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Conservation Status and Potential Distribution of the Bengal Slow Loris *Nycticebus bengalensis* in Northeast India

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Abstract: The Bengal slow loris *Nycticebus bengalensis* is a nocturnal primate, confined in India to the forests of the northeastern states. To understand better its range and occurrence in the state of Meghalaya, we surveyed nine community reserves, and interviewed 50 local people about their sightings of the species and to obtain a picture of the threats that lorises are facing. We also reviewed the available literature on their sightings, abundance, and rescues carried out in Northeast India. We confirmed the occurrence of a slow loris in five of the nine surveyed community reserves, and saw one individual in the Chimanapara Community Reserve. The review confirms the occurrence of slow lorises in all of the seven states of Northeast India. The modelled potential distribution provides the environmental limits of its range for the first time, and indicates potential sites for its occurrence in the northeast. Abundances in our survey sites in Meghalaya and also in the entire northeast are relatively low compared to many sites in the Southeast Asian countries. Reports of the numbers of slow lorises rescued almost equal the total detections recorded during all surveys carried out in Northeast India. We explore the possible reasons for their low populations and emphasize the need of educating the people as a last resort for the species' conservation and management in Northeast India, taking into consideration the cultural values and socio-political status of the local communities.

Key words: Bengal slow loris, *Nycticebus bengalensis*, Meghalaya, community reserves, Northeast India

Introduction

The Bengal slow loris occurs in numerous Asian countries, including Bangladesh, Bhutan, Cambodia, China, India, Laos, Myanmar, Thailand, and Vietnam (Nekaris *et al*. 2020). It is the only a nocturnal primate known from northeastern India (Prater 1993). There, they are recorded from humid, tropical rainforests, semi-evergreen forests, and moist deciduous forests of Meghalaya, Arunachal Pradesh, Assam, Manipur, Nagaland, Mizoram, and Tripura (Radhakrishna *et al*. 2006, 2010, 2012; Swapna *et al*. 2008; Biswas *et al*. 2009; Das *et al*. 2009, 2014, 2016; Nandini *et al*. 2009).

These states are largely hilly, dominated by native people, who are known for their unique cultural, and socio-political status (Ali and Das 2003; Biswas 2008; Bhattacharjee 2018), and the majority of the forestland is owned by them, except for a few reserved forests and protected areas. The livelihoods of these people center on agriculture, timber, and wild meat (Rangarajan 2001; Aiyadurai *et al*. 2010). In addition to habitual hunting, community hunting is one of the rituals during the festival season, and associated with marriage ceremonies, when men indulge in extensive hunting for several days (Aiyadurai *et al*. 2010). *Jhum* cultivation (slash-and-burn or shifting cultivation) is the widely used age-old agricultural practice, where forest patches are burned and farmed for a few years before moving on to another patch (Ali and Das 2003; Seitinthang 2014). The increasing human populations in these states, along with immigrants from neighboring countries result in greater demands for food, augmenting the use of forests for agriculture (Mandal 2011). Some of the forest patches are also exploited for a commercial crop, such as cashew nut, tea, beetle nut, and cardamom (Biswas 2008). This has led to the "empty-forest syndrome" in many of the northern states (Datta *et al*. 2008).

The conservation of forests and wildlife in these states is challenging as the forests are largely under the control of local communities or autonomous district councils (Radhakrishna *et al*. 2006). It is further challenging to assess the

Table 1. Details of Community Reserves (CR) surveyed for Bengal slow loris in Meghalaya.

Community reserve	Area (ha)	Geocoordinates	Altitude (m asl)	Habitat types*	Last *Jhum* cultivation
Mongalgre	20.0	25.66389017-25.66938333 N, 90.18562605-90.19138953 E	317-351	MDF	Village forest from the beginning
Dumitigre	70.0	25.60628723-25.6143495 N, 90.18183209-90.19631834 E	331-434	MDF	8-9 years
Selbalgre	20.0	25.56204347-25.57695266 N, 90.28665095-90.29027214 E	488-583	SER, MDS	Sacred groove
Thokpara	30.0	25.24902271-25.25795519 N, 90.12856033-90.13520575 E	46-114	MDS, Bamboo	8 years
Chimanpara	10.2	25.25637605-25.2596936 N, 90.13242131-90.13572457 E	68-116	MDS, Bamboo	7-8 years
Rongalgre	16.5	25.4561200-25.46152399 N, 90.1623459-90.16678171 E	94-151	DDF, Bamboo	10 years
Daribokgre	172.2	25.46737202-25.47990408 N, 90.30853109-90.33472358 E	1062-1348	SER, MDF	14-15 years
Kitmandamgre	70.0	25.79698626-25.80746304 N, 90.38840919-90.39869144 E	179-312	SER, Bamboo	11 years
Resu Halupara	50.0	25.92362734-25.93369367 N, 90.59229989-90.59945210 E	225-341	MDF, Bamboo	Village forest from the beginning

