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Distribution of the threatened Assamese Macaque *Macaca assamensis* (Mammalia: Primates: Cercopithecidae) population in Nepal

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Abstract: Sustainable conservation and management of a species require detailed knowledge of its population status and distribution pattern. The population of the Assamese Macaque *Macaca assamensis* in Nepal, probably a new subspecies endemic to the country, is yet to be studied for documenting its spatial distribution and size. We did extensive surveys across three major river systems of Nepal (Koshi, Gandaki, and Karnali river systems) by modified line transect method covering almost the entire distribution range of the species within the Nepal territory. We counted a total of 829 individuals in 43 groups that accounted for the average group size of 19.29 (±10.40) individuals. The elevation distribution of the species ranged between 130m and 2650m. Further, we assessed the potential distribution areas of the species by ecological niche modeling employing maximum entropy algorithm. The census and ecological niche modeling congruently revealed the mid-hills of eastern and central Nepal outside the protected areas as the major habitats of this nationally endangered and protected primate. Conservation attempts, therefore, should focus on this area.

Keywords: Ecological niche modeling, MaxEnt, primates, spatial distribution.

INTRODUCTION

An accurate assessment of population densities in natural habitats is the prerequisite for the determination of priorities for the sustainable conservation and management of a species (Defler & Pintor 1985; Kumara & Radhakrishna 2013). Primate census is useful in the conservation of a species as it provides multiple benefits such as i) population density or total counts that can be the baseline information for future monitoring, ii) evaluation of population changes since a previous census period, if any, iii) an assessment of population tendency with support of frequent censuses, and iv) an evaluation of different habitats for their relative importance in primate conservation. Such assessments can help conservation managers judge the success of the ongoing management activities and decide when, where, and how to mediate for the management of a species (Plumptre & Cox 2006).

Multiple direct and indirect methods are available to understand and monitor species presence and abundance. These include the total count of individuals, strip transects, line transects, capture-mark-recapture methods, and observations of signs like feces, nests, and tracks (Kumara & Radhakrishna 2013). The results from different methods vary and using different census techniques together add unknown errors. Hence, it is necessary to develop uniform methods that can be replicated over time and space to monitor the primate populations for their conservation (Plumptre & Cox 2006). Census by total count is the most reliable method since it is highly informative and accurate if the assumption that all individuals present in the group are counted once and no individual is double-counted is not violated (Kuhl et al. 2008).

Determining the spatial distribution of a species is a multifaceted task (Boubli & de Lima 2009). Species distribution modeling (SDM), also known as ecological niche modeling (ENM), can be coupled with the systematic survey of species presence to identify the potential distribution range of the species (Ortega-Huerta & Peterson 2008) relating the field observations to environment layers of predictor variables (Guisan & Thuiller 2005). SDMs establish relationships of known species occurrences with potential environment covariates and then predict the spatial and temporal distribution of the species. Among the SDM techniques available at present, maximum entropy method or MaxEnt (Phillips et al. 2004) is designed to depict the distribution of individual species using presence-only data (Phillips et al. 2006). It outperforms other existing predictive methods (Elith et al. 2006) and shows exponential growth in its application since its introduction in 2004 (Morales et al. 2017). The tool was used in many taxa including primates for multiple purposes including mapping potential distribution and habitat use (Boubli & de Lima 2009; Norris et al. 2011; Vidal-Garcia & Serio-Silva 2011; Voskamp et al. 2014; Sarma et al. 2015; Sarania et al. 2016), delineating ecological boundaries of multiple taxa (Nag et al. 2014), assessing threats and setting conservation priorities (Thorn et al. 2009; Campos & Jack 2013), paleodistribution reconstruction and phylogeography (Khanal et al. 2018a,b), and range shifts (Elith et al. 2010).

The Assamese Macaque *Macaca assamensis* McClelland, 1840 is one of the members of polytypic *Sinica*-group of macaques that is characterized by the sagittate-shaped glans penis and that has a fragmented distribution in southern and southeastern Asia. Assamese Macaques are medium-sized, arboreal, diurnal, and omnivorous cercopithecine primates that live in multimale-multifemale social groups (Chalise 1999; Molur et al. 2003). It has two known subspecies, Eastern Assamese Macaque *M. a. assamensis* and Western Assamese Macaque *M. a. pelops*, the distribution ranges of which are demarcated by the Brahmaputra River (Roos et al. 2014). The Assamese Macaque population in Nepal differs in pelage and facial color, relative tail length, and elevation distribution range to their nearest conspecific populations (*M. a. pelops*) from the adjacent countries such as India and Bhutan. Thus, the Nepalese population of Assamese Macaque was doubted for a distinct subspecies status and referred to as '*M. assamensis* Nepal population' (Molur et al. 2003; Chalise 2005, 2013; Boonratana et al. 2008).

