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Cover: The critically endangered *Lilium polyphyllum* in watercolour and acrylics. © Aishwarya S Kumar.

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COMMUNICATION

Identifying potential habitats of Himalayan Red Panda *Ailurus fulgens* (Cuvier, 1825) (Mammalia: Carnivora: Ailuridae) in Neora Valley National Park, West Bengal, India

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Abstract: The Himalayan Red Panda *Ailurus fulgens* (Cuvier, 1825) is a globally Endangered species whose population is reported to be declining in the wild. It is a priority species for the Neora Valley National Park (NVNP) since it is the flagship species of this ecosystem. Moreover, this landscape functions as an important connecting link of the Himalayan Red Panda habitat between the state of West Bengal and Sikkim. The spatial habitat of the Himalayan Red Panda in this National Park is little known. Our study attempts to identify the spatial distribution of potential habitats for the Himalayan Red Panda using the maximum entropy algorithm (MaxEnt 3.4.1). The model predicted a 55 km² of potential habitat with the current climate scenario. With climate change, predicted potential habitats are likely to experience significant loss and upward shift to a relatively higher elevation. Hence, the management of the NVNP should identify the potential habitats and accomplish realistic goals to help conserve the Red Pandas.

Keywords: Climate change, conservation, habitat ecology, habitat modelling, Himalaya, maximum entropy, reintroduction.

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Author contributions: SWB—field data collection, analysis and article writing. AG—field data collection, photographic documentation and article writing. PG—conceptualise & designed the research work. BSH—conceptualise the research work & overall supervision.

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INTRODUCTION

The Himalayan Red Panda *Ailurus fulgens* (Cuvier, 1825) belongs to the Ailuridae family of the order Carnivora, in which *Ailurus* represents the only genus (Roberts & Gittleman 1984). Although taxonomically considered as a carnivore, the species has evolved as a specialized herbivore (Roberts & Gittleman 1984). Almost 80% of its diet consists of bamboo leaves and shoots (e.g., *Arundinaria maling, A. aristata*) and reported to feed on bird eggs, insects, and grubs occasionally (Choudhury 2001; Pradhan et al. 2001). This flagship species is found exclusively in the moist, temperate, and sub-alpine forests of the Himalaya, at 2,100–4,800 m, stretching from Nepal, India, Bhutan, and southeastern China to Myanmar (Roberts & Gittleman 1984; Choudhury 2001; Mallick 2010a,b; Ghose & Dutta 2011; Dorji et al. 2012; Glatston et al. 2015; Bista et al. 2019; Hu et al. 2020). However, a recent genomic study shows that there are two species of *Ailurus fulgens*, the Himalayan Red Panda (*A. fulgens*) and the Chinese Red Panda (*A. styani*) known today rather than subspecies as considered earlier (Hu et al. 2020; Joshi et al. 2021; Lyon et al. 2022). Among the two species, *A. fulgens* is the nominate species in India (Roberts & Gittleman 1984; Choudhury 2001; Ghose et al. 2011; Dorji et al. 2012) and it is only found to the west of the Siang River of Arunachal Pradesh in India, and on southern Tibet; whereas, the Chinese Red Panda *A. styani* is found only to the east of Siang River, in eastern Arunachal Pradesh, India, and in southwestern China (Wei et al. 1999; Hu et al. 2020; Joshi et al. 2021). In West Bengal, they are only found in the Singalila National Park (SNP) of Darjeeling district and in the Neora Valley National Park (NVNP) of Kalimpong district (Choudhury 2001; Mallick 2010a,b). Red Pandas are selective in forest use; usually, the good density of bamboo, presence of water sources, well canopy covering accompanied with other important elements like a fallen log, and tree stump, make their perfect habitat (Image 1) (Dorji et al. 2012; Bista et al. 2019).

However, the shrinking habitat, livestock farming, trafficking, poaching, and road construction put their population at risk (Pradhan et al. 2001; Ghose et al. 2011; Dorji et al. 2012; Glatston et al. 2015). As a result, it is categorized as an 'Endangered' on the IUCN Red List of Threatened Species (Glatston et al. 2015), and listed under Schedule I in the Wildlife (Protection) Act of India, 1972, and as Appendix I species under the CITES (CITES 2010). This study was aimed to find out and analyze the most-used patches of Red Pandas in the NVNP, which will help in further studies and future reintroduction programs.

