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FACTORS INFLUENCING SITE OCCUPANCY OF MONTANE SLENDER LORIS (*Loris tardigradus nycticeboides*) IN SRI LANKA

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ABSTRACT - The Montane slender loris *Loris tardigradus nycticeboides* is an endangered and endemic primate species inhabiting the montane region of Sri Lanka. Recent studies suggested the *L. t. nycticeboides* should be elevated to Critically Endangered status. However, information available for the effective conservation of the *L. t. nycticeboides* is limited. This research was undertaken to clarify the above issues and to gather data on factors influencing the occurrence of *L. t. nycticeboides* using the technique of occupancy modeling. The results show that the probability of detection (p) and site occupancy (Ψ) of the *L. tardigradus* varied due to numerous factors such as altitude, canopy connectivity and canopy height. Most suitable habitats for *L. t. nycticeboides* occupancy was montane forests situated in 1600-2100m altitude with tall canopy (height >4m) and good canopy connectivity (canopy openings<25%). Focusing on reducing the negative effects of these factors from anthropogenic activities is essential to ensure that *L. tardigradus* conservation programs are effective.

KEY WORDS : *Loris tardigradus nycticeboides*, Endangered species, Endemic species, Montane region

INTRODUCTION

The Montane slender loris (*Loris tardigradus nycticeboides*) is an endangered primate inhabits the montane region of Sri Lanka (Gamage *et al.*, in review a). Recent studies by Gamage *et al.*, (2014) corroborated that L. t. nycticeboides is Critically Endangered [A1(c), C.C2 a(i)]. The Motane slender loris *L. t. nycticeboides* was previously (2004-2008) listed as one of the top 25 endangered primates in the world (Mittermeir *et al.*, 2006). Furthermore, *L. t. nycticeboides* and its relative *L. t. tardigradus* is included within the top 100 Evolutionarily Distinct and Globally Endangered (EDGE) mammals (Isaac *et al.*, 2007).

However, despite this interest only limited data are available for the accurate evaluation of their habitat requirements or applied management needs. The *L. t. nycticeboides* was previously recorded only from two specimens collected in 1937 by Tutein-Nolthenius in the Horton Plains region (Hill, 1942), and later by a sighting from eye-shine in 2002 (Nekaris, 2003). According to Hill (1942) the *L. t. nycticeboides* very rare in it's *holo* habitat. The first physical examination of the *L. t. nycticeboides* was done by Gamage *et al.* (2010) and current studies identified *L. t. nycticeboides* is a highly habitat specialist and only found in montane evergreen forests between 1600-2100m in Nuwara-Eliya and it's never occupied in the Eucalyptus/pine plantation (Gamage *et al.*, 2014; Gamage *et al.*, in review a; Gamage *et al.*, in review b). There has been some controversy over the factors influencing *L. tardigradus* abundance and distribution. For instance, Nekaris *et al.* (2012) stated that canopy continuity was not significantly associated with *L. t. tardigradus* abundance, although this feature was considered an important factor in earlier publications (Nekaris *et al.*, 2005; Gamage *et al.*, 2009) for *L. t. tardigradus*. However, recent studies identified canopy continuity (arboreal connectivity) is one of the key factors affected to the *L. tardigradus* occupancy and abundance in Sri Lanka (Gamage *et al.*, in review b). This study, further identified that elevation has an effect of the *L. tardigradus* occupancy and abundance. Therefore, we undertook this research to clarify the above issues and, more importantly, to gather information on *L. t. nycticeboides* distribution and habitat requirements that were urgently needed for its conservation.

METHODOLOGY

Sample selection

Recent studies identified the *L. t. nycticeboides* inhabited only in the montane rainforests above 1600m of Nuwara Eliya (Gamage *et al.*, in review b). Thus, our study area consisted of several localities above 1300m in Nuwara Eliya. Therefore a boundary map of the above area was obtained using digital elevation models (DEM) of the Sri Lanka. The vegetation cover map of the above area was identified from the satellite images, which then was used to extract natural vegetation cover of the area. Using a random point generator in ARC GIS version 10, 150 random sampling points were generated, which covers the boundary of the above natural vegetation area. Then out of 150 points, 44 points were randomly selected for the survey. Sampling sites were then classified according to level of arboreal connectivity, canopy height, and elevation (Table 1).