The Assamese Macaque is categorized as Near Threatened by the IUCN (Boonratana et al. 2008) and its Nepalese population, one of the least studied primates, is nationally listed as Endangered due to its restricted distribution, population threats, and small numbers in fragmented patches of the remaining habitat. Thus, the species is protected by the National Park and Wildlife Protection Act 1973 of Nepal (Boonratana et al. 2008; Chalise 2013; Chalise et al. 2013). It was reported from the mid-hills within Nepal as a sub-tropical habitat specialist, but the details on its socioecology are yet to be documented (Khanal et al. 2018a).

The distribution and conservation status of the Assamese Macaque in Nepal is not well documented. Wada (2005) surveyed the distribution of Assamese Macaque in Nepal and reported it from only the east of

Kaligandaki River. The studies so far in Nepal (Chalise 1999, 2008, 2013; Chalise et al. 2005; Wada 2005) were confined to surveying the fragmented populations of Assamese Macaque at different patches, lacking a systematic study that covers the entire range of the species. Although it is listed as an endangered species and is protected nationally, the species was described as a crop-raider in some parts of Nepal (Chalise 2010; Paudel 2017; Adhikari et al. 2018). Most of the habitats of the species fall outside the protected areas in mid-hills and no detailed documentation of population and distribution was done so far. Therefore, it is crucial to identify the population status, distribution pattern, and conservation status of Assamese Macaque in Nepal.

We aimed to explore the population status, distribution pattern, and the potentially suitable habitats of the Assamese Macaque in Nepal. We did an extensive survey along the tributaries of the three major river systems of Nepal from September 2015 to October 2016 covering almost the entire distribution of the species and performed a population census. We used the census points of the species and bioclimatic variables to determine their potential distribution areas. Here, for the first time, we describe that the westernmost distribution limit of the Assamese Macaque, as described in previous publications (Fooden 1979, 1982; Wada 2005; Timmins & Duckworth 2013), is not the Kaligandaki River of central Nepal. We recorded three groups from far western Nepal and censused them.

MATERIALS AND METHODS

Study Area

Nepal stands on 26.350–30.450^{0}N & 80.067–88.200^{0}E (Sharma 1999). It extends about 800km along the east-west Himalayan axis and its width varies between 150km and 250km, covering a total area of 1,47,181km^2. The Nepal Himalaya forms the central one-third of the entire Himalayan range and includes multiple bioclimate zones. It has geographic diversity ranging from 60m elevation in the tropical Tarai beyond the perpetual snow line to over 7,000m including Earth's highest 8,848m (Mount Everest) (Khanal et al. 2018a). Wide altitude variations and diverse climate conditions resulted in five main physiographic zones within Nepal (Table 1) (Carson et al. 1986) and such extreme altitude gradients created nine bio-climatic zones ranging from tropical to nival (Fig. 1A) (HMGN/MFSC, 2002).

Table 1. Five major physiographic zones of Nepal (Source: Carson et al. 1986).

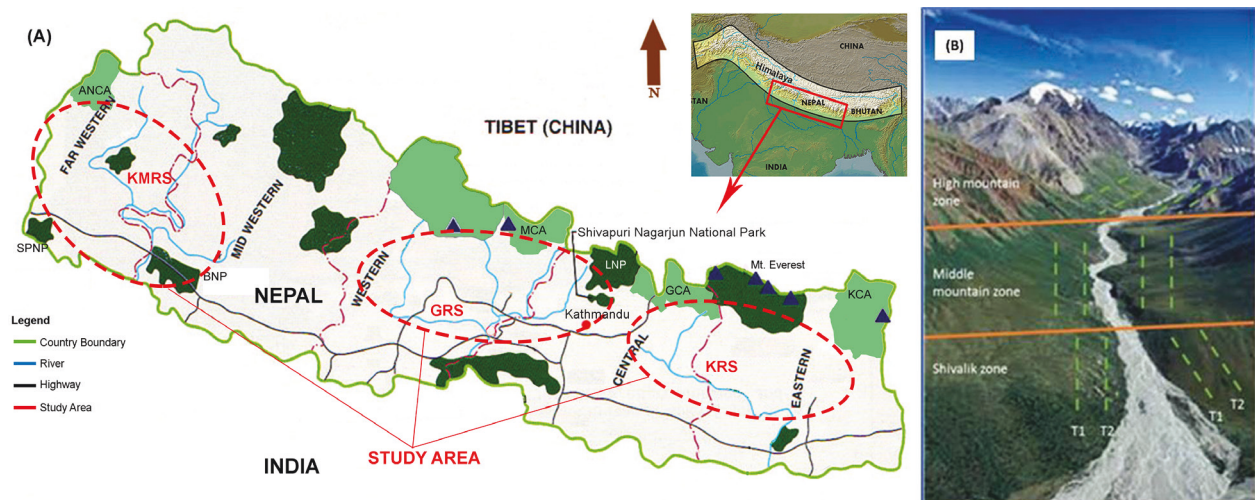| Physiographic Zone	Area (%)	Elevation (m)	Climate
High Himalaya	23	above 5,000	Tundra-type, Arctic, and Trans-Himalayan
High mountains	20	4,000–5,000 3,000–4,000	Alpine Sub-alpine
Mid-hills	30	2,000–3,000 1,000–2,000	Cool temperate monsoon Warm temperate monsoon
Siwalik Hills	13	300–1,000	Hot monsoon and subtropical
Tarai	14	< 300	Hot monsoon and tropical