*SER: semievergreen forest, MDF: moist deciduous forest, DDF: dry deciduous forest.

population status and distribution of nocturnal species such as the Bengal slow loris. Although, it is not preferred game, it is caught opportunistically for the pet trade and for its use in traditional medicine. The loss of habitat due to *jhum* cultivation is also a cause for their scarcity (Radhakrishna *et al*. 2010). In this dismal scenario, every piece of information on the species is invaluable. In addition to our field surveys in community reserves in Meghalaya, we reviewed the records of sightings from published scientific and gray literature, to give us an idea of its spatial occurrence and conservation status. Historical records, a few surveys and interviews with people in the local communities gives us a rough approximation of its range and numbers, and non-detection of its occurrence can also provide insights as to its habitat requirements and environmental limits. Together, this information allows us to indicate the potential niche for the species in northeastern India.

Methods

Study site

The Indian state of Meghalaya (25–26°N, 89°93°E) is one of the northeastern states, and is part of the Indo-Burma Biodiversity Hotspot, ranked among the top 10 hotspots for irreplaceability due to high species diversity and endemism (Myers *et al*. 2000). We surveyed nine of 65 community reserves in Meghalaya for the Bengal slow loris (Fig. 1). The topographical and habitat features of the surveyed community reserves are provided in Table 1. Those selected were in the West Garo Hills, each having an area ranging from 10 ha to 172 ha. Six of them had a history of *jhum* cultivation, and others were managed as village forests or sacred groves. The vegetation of these community reserves included semi-evergreen forest, moist deciduous forest, dry deciduous forest, and bamboo.

Data collection

The study on the Bengal slow loris was conducted between June 2019 and February 2020 in nine community reserves in Meghalaya (Table 1). We stayed in villages and, engaging the community reserve management committees, we recruited field assistants to help us carry out the surveys. We interviewed a minimum of five members of each village regarding the various activities being carried out in their community reserve. The interviews were focused on the presence or detection of slow lorises, hunting

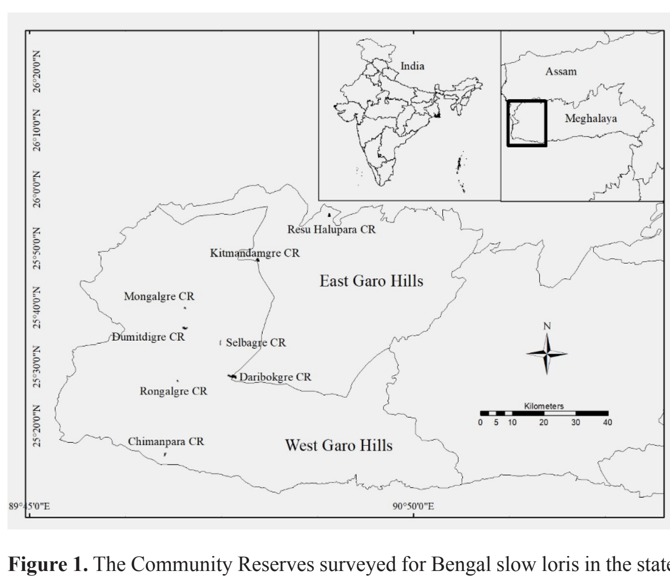

Figure 1. The Community Reserves surveyed for Bengal slow loris in the state of Meghalaya.

pressure, and the belief system concerning wildlife among the communities.

In each community reserve, we walked the trails at night at 1–1.5 km/hr, between 18:00 h and 21:00 h searching the forest canopy using Britelite flashlights. We surveyed one to two trails depending on the area of the reserve. We walked a total of 38.28 km. Animals were detected based on the reflection of light from their eyes to the flashlight. For every sighting of an animal, we recorded the time, species, number of individuals, substratum, if the detection was on the tree, then tree height and animal height, and geocoordinates using a handheld global position system (GARMIN etrx60).

