship is still found between abundance (residual displayed here for comparative purposes) of red slender lorises and number of vines. Higher numbers of vines are indicative of increased forest disturbance

which included extensive nocturnal surveys (Bernede 2003). These results lend support to the latest IUCN (2008) Red List assessment of *Loris tardigradus tardigradus* as Endangered.

Contrary to our expectations, most sites, whether lorises were present or not, had a combination of low canopy and undergrowth cover, and predominantly vertical substrates that are less suitable for lorises (Nekaris and Jayewardene 2004). These features may explain why loris abundances were low in comparison with other studies. A feature expected to be positively associated with loris presence, the number of vines and lianas connecting trees, was, in fact, negatively correlated. Increased vines and lianas are also a sign of severe anthropogenic disturbance, usually caused by logging and unrestricted access to the forest (Bhuyan et al. 2003).

Canopy continuity has been proposed as an important factor in determining arboreal mammal abundance (Malcolm 2000; Lacher and Cleber 2001) and identified as crucial for slender lorises (Singh et al. 1999) but was not significantly associated with loris abundance in this study. Arboreal continuity in general is often related to the tangled vegetation characteristic of disturbed areas and tree fall zones (Molino and Sabatier 2001; Nekaris et al. 2005). Many species of small arboreal mammals commonly occur at higher abundance in disturbed areas (Lambert et al. 2006), and disturbed areas should not be ruled out as a conservation priority (Wells et al. 2007). A method for comparing connectivity at all forest levels should be devised to assess further the suitability of these habitats for red slender lorises.

Although the impact of disturbance may appear positive in the short term (Lovejoy et al. 1986), small arboreal animals in particular may be extremely vulnerable to rapid decline following a reduction in resource availability (Wells et al. 2007). Nekaris and Jayewardene (2004) surveyed Masmullah and Oliyagankele in 2001; for both sites, estimates were lower in 2004. In a long-term study at Masmullah, Bernede (personal communication) also commented on a marked decrease in encounter rate. Indeed, Forest Department records show a decrease in the size of this forest from 793 ha in 2001 to 296 ha in 2005. The main cause of this seems to be human encroachment, including use of forested land for rice paddies, cattle grazing, and logging for firewood (Ashton et al. 2001). For example, one of the major areas in Masmullah where Nekaris et al. (2005) conducted their study in 2002 had been burnt down in 2005. These observations support our major finding that forest fragment size directly affects the abundance of slender lorises.

Conclusion

Slender lorises are threatened by multiple factors not limited to deforestation, compounding the need for conservation intervention. Our study shows that habitat loss and decreasing patch sizes over time have contributed to their ongoing population decline. An unremitting trend due to agricultural and logging demands will probably lead to short-term local extinctions of red slender lorises in Sri Lanka. Habitat protection and expansion of the protected areas network are essential for the survival of the remaining wild populations of red slender lorises.

Acknowledgments We thank Judith Masters and Carol Scheepers for organizing the International Congress on Prosimians and for inviting us to participate in this volume. We thank the Department of Forestry and the Department of Wildlife Conservation for research permits to carry out this study. We are grateful to the following individuals who assisted in the project: S. Wimalasuriya and G. de Silva Wijeyeratne for logistical aid and M. Abare, S. Gamage, E. Leavitt, Madumadarawa, Nallaka, and J. Stokes for assistance in the field. Funds for the project were provided by People's Trust for Endangered Species, Columbus Zoological Park and Aquarium, Primate Action Fund of Conservation International, and Primate Conservation Inc.

References

Ashton PMS, Gunatilleke CVS, Singhakumara BMP, Gunatilleke IAUN (2001) Restoration pathways for rain forest in southwest Sri Lanka: a review of concepts and models. For Ecol Manage 154:409–430

Bernede L (2003) Biodiversity assessment of a regenerating rainforest patch at Bangamukande Estate, Pitigala, Galle District, Sri Lanka. Unpublished MSc dissertation, Oxford Brookes University, Oxford

Bhuyan P, Khan ML, Tripathi RS (2003) Tree diversity and population structure in undisturbed and human-impacted forest stands of tropical wet evergreen forest in Arunachal Pradesh, Eastern Himalayas, India. Biodivers Conserv 12:1753–1773