Figure 1. Study area and survey design. A - The three major river systems and survey area in Nepal, B - Transect layout on both the sides of the river axis (not in scale).

Assamese Macaques were reported in Nepal from 300m to 2,350m (Chalise 2013) that includes the Siwalik Hills, lower mid-hills, and upper mid-hills. Surveys were conducted in three physiographic zones (Tarai, mid-hills, and lower Himalaya) across the three major river systems — Nepal-Koshi River system in eastern Nepal, Gandaki River system in central Nepal, and Karnali-Mahakali River system in western Nepal (Fig. 1A).

It included mid-hills and the lower-Himalaya region of eight protected areas of Nepal and non-protected Assam Macaque habitats in the mid-hills. The Tarai and Siwalik zone below 1,000m has tropical forests that can be categorized as *Shorea robusta* forest, *Acacia catechu-Dalbergia sissoo* forest, other riverine forest, and *Terminalia-Anogeissus* deciduous hill forest. The mid-hills bear sub-tropical forest up to 1,700m dominated by *Pinus roxburghii*, *Schima-castanopsis*, and *Alnus nepalensis* and riverine forest with *Toona* and *Albizia* species. The areas from 1,700m to 2,700m bear lower temperate forest dominated by *Quercus leucotricophora*, *Q. lanata*, *Q. floribunda*, *Q. lamellose*, abundant lauraceae, and *Pinus wallichiiana* (Jackson 1994). The lesser Himalaya has temperate forests dominated by the *Quercus*-pine-rhododendron combination (Chalise et al. 2005; Khanal et al. 2018b).

Field Survey Design

The standard method for counting predominantly arboreal monkeys is along the line-transects (Marshall et al. 2008). Spatial distributions of study species in the four physiographic zones across the river systems were surveyed by a modified line-transect method (Buckland et al. 2010). Two line-transects, each of 5km length, were used on either side of the rivers and their tributaries in each physiographic zone (Fig. 1B; 2).

The line-transects were roughly parallel to the river axis. The first transect was within 1km and the second transect was within 4–5 km perpendicular distance from the river center. The Tamor, Arun, and Sunkoshi rivers of Koshi River system, Trishuli-Budhigandaki, Marshyangdi, and Kaligandaki of Gandaki River system, and Bheri, Karnali, and Chamelia rivers of Karnali-Mahakali River system were surveyed. A total of 48 line-transects were surveyed in each river system. In addition to the river systems, surveys were also done in Shivapuri Nagarjun National Park that lies in the mid-hills between Koshi River system and Gandaki River System.