Our methodology involved repeated spotlight surveys of transects measuring 2km, which represented a particular habitat type and two to five non-overlapping transects were demarcated to maintain a total survey distance of 2km.

The surveys were conducted when Slender Loris were most active, (between 1900-2200 and 0230-0530 hours), and repeated upon fist observation of loris / if not repeated nine times within a six day sampling period (Gamage *et al.*, in review b). In each site had a one six day sampling period, however, unfavorable weather conditions made full completion of nine repeated surveys impossible in some sites. Two-member teams walked along survey transects at about 1km per hour looking for eye shine with the help of dimmed, wide-beam and heavily red -filtered head torches (LED lenser™ H7) that were used to minimise disturbance (Gamage *et al.*, 2010).

Data Analysis

In this study a single-season standard occupancy design was used to estimate the probability of a given site being occupied by *L. t. nycticeboides* (MacKenzie and Royle, 2005). The data were analysed by using the programme PRESENCE 2.3 and GENPRES2_INT. ArcGIS® and ArcMap™ version 10 was used to selection of sampling sites.

The occupancy model makes the following assumptions:
(1) sampling plots are closed to changes in occupancy during the sampling period
(2) any heterogeneity in occupancy across plots

TABLE 1: Definition of covariates used for L. t. nycticeboides site occupancy in the Nuawara Eliya.

Covariate	Definition and range
Elevation	Lower montane (LM) [<1600 m above sea level], montane (MO) [1600-2100m above sea level], upper montane (UM) [>2100m above sea level]
Canopy Connectivity	Good [Connected canopy with 0 - 25% of canopy openings]; poor [area with >25% of canopy openings]
Canopy height	Short (height < 4m) and tall (height > 4m)]

is accounted for by model covariates
(3) any heterogeneity in the probability of detection across plots and surveys is accounted for by covariates
(4) detections within each plot are independent (MacKenzie *et al.* 2006).

A two-step process was used to estimate loris occupancy parameters. To find the best model for detection, the first step modeled all covariates while holding occupancy constant [i.e., ψ(.)p(covariate)]. The second step compared occupancy models simultaneously with the best model for detection probability (Kroll *et al.*, 2008). Goodness of fit was assessed for models within each covariate according to their Akaike Information Criterion (AIC) values (Akaike, 1973; Burnham and Anderson, 2002). The models were ranked according AIC values, and the lowest value indicated the best-fit model to the data. AIC weights (AIC_{wgt}) were also calculated to identify the best-fitting model and to calculate model averaged estimates and confidence intervals for the probability of detection and occupancy of *L. t. nycticebides* (Burnham and Anderson, 2002; Kroll *et al.*, 2008) in the wet and intermediate zones.

RESULTS

A total of 44 sites surveyed during June 2012 and May 2014. These sites were located at Lower montane (n=8), montane (n=25), upper montane (n=11). A total of 328 transect surveys (656 km walked) was completed, and in 13 of the survey transects (3.96 %) the *L. t. nycticeboides* was detected.

The overall probability of detection and occupancy estimates were 0.4630 (SE = 0.1295) and 0.1225 (SE = 0.0373) respectively for the 44 sites. The simulated standard error (SE) values for site occupancy and probability of detection vs. number of surveys for a site (MacKenzie *et al.*, 2006) based on these results shows, SE for occupancy and detection was remaining lower and constant after seven surveys at a site (Figure 1).