Douglas PH, Moore RS, Wimalasuriya S, Gunawardene A, Nekaris KAI (2007) Microhabitat variables influencing abundance and distribution of diurnal primates (*T. vetulus vetulus* and *Macaca sinica aurifrons*) in a fragmented rainforest network in southern Sri Lanka. Eur Fed Primatol Conf Proc. Charles University, Prgaue, p 17

IUCN Red List (2008) Species information on *Loris tardigradus tardigradus*. Accessed last on 29 Sept 2011. Available at http://www.iucnredlist.org/apps/redlist/details/12375/0

Kar-Gupta K (1995) Slender loris, *Loris tardigradus*, distribution and habitat use in Kalakad-Mundanthurai Tiger Reserve, India. Folia Primatol 69(Suppl 1):401–402

Lacher TE, Cleber JRA (2001) Terrestrial small mammal richness and habitat associations in an Amazon forest-cerrado contact zone. Biotropica 33:171–181

Lambert TD, Malcolm JR, Zimmerman BL (2006) Amazonian small mammal abundances in relation to habitat structure and resource abundance. J Mammal 87:766–776

Lovejoy TE, Bierregaard RO Jr, Rylands AB, Malcolm JR, Quintela CE, Harper LH, Brown KS Jr, Powell AH, Powell GVN, Schubart HOR, Hays MB (1986) Edge and other effects of isolation on Amazon forest fragments. In: Soulè ME (ed) Conservation biology. The science of scarcity and diversity. Sinauer Associates, Sunderland, MA, pp 257–285

Malcolm JR (2000) Influence of timber extraction routes on central African small-mammal communities, forest structure and tree diversity. Conserv Biol 14:1623–1638

Mill RR (1995) Regional overview: Indian subcontinent. In: Davis SD, Haywood VH, Hamilton AC (eds) Centres of plant diversity: a guide to strategy for their conservation, vol 2: Asia, Australia and the Pacific. World Wildlife Fund for Nature and the IUCN Press, Cambridge, pp 62–135

Molino JF, Sabatier D (2001) Tree diversity in tropical rain forests: a validation of the intermediate disturbance hypothesis. Science 294:1702–1704

Nekaris KAI (2003) Spacing system of the Mysore slender loris (*Loris lydekkerianus lydekkerianus*). Am J Phys Anthropol 121:86–96

Nekaris KAI, Jayewardene J (2004) Distribution of slender lorises in four ecological zones in Sri Lanka. J Zool 262:1–12

Nekaris KAI, Liyanage WKDD, Gamage S (2005) Relationship between forest structure and floristic composition and population density of the southwestern Ceylon slender loris (*Loris tardigradus tardigradus*) in Masmullah Forest, Sri Lanka. Mammalia 69(2):1–10

Nekaris KAI, Pimley ER, Ablard K (2007) Anti-predator behaviour of lorises and pottos. In: Gursky SG, Nekaris KAI (eds) Primates and their predators. Springer Media, New York, pp 220–238

Nekaris KAI, Blackham G, Nijman V (2008) Conservation implications of low encounter rates of five nocturnal primate species (*Nycticebus* spp.) in Asia. Biodivers Conserv 17:733–747. doi:10.1007/s10531-007-9308-x

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

SAMD (Southeast Asian Mammal Databank) (2008) Accessed on 29 Sept 2011. Available at http://www.ieaitaly.org/samd/

Sellers W (1996) A biomechanical investigation into the absence of leaping in the locomotor repertoire of the slender loris (*Loris tardigradus*). Folia Primatol 67:1–14

Singh M, Lindburg DG, Udhayan A, Kumar MA, Kumara HN (1999) Status survey of the slender loris in Dindigul, Tamil Nadu, India. Oryx 33:31–37

Singh M, Kumar MA, Kumara HN, Mohnot SM (2000) Distribution and conservation of slender lorises in Southern Andhra Pradesh, South India. Int J Primatol 21:721–730

Southwood TRE, Henderson PA (2000) Ecological methods, 3rd edn. Blackwell, Oxford

Sutherland WJ (2002) Mammals. In: Sutherland WJ (ed) Ecological census techniques: a handbook. Cambridge University Press, Cambridge, pp 260–278

Wells K, Kalko EKV, Lakim MB, Pfeiffer M (2007) Effects of rain forest logging on species richness and assemblage composition of small mammals in Southeast Asia. J Biogeogr 34:1087–1099

Zar JH (1999) Biostatistical analysis, 4th edn. Prentice Hall, New Jersey