Population Survey

We conducted our field survey between September 2015 and October 2016. Wherever the groups were
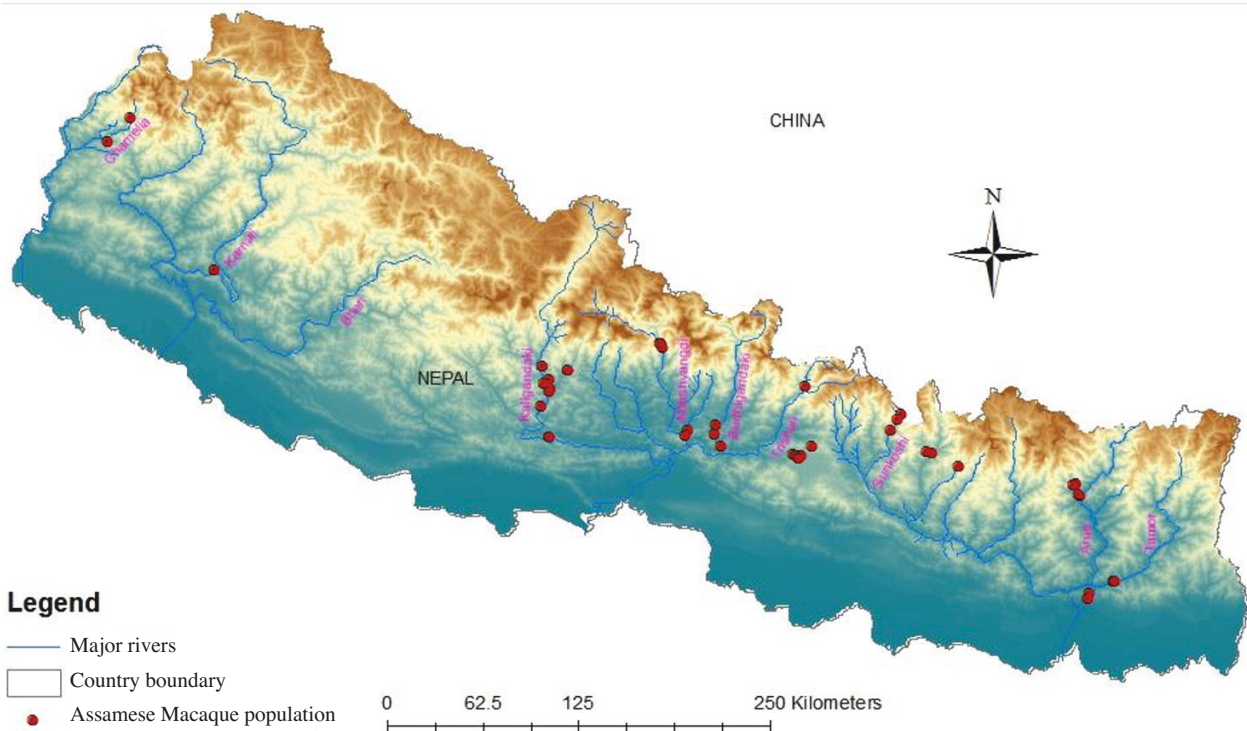

Figure 2. Survey area and Assamese Macaque census points in Nepal.

observed, detailed population censuses were conducted. A closely bonded social assemblage of monkeys sharing resources, at least 200m apart from the nearest assembly, was considered a group (Chalise 2005; Lehmann & Dunbar 2009). The geographic location of the group was noted using GPS and vegetation samplings were done using 20m × 20m quadrates. Distances of group occurrence from the nearest river, human settlement, and crop fields and other relevant measurements were noted. The group size and population composition were observed in detail from a distance varying from about 10m to 100m aided with binoculars whenever necessary. The individuals were divided into four age groups, namely, adults (male and female), sub-adults, juveniles, and infants, following the method of Chalise (2003). The counting was repeated until the concurrent readings were obtained for total count and age groups. On encountering the signs confirmed for Assamese Macaque, even if the group was not observed, the GPS locations were noted and the vegetation survey was done.

Data Analysis
Estimation of Population Parameters

Male to female sex ratios were calculated among the adult and sub-adult age groups separately as the number of males out of 100 females. Infant to female ratio was calculated by dividing the total number of infants by the total number of adult females in the group. The average group size was computed as the mean of the number of individuals among the observed groups.

$$\text{Average group} = \frac{\text{Total number of individuals observed}}{\text{Total number of groups observed}}$$

$$\text{Sex ratio (male: female)} = \frac{\text{Number of males of that age group}}{\text{Number of females of same age group}}$$

$$\text{Infant female ratio} = \frac{\text{Total number of infants}}{\text{Total number of females in reproductive age groups}}$$

The number of individuals varied among the different groups and the group size data was tested for normal distribution by Shapiro-Wilk test. It revealed that the data were not normally distributed (W=0.941, P=0.029), hence, they were normalized first and then the significant difference in group size among the three river systems was tested statistically by One-way ANOVA using Graphpad Prism v.5.01 (Motulsky 1999).

Distribution pattern

The number of groups and individuals observed were categorized based on their presence at different river systems and elevation zones. The statistical significance of the differences in their distribution pattern was tested by one-way ANOVA.

Population distribution in protected and non-protected areas

To assess the conservation status of the Assamese Macaque, the total population observed was subdivided to two groups — population inside protected areas (national parks and buffer zones, conservation areas, wildlife reserves, and hunting reserves) and population outside protected areas. The significant difference in the group size between the two populations was tested by t-test.