The table (2) shows different models with various factors affecting to *L. t. nycticeboides* probability of detection. It's clearly shows all

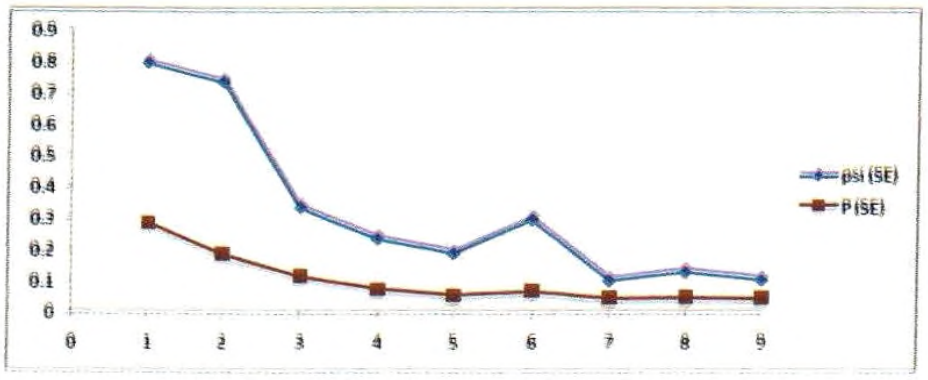

FIGURE 1: Graph of simulated standard error (SE) values for site occupancy / probability of detection vs. number of surveys for a site based on the overall results (ψ = 0.4630, **p** = 0.1225, number of sites = 44) using single season standard occupancy model (GENPRESS 4 was used to generate the simulated values): ψ(SE) = standard error for individual site occupancy, **p**(SE) = standard error for individual site estimate of probability of detection. Bold entries for optimal number of surveys for a site to get lowest SE for occupancy and probability of detection.

single factor models Ψ(.)p(single covariate) had much higher AIC values than the fixed model Ψ(.)p(.) while multiple factor models Ψ(.)p(covariate 1 + covariate 2 + .) had relatively lower AIC values. The highest ranking model was Ψ(.)p(high canopy + canopy connectivity high + montane) thus, this model was used as the base model to examine occupancy for *L. t. nycticeboides* in Nuwara Eliya.

The untransformed estimates of coefficients for covariates (β) vales given in table (3) it's shows three factors were positively associated with the *L. t. nycticeboides* site occupancy, *viz.* montane (β = 30.10, AIC = 150.93), tall canopy (β = 20.43, AIC = 152.06) and canopy connectivity good (β = 0.43, AIC = 162.75). While four factors were negatively associated with the *L. tardigradus* site occupancy, *viz.* canopy connectivity poor (β = -21.20, AIC = 152.10), short canopy (β = -20.29, AIC = 152.10), upper-montane (β = -2.20, AIC = 156.08) and lower-montane (β = -0.48, AIC = 162.15).

The table (4) shows different models with various factors affecting to *L. t. nycticeboides* site occupancy and the highest ranking model was, Ψ(montane + canopy connectivity good + tall canopy)**p**(tall canopy + canopy connectivity good + montane), which represented 54% of the variance affecting Ψ.

TABLE 2: Model selection procedure to estimate best model for detection of *L. t. nycticeboides*, obtained from 44 survey sites in Nuwara Eliya. Seven variables were considered: *LM* = lower montane, *MO* = mid montane, *UM* = upper-montane, *CCG*= canopy connectivity good, *CCP*= canopy connectivity poor, *TCA* = tall canopy and *SCA* = short canopy.

Model	AIC	Model likelihood	K
Ψ(.)**p**(*TCA*+*CCG*+*MO*)	163.00	1.0000	4
Ψ(.)**p**(*TCA*+*CCG*+*MO*+*LM*)	163.05	0.9753	5
Ψ(.)**p**(*TCA*+*CCG*)	163.32	0.8521	3
Ψ(.)**p**(.)	167.32	0.1153	2
Ψ(.)**p**(*MO*+*CCG*)	169.39	0.0410	3
Ψ(.)**p**(*TCA*)	170.12	0.0284	2
Ψ(.)**p**(*CCG*)	171.13	0.0172	2
Ψ(.)**p**(*MO*)	179.94	0.0002	2
Ψ(.)**p**(*CCP*)	218.31	0.0000	2
Ψ(.)**p**(*LM*)	221.13	0.0000	2
Ψ(.)**p**(*SCA*)	222.57	0.0000	2
Ψ(.)**p**(*UM*)	223.82	0.0000	2

Where (.) denotes occupancy or detection, constant while (*LM* or *MO* or *UM* or *CCG* or *CCP* or *TCA* or *SCA*) denote detection according to the covariates. AIC = Akaike Information Criterion vale; K = number of covariates in the model; Ψ = occupancy estimate; **p** = detection probability.