Modelling of potential habitat

We obtained only a few records during the surveys. Results from previous studies are likewise scarce. For this reason, we opted to model the potential niche of the species. We reviewed the relevant literature on slow lorises, both primary and secondary sources, to compile occurrence locations. In all, we obtained 93 locations, including 38 rescues (see Supplementary materials, Tables S1 and S2), in six of the north-eastern Indian states (Arunachal Pradesh, Assam, Manipur, Tripura, Meghalaya, and Nagaland). With geocoordinates of sighting locations from primary sources and for rescued sites, we mapped all localities using google-maps and topographic sheets of scale 1:50000. Some locations were within a 1-km radius, and we ran spatial thinning with all compiled locations to combine records that were within a 2-km radius of others, to avoid over-prediction. Spatial thinning is important for model calibration and evaluation to avoid over-fit of models over environmentally biased locations. We used 66 occurrence locations to predict the distribution of slow loris for Northeast India.

Nineteen bioclimatic variables, two topographic variables (elevation and slope) and one vegetation variable (NDVI) to explain the climatic condition (Table 2) of Northeast India. The habitat of the slow loris was considered for developing the species-distribution model. Bioclimatic and terrain layers were downloaded from WorldClim2 database (Fick and Hijmans 2017). A Normalized Difference in Vegetation Index (NDVI) was extracted from Bhuvan-India. Due to the inherent correlation among the variables, which would lead to the poor prediction of species' ecological niche, we ran an autocorrelation check to remove highly correlated variables. To remove the autocorrelated variables, we applied a cross-correlation procedure using SDMtoolbox (Brown 2014) and retained only one variable when the correlation coefficient value > 0.7, on the basis of its ecological significance to the study animal. At the end, we retained seven bioclimatic variables, two topographic variables, and one vegetation variable for predicting the ecological niche

Table 2. Bioclimatic variables used for predicting the potential habitat of Bengal slow loris for north-eastern states of India.

Sl. No.	Eco-geographical variables	Source
1	BIO1 = Annual mean temperature	Worldclim; Fick and Hijmans (2017)
2	BIO2 = Mean diurnal range (Mean of monthly [max temp - min temp])	
3	BIO3 = Isothermality (P2/P7) (* 100)	
4	BIO4 = Temperature seasonality (standard deviation *100)	
5	BIO5 = Max temperature of warmest month	
6	BIO6 = Min temperature of coldest month	
7	BIO7 = Temperature annual range (P5-P6)	
8	BIO8 = Mean Temperature of wettest quarter	
9	BIO9 = Mean Temperature of driest quarter	
10	BIO10 = Mean Temperature of warmest quarter	
11	BIO11 = Mean Temperature of coldest quarter	
12	BIO12 = Annual precipitation	
13	BIO13 = Precipitation of wettest month	
14	BIO14 = Precipitation of driest month	
15	BIO15 = Precipitation seasonality (Coefficient of Variation)	
16	BIO16 = Precipitation of wettest quarter	
17	BIO17 = Precipitation of driest quarter	
18	BIO18 = Precipitation of warmest quarter	
19	BIO19 = Precipitation of coldest quarter	
20	Elevation	SRTM
21	Slope	SRTM
22	NDVI	Bhuvan

of the slow loris. Upon finalizing the bioclimatic variables, all were masked to the Northeast India boundary (including all the seven states). All layers were subsequently converted into ASCII format, as the MAXENT program accepts this format.

We used Maxent v.3.2.1. to predict the distribution of the slow loris (see https://biodiversityinformatics.amnh.org/open_source/maxent/ Phillips *et al*. 2006, 2009; Phillips and Dudík 2008). This algorithm, requiring only occurrence data, is widely popular and has consistently performed well in comparison with other modelling approaches (Elith *et al*. 2006; Hernandez *et al*. 2006) due to its high predictive accuracy and ease of use (Merow *et al*. 2013). In maximum entropy density estimation, the species' true distribution is represented as a probability over the set of sites in the study area. This probability distribution assigns a non-negative value to every site and the sum of the values to one. It produces a model that respects a set of constraints derived from the occurrence data. The constraints are expressed in terms of simple functions of the environmental variables, called features. Specifically, the mean of each feature is required to be close to the empirical average over the presence sites (Phillips and Dudík 2008). It accepts both categorical and continuous environmental variables for model calibration and produces outputs in three different formats for easy interpretation of the results (Kumar *et al*. 2019).