Ecological niche modeling

The 19 bioclimatic variables (version 1.4) (Table 2) in a 30 arc second spatial resolution representing the present bioclimatic conditions were retrieved from the WorldClim global climate database portal (WorldClim 2018). For the ecological niche modeling (ENM) of the Assamese Macaque, the geographic coordinates of the 43 groups collected using GPS during the field surveys were used. The Nepalese population of Assamese Macaques are considered endemic to Nepal. Therefore, for modeling their distribution, all bioclimatic variables were clipped to the boundary of Nepal using ArcGIS 10.3.1 and exported in ASCII format. Seven bioclimatic variables (Bio: 1, 3, 5, 11, 12, 15, 18) were selected for the ENM after removing highly correlated (r ≥ |0.8|) variables on the Pearson correlation test (P <0.05).

MaxEnt v.3.4.1 (Phillips et al. 2006) was used to model and map the current potential distribution of *M. assamensis*. For model evaluation purposes, the species presence data were randomly divided into 75% as the training dataset and 25% as the validation dataset. To account for uncertainty introduced by training and validation set splits, 25 replicated models based on the cross-validation method were generated (Otto-Bliesner et al. 2006). The accuracy of the models was evaluated by using the area under the curve (AUC) of the receiving operating curve (ROC).

The logistic output of habitat suitability was converted to the binary output of unsuitable and suitable habitats using the threshold of maximum training specificity and sensitivity (maxTSS=0.348) as explained for the model generated by presence-only data by Liu et al. (2013). Then, the potential altitude range of suitable

Table 2. Bioclimatic variables used in the construction of ENM for Assamese Macaque

	Abbreviation	Description
1*	**Bio1**	**Annual mean temperature**
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

* - Bioclimatic variables used in the model development

habitats was evaluated by overlaying the binary output on the SRTM DEM (Jarvis et al. 2008). The elevations of the suitable habitat pixels were extracted and their mean, maximum, and minimum were computed.

RESULTS

Total population and river system-wise distribution of Assamese Macaque in Nepal

A total of 829 individuals of Assamese Macaques from 43 groups were observed during the field survey. The highest number of groups and individuals were observed from Gandaki River system (21 groups and 377 individuals) in central Nepal, followed by the Koshi River system (13 groups and 287 individuals), Shivapuri Nagarjun National Park (six groups, 104 individuals), and Karnali-Mahakali River system (three groups and 61 individuals) (Figs. 2 & 3). The overall average group size was calculated to be 19.29 (±10.40). The groups varied in their sizes and ranged between three to 39 individuals per group; however, variations were not significant among the four study areas (One-way ANOVA, F=0.448;

df=(3, 39); P=0.692). The highest average group size was computed from Koshi River system (22.07±11.73 individuals per group) and the lowest from Shivapuri Nagarjun National Park (17.33±10.13 individuals per group).

Age-sex composition

The overall adult to young ratio was computed to be 1:1.037, i.e., close to 1:1 ratio. The adult male to female sex ratio was found to be 1:1.91 and the infants to adult female ratio was 0.592:1. The adult to young ratio and adult male to female sex ratio did not vary among the groups of different river systems [One-way ANOVA; adult sex ratio: F=1.050, df= (3,39), P= 0.381; adult to young ratio: F= 1.554, df= (3,39), P= 0.216].

Elevation-wise distribution

The Assamese Macaque groups were recorded across in the elevation range from 130m at Chatara in eastern Nepal to 2,650m at Langtang National Park in central Nepal. More than one-third of the groups (34.88%) were recorded from the elevation ranges between 1,001m and 1,500m while the highest number of individuals were observed from elevations less than 500m. Population distribution did not vary at different elevation zones of the four study areas (Fig. 4) (F=2.199; df=(3, 16); P=0.127).

The average group size was the highest (22.88 individuals per group) for the elevation range of 501–1000 m and the least (15 individuals per group) for the elevation range of 1501–2000 m (Table 3). There, however, was no significant difference in the group size at various elevation ranges (F=0.758; df=(4, 38); P=0.558).

Population distribution in protected and non-protected areas

Out of the total 829 individuals counted from 43 groups of Nepal territory (Fig. 3), 22 groups accounting for 407 individuals were observed from protected areas (PAs, national park or conservation area), whereas 422 individuals from 21 groups were observed outside the protected areas. It accounted the average group size of 18.5 ±10.24 and 20.1 ±10.77 individuals per group for inside and outside the PAs, respectively; however, there was no significant difference in group size between the populations inside and outside the protected areas (t= 0.497, df=41, P= 0.621).

