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PREDICTING THE DISTRIBUTION OF SUITABLE HABITATS FOR *PANDANUS UNGUIFER* HOOK.F. - A DWARF ENDEMIC SPECIES FROM SIKKIM HIMALAYAS, THROUGH ECOLOGICAL NICHE MODELING

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Abstract

Pandanus unguifer is a threatened species endemic to Sikkim and Darjeeling district of West Bengal. The species bears mildly fragrant creamy white colored flower and is the only Pandanus species that produces flowers in potted condition and hence, is of ornamental value. We used field collected-coordinates of five presence occurrence localities of the species for habitat distribution modeling. Additionally, downloaded environmental data from worldclim database were used for correlation. Amongst the input environmental variables, Mean diurnal range in temperature (Bio2) and Precipitation seasonality (CV) (Bio15) were influential factors and contributed 48.7% and 40.8% respectively to the MaxEnt model. The Rest of the remaining layers collectively contributed 10.5% to the final habitat model. Of the total 5963 sq.km suitable area only 153 sq. km has a very high probability of having P. unguifer which is only 2.57% of the total area. The study revealed the highest potential distribution of the species in Darjeeling district of West Bengal compared to Sikkim. However, resource extraction due to the felling of trees for fodder and small timber, road-widening and agricultural expansion are the causative factors threatening the existence of the species in its natural habitat. Thus urgent conservation initiatives are required to protect the existing endangered endemic species richness of these regions.

Keywords*: Darjeelin; Endangered; Endemic; Pandanus; Sano-Tarika; Sikkim*

Introduction

Ecological Niche Modeling (ENM) is a computer-based tools used to predict the distribution of species in correlation with the set of species occurrence locality and the environmental variables [1]. The availability of high-resolution bioclimatic data has lead to the wide use in ecological research and restoration ecology [2-4]. These tools find use in predicting the distribution of species across landscapes and have been used for prioritizing field surveys [5,6]. There are various algorithm used to predict the distribution of species [7-12]. However, comparatively, there are fewer examples of studies using small sample sizes [13]. We, therefore, used a method based on the principle of maximum entropy (MaxEnt) which has high success rates with sample sizes as low as five [14, 15].

P. unguifer belonging to the family *Pandanaceae* is a threatened and endangered species, endemic to Sikkim and Darjeeling district of West Bengal, India. The species has been assigned to Endangered category (EN B1ab [i,ii,iii] + B2ab [i,ii,iii]) as per IUCN Red List Criteria [16]. The species was first described by *J.D. Hooker* in *Flora of British India* in 1878 from Mungpo localities below Surail, West Bengal, India. The species have high ornamental

value because of the fragrant creamy white colored flower. The plants are locally known as "*Sano-Tarika*" (Small *Pandanus*) because of small dwarf size life forms.

Given that knowledge on the areas where appropriate environmental conditions exist to sustain the species is a pre-requisite for species conservation. Thus, the characterization of a niche of species is fundamental to conservation biology. A complete inventory of the populations of the species is equally important for correct classification from a threat perspective [17]. Thus in this regard, the present work was initiated with the following two objectives: (i) to predict and identify the potential suitable habitat of *P. unguifer* in its natural range and (ii) to assess the habitat status of predicted area primarily through field survey and secondarily through Google Earth superimposed imaginaries and plan conservation accordingly.