MATERIALS AND METHODS

Study Area

The Neora Valley National Park (NVNP) is located between latitudes 26.88417–27.12639 ^{o}N and longitudes 88.75000–88.83333 ^{o}E located in Kalimpong district which forms the ecological trijunction with Sikkim and Bhutan, is the last wilderness in West Bengal (Mallick 2010a,b) (Figure 1). The park, spreading over 88 km^2 is one of the oldest reserve forests in India. NVNP is also considered an integral part of the Kanchenjunga landscape (Sharma & Chettri 2005; Chettri et al. 2007) and is considered West Bengal's crowning glory because of its vast environment gradients (183–3,200 m) and climatic conditions, supporting a unique and ecologically important undisturbed patch of late succession forest (Mallick 2010a).

Occurrence records and predictor variables

The occurrence coordinates were collected using a handheld GPS (Garmin eTrex 10) for six months (January–June of 2022) long study from the NVNP. Those locations include the occurrence of droppings, trap camera footages (Image 2) (Cuddeback H20 MP IR-Model H-1453 & Y24 32MP IR), and direct sighting coordinates of a Red Pandas by forest officials of the NVNP as a proxy to denote their presence.

For modeling the potential habitats, 19 bioclimatic variables were downloaded from WorldClim (www.worldclim.org) with 1 km spatial resolution (Hijamans et al. 2005; Su et al. 2021). The bioclimatic variables included annual trends (mean annual precipitation and temperature), seasonality (annual range in precipitation and temperature), and extreme environmental factors (temperature of the coldest and warmest month and precipitation of the wet and dry quarters).

Modeling

MaxEnt (Maximum entropy algorithm) model in one of the most utilized modeling tools for presence-only records (Elith et al. 2011) where collinearity does not affect the performance of this model (DeMarco & Nóbrega 2018). For the creation of the model, 19 bioclimatic variables (Image 3) along with slope, altitude, aspect, and landcover were used as the predictor variables (Pradhan et al. 2001; Thapa et al. 2020; Su et al. 2021). A 30 m resolution digital elevation model