Ecological Niche of the Assamese Macaque

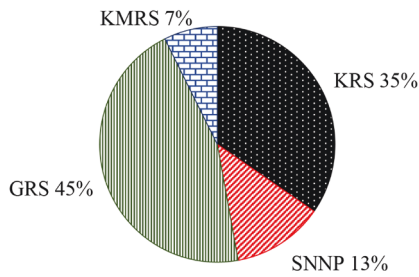The MaxEnt model generated for the Assamese

Figure 3. Percentage of Assamese Macaque population in three major river systems and Shivapuri Nagarjun National Park in Nepal.
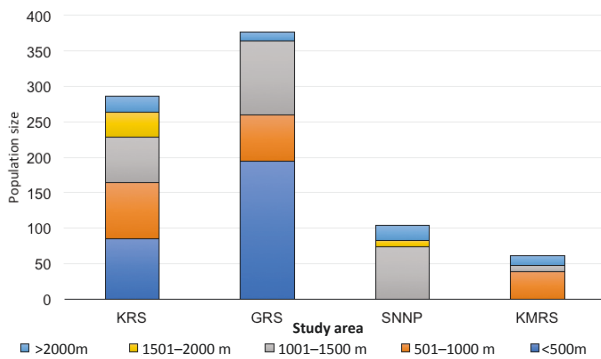

Figure 4. Elevation-wise distribution of Assamese Macaque population in different sampling localities (KRS - Koshi River system, GRS - Gandaki River system, SNNP - Shivapuri Nagarjun National Park, KMRS - Karnali-Mahakali River system) of the Nepal Himalaya.

Macaque performed well with a mean AUC value of 0.899 ± 0.064 (Fig. 5B) for 25-fold cross validation indicating the robustness in prediction of distribution of suitable habitat (Fig. 6). The prediction of habitat suitability completely matched with the prevailing distribution records of the Assamese Macaque within Nepal territory. Among the eight predictive bioclimatic variables, precipitation of warmest quarter of the year (bio18, 67.7%) contributed the highest to the model, followed by the isothermality (bio3, 21.2%) and annual mean temperature (bio1, 4.2%).

The Jackknife test of MaxEnt model (Fig. 5A) on variable importance showed that bio18 (precipitation of warmest quarter) has the highest gain when it is used in isolation. It validated that bio18 has the maximum useful information among the variables and contributed most to the model development. Further, omission of bio18 decreased the gain of model indicating that it holds the most information for Assamese Macaque suitable habitat determination among the variables used for the model development. According to the response curve plots, the precipitation of warmest quarter above 1200mm and isothermality around 50 were ideal to define the suitable habitat for Assamese Macaque (Fig. 5C). Such conditions are fulfilled by the mid-hills of central Nepal supporting the broad-leaved vegetations.
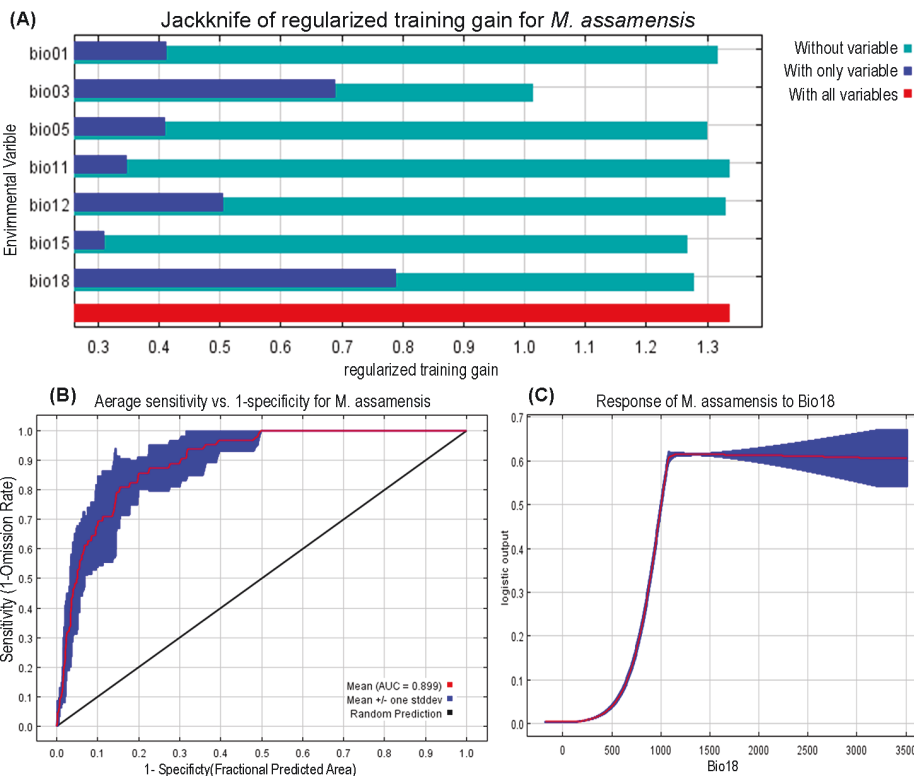