DISCUSSION

Our results indicate that **p** for *L. t. nycticeboides* was not equal in all survey sites and varied due to numerous factors such as altitude, canopy connectivity and canopy height, in agreement with previous suggestions that environmental variables could affect the probability of detection for a given species (Bailey *et al.*, 2004; MacKenzie, 2006). Several researchers have suggested that variation in **p** may be associated with organism density (Kroll *et al.* 2008), recent studies in the wet zone Sri Lanka confirmed that *L. tardigradus* abundance was positively associated with **p** (Gamage *et al.*, in review). The results show very low probability of detection (**p**) value for *L. t. nycticeboides* this may be due to low abundance / density. And confirmed previous statements by Hill (1942) the *L. t. nycticeboides* was very rare. Furthermore, this very low **p** value also an indication small population of *L. t. nycticeboides* thus support to the previous estimation of 60-100 matured individuals by Gamage *et al.*, (2014).

Overall results indicate *L. t. nycticeboides* occupancy is closely associated with altitude, canopy height and canopy connectivity; the best habitat was 1600-2100m altitude, tall canopy (height >4m) montane forests with good canopy connectivity (canopy openings<25%). Four out of seven factors considered for the study was negatively associated with the *L. t. nycticeboides* occupancy, one of these factors (*viz.* canopy connectivity poor) heavily influenced by anthropogenic activities; such as uncontrolled firewood extraction, logging and encroachment. Furthermore, forest dieback in the montane region is also influenced to the reduction of canopy connectivity. Recent studies show available natural vegetation for the *L. t. nycticeboides* is less than 3500ha (Gamage *et al.*, 2014), thus the future of montane slender loris remains under threat.

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TABLE 3: Covariates influencing to *L. tardigradus* site occupancy ranked according to AIC values and untransformed covariates of coefficients (β) for the different covariates.

Covariates	β	AIC
Montane (1600-2100m)	30.10	150.93
Tall canopy (height >4m)	0.43	152.06
Canopy connectivity poor	-21.20	152.10
Short canopy (height<4m)	-20.29	152.10
Upper-montane (>2100m)	-02.20	156.08
Lower-montane (<1600m)	-01.46	162.15
Canopy connectivity good	00.30	162.75

TABLE 4: Covariates influencing to *L. tardigradus* site occupancy ranked according to AIC values and untransformed covariates of coefficients (β) for the different covariates.

Model	AIC	Model likelihood	K
Ψ(*MO*+*CCG*+*TCA*)**p**(*TCA*+*CCG*+*MO*)	144.77	1.0000	6
Ψ(*MO*+*CCG*)**p**(*TCA*+*CCG*+*MO*)	145.52	0.6873	5
Ψ(*MO*+*CCG*+*TCA*+ *LM*+ *UM*+ *CCP*+ *SCA*)**p**(*TCA* +*CCG*+*MO*)	150.82	0.0486	10
Ψ(*MO*)**p**(*TCA*+*CCG*+*MO*)	150.93	0.0460	4
Ψ(*TCA*)**p**(*TCA*+*CCG*+*MO*)	152.06	0.0261	4
Ψ(*CCP*)**p**(*TCA*+*CCG*+*MO*)	152.10	0.0256	4
Ψ(*UM*)**p**(*TCA*+*CCG*+*MO*)	156.08	0.0035	4
Ψ(*LM*)**p**(*TCA*+*CCG*+*MO*)	162.15	0.0002	4
Ψ(*CCG*)**p**(*TCA*+*CCG*+*MO*)	162.75	0.0001	4
Ψ(.)**p**(*TCA*+*CCG*+*MO*)	163.00	0.0001	4
Ψ(.)**p**(.)	167.32	0.0000	2

Where (.) denotes occupancy or detection, constant while (*LM* or *MO* or *UM* or *CCG* or *CCP* or *TCA* or *SCA*) denote detection according to the covariates. AIC = Akaike Information Criterion vale; K = number of covariates in the model; Ψ = occupancy estimate; **p** = detection probability.

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