We set the following model parameters: 10^{-5} convergence threshold with 500 iterations, 10000 background points, variable importance by jackknife procedure, response curves, and random seed were enabled. Since we had 64 locations, we set auto feature options. We partitioned our dataset by bootstrapping with 10 replicates and 70% of the data were used for model training and 30% of the data were used for testing the predicted model.

We enabled the logistic format to view the predicted distribution of the slow loris as it projects each grid cell/pixel with a unique predicted value in a continuous number between 0 (low suitability) and 1 (high suitability). This model output format provides an indication for model interpretation, but no clear distinction of suitable sites. Hence, we adopted maximum test sensitivity plus a specificity threshold rule to delineate the predicted distribution into suitable and unsuitable. This approach has been widely used in conservation projects as it produces rather better results for species distribution modelling than other approaches (Liu *et al*. 2013).

The predictive performance of the models was evaluated through the receiver operating characteristic (ROC), represented as the sensitivity values (true positive fraction) against 1-specificity (the false-positive fraction) for threshold values (Fielding and Bell 1997; Merow *et al*. 2013). Area Under the Curve (AUC) of the ROC is considered as a measure of overall model performance and the values usually ranging from 0.5 (random) to 1.0 (perfect discrimination). The AUC values close to 1 indicate a better prediction of the species' distribution. We took the AUC of the receiver operating characteristic (ROC) plot as a measure of model fitness (Fielding and Bell 1997). The average of 20 replicated models produces a forecast of species presence probability, which is a robust procedure to derive consensus predictions of species likelihood of presence (Marmion *et al*. 2009). The average model of 20 replicates, produced by Maxent software, was selected as the final model. The final suitability map was then masked to a different categorical

Table 3. Details of occurrence or detections of Bengal slow lorises in community reserves in Meghalaya.

Community Reserve	Occurrence report by the local people			Survey report			
	No. of people interviewed	Report of people	Presence*	No. of trails (Total distance in km)	Distance walked (km)	No. of lorises	Encouter rate (per km)
Mongalgre	10	No sightings in recent years	CC	1 (0.63)	3.37	0	0
Dumitigre	10	No sightings in recent years	CC	2 (2.10)	5.61	0	0
Selbalgre	Interview was not done			1 (0.59)	2.37	0	0
Thokpara	5	Seen in the CR	P	2 (4.30)	8.20	0	0
Chimanpara	5	Seen in the CR	P	1 (0.55)	1.10	1	1.10
Ronglgre	5	No proper information	CC	1 (1.40)	2.50	0	0
Daribokgre	5	Seen in and around CR	P	2 (3.30)	9.90	0	0
Kitmandamgre	5	Used to be seen, but not recently	P	1 (1.78)	1.78	0	0
Resu Halupara	5	Seen in the CR	P	1 (1.40)	3.45	0	0
Total	50			12 (16.05)	38.28	1	0.03

*CC = Could not confirm the presence in recent years, P = Present

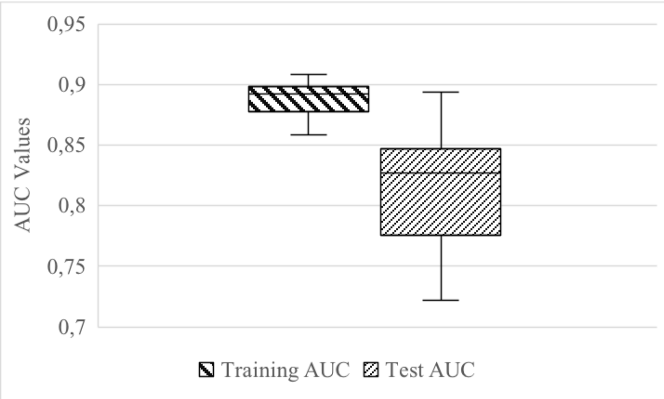

Figure 2. Test and training AUC values of replicated ecological niche models of Bengal slow loris in Northeast India.

variable for interpreting their distribution pattern in Northeast India.

Results

Observations

We interviewed 50 villagers in eight of the community reserves. Interviewees indicated the presence of slow lorises in four community reserves: Chimanpara, Thokpara, Daribokgre, and Resu Halupara. No recent sightings were reported in Mongalgre, Dumitigre, and Kitmandamgre. At Ronglgre, we were unable to conclude their presence or otherwise. No interviews were carried out at the Selbalgre community reserve (Table 3).