Figure 5. Ecological niche modeling for Assamese macaque by MaxEnt. (A) The variable importance by Jackknife test. (B) The average area under curve (AUC) for 25 replicates of MaxEnt run. The red line represents average value and the blue bar represents ±1 standard deviation. (C) Response curve plot for the variable that has the highest contribution to the model.
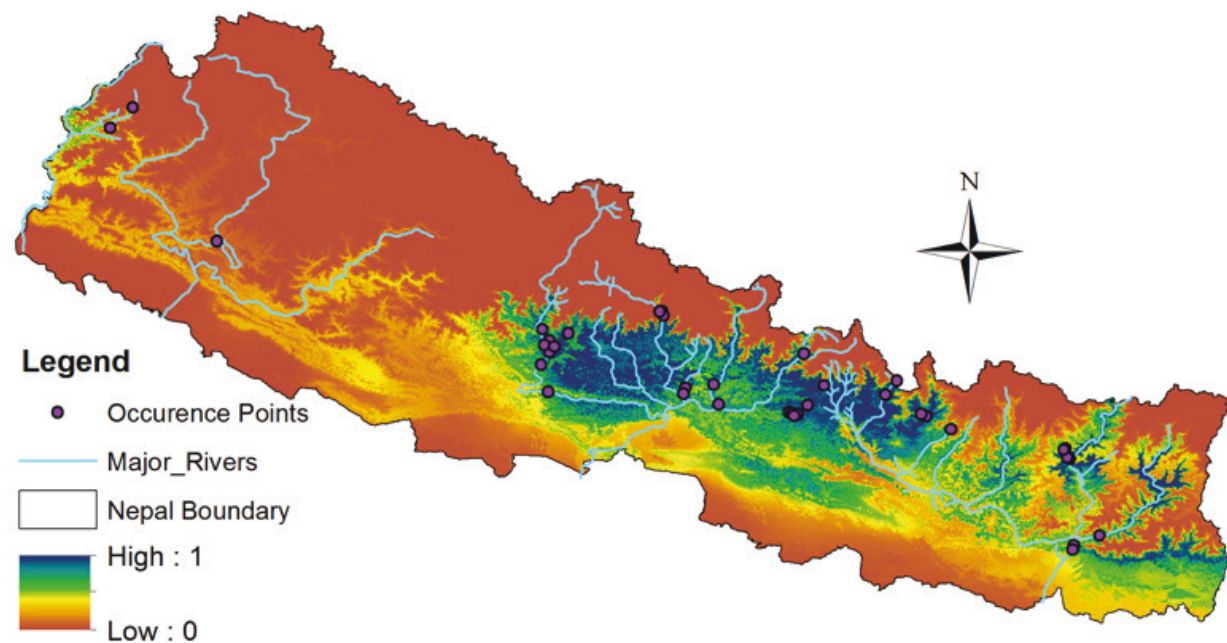
Figure 6. Ecological niche model showing potential distribution of Assamese Macaque in Nepal.

Table 3. Average group size of Assamese Macaque population at different elevation gradients.

	Elevation range	No. of groups	Total population	Average group size (SD)
1	< 500m	13	280	21.54 (±10.62)
2	501–1000 m	8	183	22.88 (±13.57)
3	1001–1500 m	15	250	16.66 (±9.87)
4	1501–2000 m	3	45	15 (±7.99)
5	> 2000m	4	71	17.75 (±4.99)

The MaxEnt model predicted potential habitat of Assamese Macaque within the elevation range between 85m and 2,987m. The mean height of the potential habitat was found to be 1532m, however, maximum number of suitable habitat pixels (55.03%) were predicted from the elevation range between 500m and 1,500m. Currently, 23.49% area of Nepal territory is potential habitat of the Assamese Macaque.

DISCUSSION

Assamese Macaques are the least researched primates in Nepal Himalaya. They are distributed in subtropical and temperate zones (Chalise 2013). Because of the limited and unsystematic studies, population status and distribution patterns of this species is poorly documented. For the successful conservation and management of such primates it is crucial to have basic data on their demographic status and spatial extents of distribution.

Assamese Macaques are sporadically distributed across the fragmented forest patches in Nepal. Wada (2005) recorded a total of 10 groups of Assamese Macaques distributed only east of the Kaligandaki Valley in central Nepal, within the elevation range of 200–1,800 m. In the most recent study, Chalise (2013) recorded a total of 1099 individuals in 51 groups from 380m to 2350m. Both of those studies failed to cover the spatial and temporal facets of demographic research, as the work of Wada (2005) was confined only along six rivers and that of Chalise (2013) was the accumulation of observations at different time periods during last two decades. This study considered both the spatial and temporal aspects and did systematic survey across the entire distribution range of the species within a calendar year. It recorded a total of 829 individuals of Assamese Macaque from 43 groups.