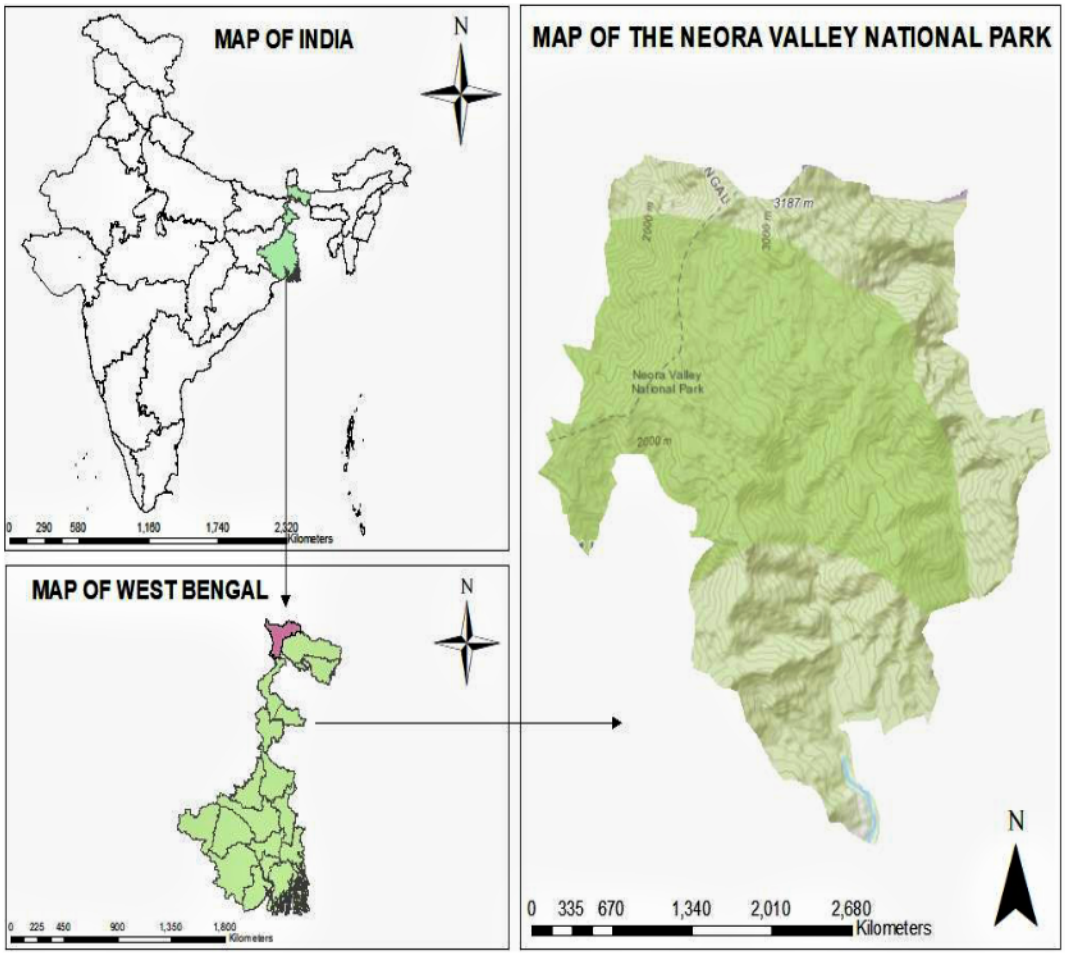

Figure 1. Study area: The Neora Valley National Park.

(DEM) was used here to calculate the slope and aspect (Su et al. 2021). This model has been run with the given settings: 5-fold cross-validation, regularization multiplier = 2.5, feature = linear, quadratic and hinge, and output type = logistic, where 70% of the occurrence data was used for training and the remaining 30% for testing the model.

The accuracy of the species distribution model was evaluated on the area under curve (AUC) by measuring the area under the receiver operating characteristic (ROC) curve which is widely used for comparing the performance of this model. The AUC value ranges from 0 to 1 where the higher value suggests better performance with better discriminatory capability than the randomly generated model (Phillips et al. 2006).

To generate a suitable habitat map for the Himalayan Red Panda, above 10% training presence logistic threshold was selected. The Jackknife test has been used here to evaluate the relative importance of each environmental predictor variable (Su et al. 2021).

RESULTS

The NVNP comprises of a large variety of habitats and niches, comprising the catchment and watershed of the Neora River which is fed by nine main streams and 16 subsidiary streams (Mallick 2010a). The main habitat types where we found the sign of the Himalayan Red Pandas, over 2,000 m altitude were mostly Oak *Quercus* and *Rhododendron* Forest along with dense bamboo *Malingo* thickets. Most of the pallets were found on those trees. The total count of direct sighting and pallet occurrence data along with indirect sighting data (questioner survey) were taken for the modeling. The MaxEnt model with the mean AUC value of 0.999 predicted that the NVNP is highly suitable habitat area for the Himalayan Red Panda under the current climate scenario (Figure 2). The mean AUC = 0.999 suggest that model performance is relatively better than random predictions.

Amongst the 21 predictor variables (19 bioclimatic,

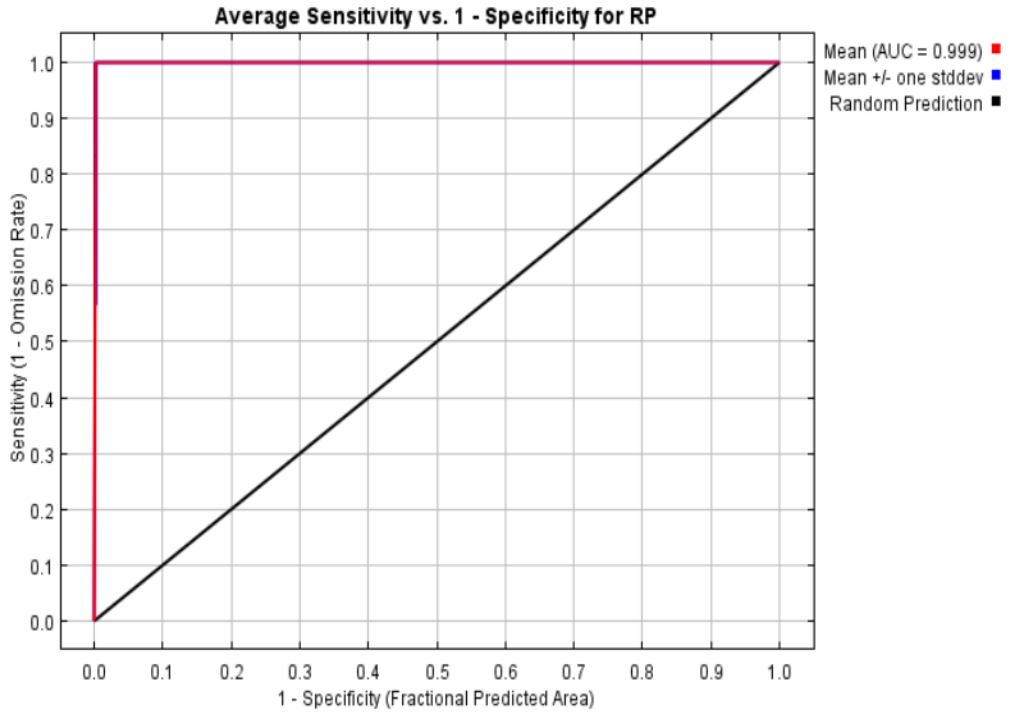

Figure 2. High value (0.999) of this Area Under ROC Curve (AUC) model of the species distribution map (SDM) shows that the NVNP is highly suitable for the Himalayan Red Panda *Ailurus fulgens*.