Of the nine community reserves we surveyed, we saw just one slow loris in Chimanpara Community Reserve near a stream. The encounter rate of slow loris as such was 0.03 lorises/km walked (Table 3). The loris was seen at 18:34 h, on a tree up 8 m, at 25.25725 N and 90.13514 E.

Ten of the villagers interviewed told us that they believed that slow lorises bring misfortune or even death if they encounter one. Slow lorises are often killed due to this misconception.

Modelling of potential habitat

The AUC value ranged from 0.8585 to 0.9081 for training (average = 0.8895) and 0.7217 to 0.8941 for testing (average = 0.8181) model and values were higher than random (0.5). The variation in AUC values between the replicated models was much higher in the testing data than the training data (Fig. 2). Among the seven variables considered for model building, slope contributed the maximum to the percent of contribution and permuted contribution in most of the replicates (Figs. 3a and 3b), followed by precipitation of warmest quarter (Bio18), precipitation of driest quarter (Bio17) and temperature annual range (Bio7). The environmental variable with the highest gain, when used in isolation, was elevation and it contained more useful information than other variables. Similarly, the environmental variable that decreases the gain the most when omitted was slope and it contained more information that was not present in the other variables. It is clear that the terrain characteristics, rainfall, and temperature determined the distribution of nocturnal slow lorises in Northeast India. The predicted ecological niche of the slow loris for all of Northeast India is shown in Figure 4.

Climatic conditions of suitable and unsuitable sites of four environmental variables (elevation, slope, precipitation of warmest quarter and precipitation of driest quarter) were plotted to evaluate the slow loris' ecological niche (Figure 5). Across the elevation range, suitable sites were between 10 to 2,192 m elevation, while it was 704 to 2841 mm in precipitation of the warmest quarter. The maximum test sensitivity plus specificity threshold (0.3681) was applied to delineate the suitable and unsuitable sites. The cell values above 0.3681 were categorized as suitable cells (Table 4, Fig. 4), which is nearly 63,640 km² in the focal area, and

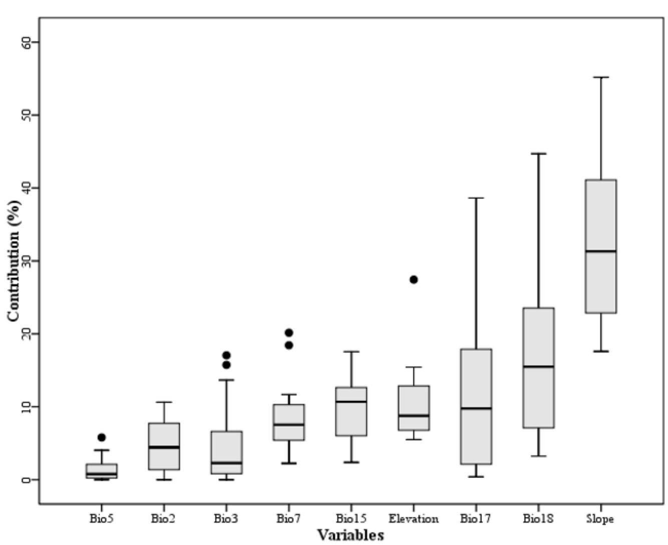

Figure 3a. The contribution of bioclimatic variables for the prediction of potential habitat of Bengal slow loris in Northeast India.

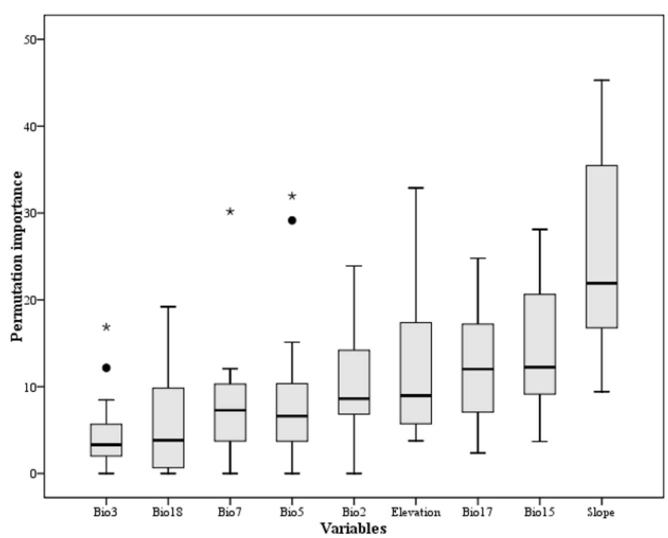

Figure 3b. The permutation importance of bioclimatic variables for the prediction of potential habitat of Bengal slow loris in Northeast India.