Current average group size of Assamese Macaque (19.29 individuals per group) was consistent with that of Wada (2005), i.e., 19.1; however, it differed with that of Chalise (2013), 21.55 individuals per group, that might be accounted to the temporal variations in their observation as the observations were made at different periods within last two decades. The organisms are restricted to specific altitudinal ranges as a consequence of microclimatic limitations imposed by ambient

temperature and humidity on species metabolisms and on their phenological preferences (Sekercioglu et al. 2008). Wada (2005) reported larger average group size of Assamese Macaques on lower elevations than that of mid-hills. In the present study, the population size of Assamese Macaque differed significantly at different elevation ranges, however, no such significant variations on average group size were recorded along the elevation gradients. Wada (2005) reported the distribution range of the species in between 200m and 1,800m, whereas Chalise (2013) explained that of 380m and 2,350m. The present elevation range of distribution (130–2,650 m) also differed with those studies, it was consistently wider both on lower and upper limits. It shows that the species is experiencing the elevational range expansion, especially towards the higher elevation.

This study observed the highest number of groups and individuals from Gandaki River system (21 groups and 377 individuals) in central Nepal followed by the Koshi River system (13 groups and 287 individuals). It revealed the central Nepal to be the glacial refugia for Assamese Macaques which had eastward range expansion after LGM as revealed by the molecular data and ecological niche modeling (Khanal et al. 2018a). Eastern and central Nepal receives higher amount of precipitation from summer monsoon than the western Nepal (Owen et al. 2005), such higher precipitation might facilitate the grow of broadleaf forest in mid-hills which is the most preferred habitat of the species. Additionally, Assamese Macaques entered the Nepal Himalaya from south-east Asian ancestral stock via northeastern India (Khanal et al. 2018a) that may be the principal reason of the higher density of the species in eastern and central Nepal.

The ecological niche modeling results were consistent with the observed distribution pattern of the Assamese Macaque in Nepal Himalaya. It predicted suitable habitats on Siwaliks, mid-hills and lower Himalaya of eastern and central Nepal including the areas of Koshi River and Gandaki River systems, in majority. Using the DNA sequences analyses and niche modeling, Khanal et al. (2018a) reported potential glacial refugia at central Nepal and the expansion of population as well as the species range after the last glacial maximum. Many studies (Wada 2005; Chalise 2013) including the most recent one by Regmi et al. (2018) employing field surveys and ENM reported the westernmost limit of the Assamese Macaque to be the Kaligandaki River at central Nepal, however, during this study some groups of the species were observed from far western Nepal too. The occurrence points employed in the model development are evenly scattered avoiding the sampling bias, and the distributional model developed incorporated all the observed points depicting the robustness of the prediction. The observed elevational range of Assamese Macaque fell within that of the predicted habitat.

A very high percent (~79%) of Asian primate species are threatened with the global extinction (Schipper et al. 2008). Such a high level of threat echoes extreme hunting pressure and habitat depletion impacts (Primack 2006). It may be especially alarming for those species which have small populations and limited geographic ranges (Rovero et al. 2015). Assamese Macaques are considered nationally endangered and are protected by the National Park and Wildlife Protection Act 1973 of Nepal (Khanal et al. 2018a). There are limited protected areas in mid hills of Nepal, so most of the primate habitats lie outside the protected areas and they are under severe anthropogenic influences (Chalise 2013). This study revealed that more than half of the Assamese Macaque population resides outside the protected area system of the country. The mid-hills area with amenable temperature and ample precipitation provide the suitable habitat for Assamese Macaque (Khanal et al. 2018a), but that remains outside the protected area system of the country. Because of this, at many places of the mid-hill districts the species has been described as the notorious crop raiders bringing them into negative interactions with subsistence farmers (Chalise 1999, 2003, 2010, 2013). Extending protected areas benefits to resource-dependent smaller landholders who experience higher losses from human-wildlife conflicts (Karanth & Nepal 2012). Establishment of protected areas in mid hills would conserve the Assamese Macaque habitat together with other plant and animal species.

CONCLUSION

We conclude that Assamese Macaque population in Nepal is distributed within the narrow elevational range especially at the mid-hills. The population is sporadically distributed at fragmented forest patches of the mixed riverine broadleaved forests. More than half of the Assamese Macaque population is resided outside the protected areas of mid-hills within which most of the suitable habitats of the species fall; therefore, conservation efforts should be focused in those areas.

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