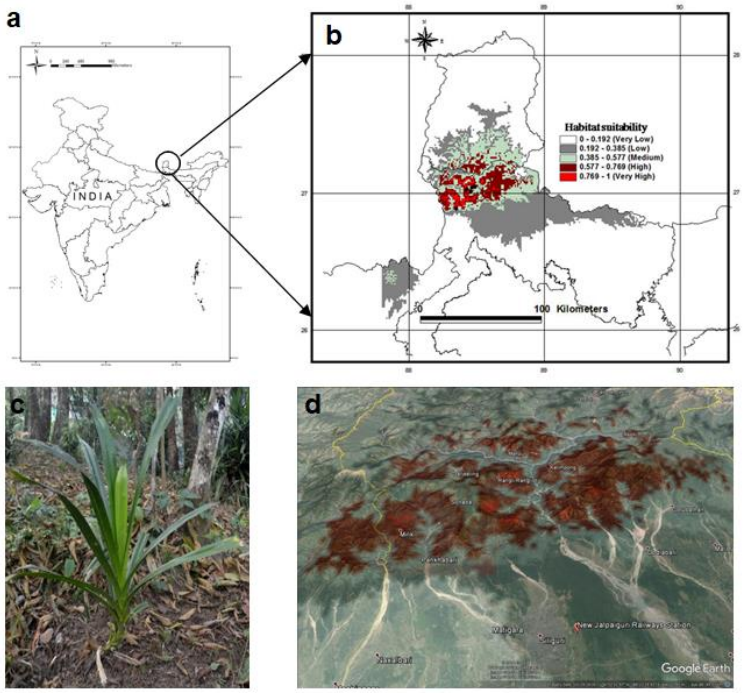

Fig. 1. (a) Study site (b) Potential habitat distribution of *P. unguifer* in Sikkim Himalayas (c) *P. unguifer* in its natural habitat (d) Superimposed habitat suitability map.

Materials and Methods

Collection locality and Environmental variables

To predict the suitable habitat of species in its natural range we collected five distribution records of *P. unguifer* from Sikkim and Darjeeling district of West Bengal, which represent the total known distribution of the species. The distributional record (geographic coordinates) or the occurrence points were collected using a Garmin GPS. The coordinates were later used for model the distribution of species.

Two types of variables (*viz*. bioclimatic variables and altitude) were used in this study. The nineteen bioclimatic variables [2], with 1 km resolution were downloaded from the Worldclim dataset (http://www.worldclim.org/). We used bioclimatic variables because it is considered biologically more meaningful in understanding the eco-physiological tolerances of a species [18, 19]. The 19 bioclimatic variable were first subjected to a correlation test using ENM Tools 1.3 [20]. The variables with a cross-correlation coefficient value of > 0.9 were

excluded and thus out of 19 bioclimatic variables, six were used to model the distribution of species along with altitude.

Niche modelling

MaxEnt ver. 3.3.3e (https://www.cs.princeton.edu/wschapire/maxent)were used to model the distribution of *P. uniguifer* [21]. Ten replicated runs were executed for the species with a threshold rule of 10 percentile training presence and all other parameters were kept default [22]. The average, maximum, minimum, median and standard deviation were generated from all the replicated runs.

Validation of model robustness

We employed partial AUC metric to ensure the consistence of model performance [23]. Partial AUC was estimated using Niche Tool Box available online (http://shiny.conabio.gob.mx:3838/nichetoolb2/) and for the purpose of the study we executed 500 bootstrap with 0.05 proportion of omission to obtain the distribution of AUC ratio. The potential habitat distribution were categorized into five classes i.e. very-high (0.769-1), high (0.577-0.769), medium (0.385-0.577), low (0.192-0.385) and very low (0-0.192) [24].

Habitat assessment

The assessment of habitat was done by superimposing the predicted distribution map onto Google Earth. The final predicted grid output file was exported as a KMZ file using DIVAS-GIS software ver. 7.5.0. The KMZ file was later visualized for habitat assessment.

Results

Target species

P. unguifer is a clump-forming shrub with a decumbent simple stem, abruptly acuminate and gradually narrowing at the base. The male inflorescence is a compound, terminal spike. Female inflorescence solitary, spreading and surrounded by an involucre of spathes. The fruits turn yellow when ripe.

Habitat - *P uniguifer* grows in a tropical and subtropical mixed deciduous forest at an altitude of 500-1300m consisting of trees like Schima *wallichii* Choisy, *Alnus nepalensis* D.Don, *Engelhardtia spicata* Lechen ex Blume, *Macaranga denticulate* Blume, *Viburnum cordifolium* Wall ex DC.