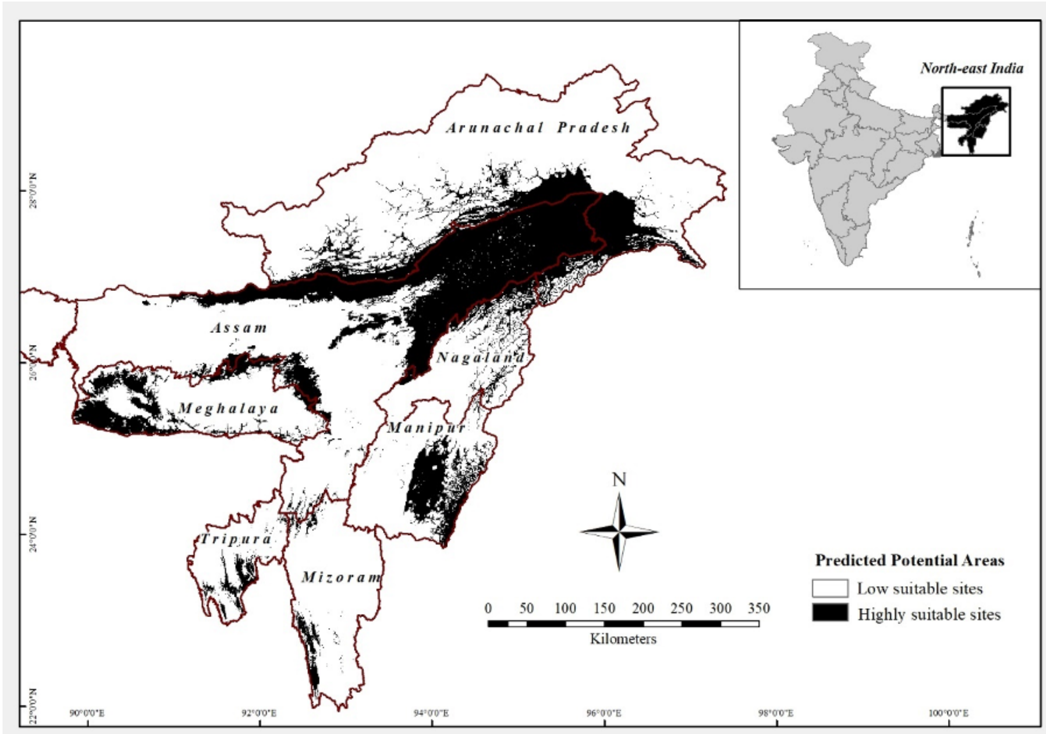

Figure 4. The predicted potential habitat of Bengal slow loris for the entire Northeast India.

the values less than this were categorized as unsuitable cells (191,440 km²). Nearly 25% of Northeast India is found to have suitable habitat for the slow loris, ignoring the current trend of deforestation and hunting. Although the suitable areas were predicted over the entire Northeast Indian states, more suitable sites were found in Assam, which accounted for 39% of total potential areas. Arunachal Pradesh, Meghalaya, Manipur, and Nagaland supported reasonably good potential areas (Table 5). The estimated total suitable habitat within the protected area network was 4,256 km² (6.68%). Nearly 23% of the area of the total protected area has the predicted potential habitat of the slow loris.

Discussion

The review of occurrence reports and population assessments of slow loris revealed that they occur in all the states of Northeast India. The reports are confined, however, to few forest patches and many of the reports are for rescued individuals (Supplementary materials, Tables 1 and 2; Srivastava 1999, 2006). The modelled potential distribution also indicated the persistence of suitable habitat in all the seven states, and provides the first-ever range of environmental limits of its niche. A large proportion of the potential sites, however, are predicted over Assam State. The predicted distribution orients exploration of potential sites across the Northeast, and may shed more light on the distribution and habitat use pattern of this cryptic and elusive primate. The terrain, temperature and rainfall pattern of the modelled area, determines the potential distribution of slow loris. Most of the potential sites are predicted over the eastern flood plains of Brahmaputra and eastern plains of Assam and Arunachal Pradesh, and the model indicates that the species could be distributed in low elevation (less than 2000 m asl) deciduous and secondary forest. Further, the predicted potential distribution occupies a unique position in precipitation in the warmest (pixel range= 210 to 6124 mm; use range = 704 to 2841 mm) and driest quarters (pixel range= 8 to 99 mm; use range = 20 to 99 mm) compared to the available range in those variables.