Image 1. Habitat of the Himalayan Red Panda *Ailurus fulgens*, Neora Valley National Park. © Asim Giri.

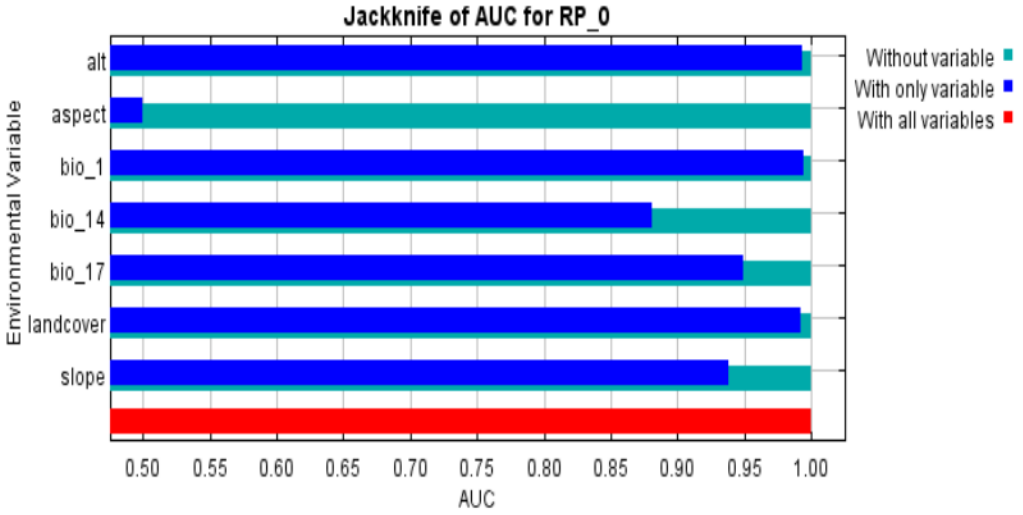

Figure 3. The individual environmental predictor variables (in blue) in this Jackknife test shows the relative dependance to all variables (in red). (alt—altitude | bio_1—annual mean temperature | bio_14—precipitation of driest month | bio_17—precipitation of driest quarter)