Slow lorises largely feed on plant exudates and nectar (Swapna *et al*. 2010; Das *et al*. 2014). The exudates are usually patchily distributed but are highly preferred foods (Swapna *et al*. 2010). The confined potential distribution of

Table 4. The predicted area of potential habitat of Bengal slow loris in Northeast India.

Predicted probability	Predicted area (km²)
0.1	84742
0.2	44827
0.3	39738
0.4	32483
0.5	28442
0.6	15299
0.7	7345
0.8	2169
0.9	36
1.0	1

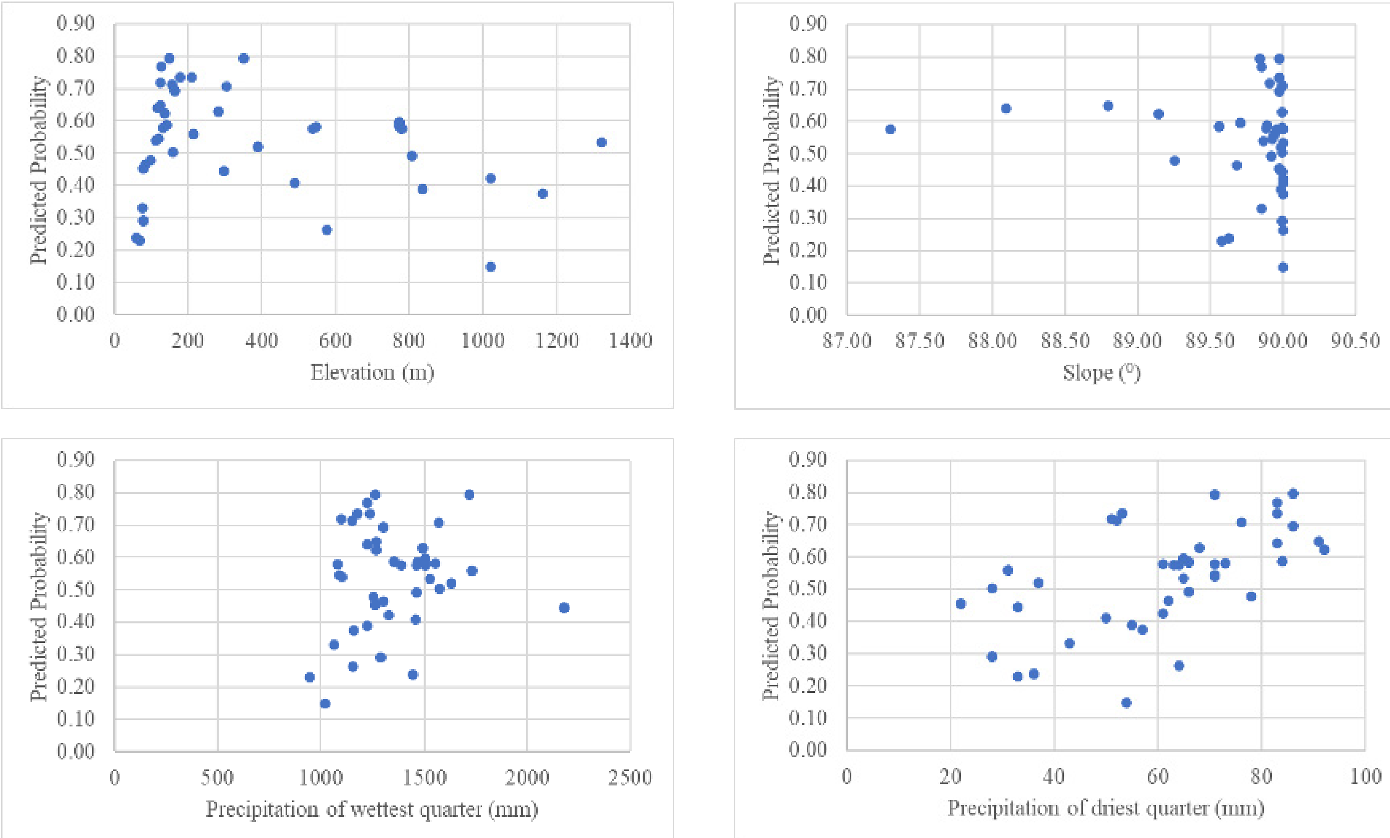

Figure 5. Predicted probability values of Bengal slow loris in response to environmental variables (elevation, slope, precipitation of wettest quarter, and precipitation driest quarter) in Northeast India.

slow loris to low elevation forests compared to alpine forests may be due to the availability of these foods, which may be seasonal, as the alpine forests experience very low temperature and are also seasonally covered with snow. Their dependency on the exudates and nectar of specific plants makes the animals range over large areas in search of these food resources, thus the home range size is relatively larger in disturbed forests than in primary forests (for example, 8.9 ha for *N. coucang* in Malaysia: Wiens 2002). Most of the forests in Northeast India have been degraded due to exploitation for timber, encroachment for developmental activities, conversion of forests for agriculture, and the practice of *jhum* cultivation (FSI 1998; Reddy *et al*. 2017). Although some of these states have a high percentage of forest cover, much can be secondary and degraded (FSI 1998). Further, hunting is prevalent in Northeast India which has depleted most of the wildlife (Mishra *et al*. 2006; Aiyadurai *et al*. 2010) including slow lorises (Radhakrishna *et al*. 2006). The highest abundance of slow loris reported in India was only 0.33 in Lumding Reserve Forest of Assam (Radhakrishna *et al*. 2006). The few survey attempts for slow lorises in India are confined to Arunachal Pradesh, Assam, Meghalaya, and Tripura. The summarised information indicates that their relative abundance is highest (0.21 lorises/km) in Arunachal Pradesh, followed by Tripura (0.16 lorises/km), Assam (0.07 lorises/km) and Meghalaya (0.02 lorises/km) (Table S1). The overall abundance of loris for Northeast India is estimated at 0.08 lorises/km, which is considerably lower than has been reported for two species of *Nycticebus* in many Southeast Asian countries, for example, 0.38–0.50 in Phnom Samkas Wildlife Sanctuary in Cambodia (Coudrat *et al*. 2011), 0.50 in Phnom Kulen National Park in Cambodia (Starr *et al*. 2010), 0.34–1.02 in Khao Ang Rue Nai Wildlife Sanctuary in Thailand (Pliosungnoen *et al*. 2010), 0.40–0.87 in Xe Namnoy in southern Lao PDR (Evans *et al*. 2000), and 0.30–0.65 in Phou Xang He in central Lao PDR (Duckworth 1994).

In India, the records of rescued lorises (66 lorises) total more than the detections during the surveys (Table S2). As the rescue reports reveal, 51 of the 66 rescued lorises were

Table 5. The predicted area of potential habitat of Bengal slow loris in northeastern states of India.

State	Potential areas (km²)	Percent of potential areas within the state
Arunachal Pradesh	15,123	18.06
Assam	30,554	38.95
Manipur	5,737	25.70
Meghalaya	6,337	28.25
Mizoram	1,331	6.31
Nagaland	3,274	19.76
Tripura	1,284	12.24

when they strayed into houses or were taken from fallen trees or found injured on the road. Eleven of them were kept in captivity for medicinal purpose or as pets, and three were being sold on the roadside. This does not indicate, however, the intensity of poaching. Radhakrishna *et al*. (2006) reported that poaching may be one of the reasons for its depletion in the wild.

Most of the community reserves in Meghalaya are of just a few hectares, isolated between cultivated areas, and had previously undergone *jhum* cultivation. The habitat is as such secondary and degraded. This may be the reason for their low abundance in community reserves in Meghalaya as reported in our survey, and the same is true for all of Northeast India (Radhakrishna *et al*. 2006). Considering the nascent nature of the socio-political system of the local people, educating them is the last resort to conserve slow lorises in Northeast India.

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Supplementary materials

Table SI. A review of abundance of slow loris across its range in Northeast India as reported by different studies including our present study

Table S2. Details of the reported rescue conducted for slow lorises in different parts of the Northeast India between 1996 to 2019.

URL: http://www.primate-sg.org/storage/pdf/PC35_Suppl_Mat_Kumara_Nycticebus_India_2021.pdf

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