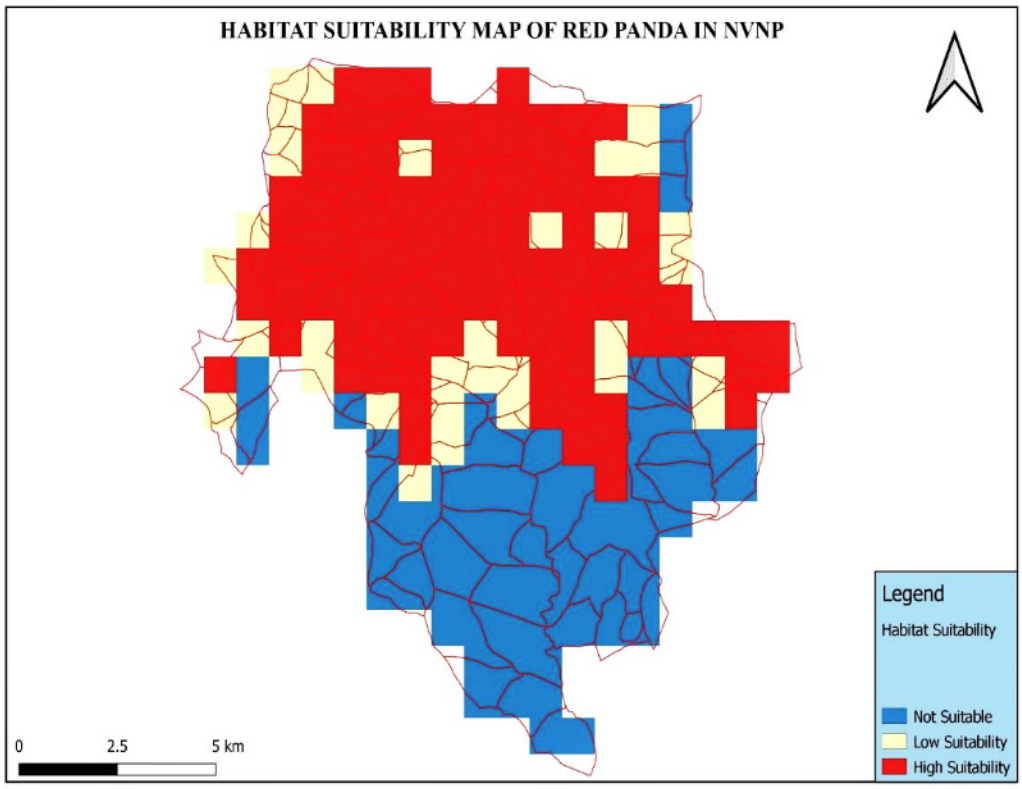

Figure 4. Potential habitat area for the Himalayan Red Panda *Ailurus fulgens*.

slope, and aspect) with approximately 1 km spatial data (30 seconds), annual mean temperature (Bio1), altitude, precipitation of driest month (Bio14), precipitation of driest quarter (Bio17), landcover and slope were the main contributing factors (Figure 3).

From these factors, a habitat suitability map was created using MaxEnt, which predicts that approximately 55 km^2 of area inside the NVNP is a potential conservation zone for the Himalayan Red Pandas (Figure 4).

Image 2. A—droppings of the Himalayan Red Panda | B—camera-trap photograph of the Himalayan Red Panda captured during our survey in Neora Valley National Park.

DISCUSSION

The IUCN conservation status of the Himalayan Red Panda has changed from 'Vulnerable' to 'Endangered', which indicates that the species has been experiencing a decrease in population over the years and facing significant threats. Understanding the spatial distribution of the potential habitat of species with the help of a model enables to assess the existing threats and planning for future uncertainties.

The model predicted approximately 55 km^2 of potential habitat consisting the areas above 2,000 m elevation with slope more than 30°, the aspect facing south-east and west, areas with dense bamboo *Malingo* and canopy cover, and water sources are the important habitat factors for the Himalayan Red Panda under the current climatic scenario, but the actual habitat is likely to be less since the correlative species distribution model predicts a fundamental niche that is larger than the realized niche (Polechova & Storch 2008). Further, the species can be limited by other environmental factors like land use, edaphic and anthropogenic disturbances that are not incorporated in the model (Ranjitkar et al. 2014).

The Himalayan ecosystem is rapidly changing under the influence of current global and regional warming and is expected to exacerbate with the predicted increase in mean temperature by 3.0–4.8°C by 2100 (Stocker 2014). Anthropogenic threats are the primary causes of changing climate which is expected to affect

Bioclimatic variables are coded as follows:

BIO1 = Annual Mean Temperature

BIO2 = Mean Diurnal Range [Mean of monthly (max temp - min temp)]

BIO3 = Isothermality (BIO2/BIO7) (×100)

BIO4 = Temperature Seasonality (standard deviation ×100)

BIO5 = Max Temperature of Warmest Month

BIO6 = Min Temperature of Coldest Month

BIO7 = Temperature Annual Range (BIO5-BIO6)

BIO8 = Mean Temperature of Wettest Quarter

BIO9 = Mean Temperature of Driest Quarter

BIO10 = Mean Temperature of Warmest Quarter

BIO11 = Mean Temperature of Coldest Quarter

BIO12 = Annual Precipitation

BIO13 = Precipitation of Wettest Month

BIO14 = Precipitation of Driest Month

BIO15 = Precipitation Seasonality (Coefficient of Variation)

BIO16 = Precipitation of Wettest Quarter

BIO17 = Precipitation of Driest Quarter

BIO18 = Precipitation of Warmest Quarter

BIO19 = Precipitation of Coldest Quarter

Image 3. List of 19 coded bioclimatic variables available at worldclim.org.

vegetation patterns and will significantly influence the disturbance, structure, and ecology of forests (Sharma et al. 2009; Lyon et al. 2022). Upward range expansion is widely documented as a response of vegetation to a warming climate (Kullman 2002). The phenomenon of such range expansion will alter the availability of food and shelter in the current habitat, influencing the future upward distribution of the Himalayan Red Panda.

CONCLUSION

In this study, we used the presence-only species distribution modeling tool, MaxEnt to model the potential habitat distribution of the Endangered Himalayan Red Panda in NVNP. The information generated through the MaxEnt model can help conservation planners to be informed and decisive for making action plans in the future. The conservation management of NVNP should set priorities for the identification and accomplishment of realistic goals that would help preserve the habitat of the Himalayan Red Pandas.

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