Threat - We observed that the natural habitat of *P. unguifer* is under severe biotic pressure, owing to activities like road-widening, agricultural expansion and construction.

Model evaluation and Contributing variables

The predicted potential distribution of the species is given in figure 1. Test for model performance for *P. unguifer* yielded satisfactory results for ROC_{full} (mean AUC 0.936±0.04) and $ROC_{partial}$ (mean AUC 0.983±0.01) (Table 2). Amongst the input environmental variables, Mean diurnal range in temperature (Bio2) and Precipitation seasonality (CV) (Bio15) were significantly influential factors and contributed 48.7% and 40.7% respectively to the MaxEnt model. The rest of the remaining layers collectively contributed 10.5% to the habitat model of the species (Table 1). The jackknifing plots, comparing the environmental variables in the model prediction also showed that the mean diurnal range in temperature (Bio2) and precipitation seasonality (CV) (Bio15) were the two main variables (Fig. 2).

Habitat assessment

The predicted potential distribution map of *P. unguifer* on superimposing onto Google Earth satellite imageries affirms areas with high and very high category with continuous forest patches, cultivated areas with human settlements. The areas with medium and low habitat suitability were continuous forest with less human populated. The predicted potential habitat distribution map towards Darjeeling district was mostly tea garden and thus such sites do not act for *in-situ* conservation of the species. However, areas predicted towards the South district

of Sikkim were mostly owned by the local community and thus such site can be considered for conservation through reintroduction in the area predicted to be suitable (Fig. 1d).

Table 1. Environmental variables and their percentage contribution to the model

Environmental variables	Percent contribution	Permutation importance
Annual mean temperature (ºC; Bio1)*	0.2	1.3
Mean diurnal temperature range [mean of monthly (max temp – min temp)] (ºC; Bio2)*	48.7	16.4
Isothermality (P2/P7) (Bio3)*	1.3	0.2
Precipitation of driest month (mm; Bio14)*	3.5	6.1
Precipitation seasonality (CV) (Bio15)*	40.8	40.5
Precipitation of coldest quarter (mm; Bio19)*	5.5	35.5
Altitude (m)*	0.1	0

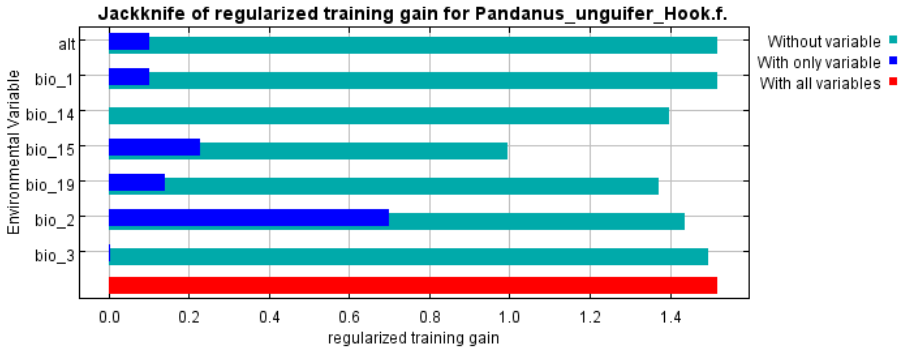

Fig. 2. Result of jackknife test for evaluating the relative contribution of the predictor environmental variables to the habitat model of *P. unguifer*

Table 2. Full and partial ROC-AUC measures for model evaluation. The mean value for $AUC_{partial}$ at 0.5 is 0.5

ROC space	Proportion of omission	Mean AUC±SD	Mean AUC_{ratio}(±SD)
ROC_{full}	0	0.936±0.04	-
$ROC_{partial}$	0.05	0.983±0.01	1.967±0.02

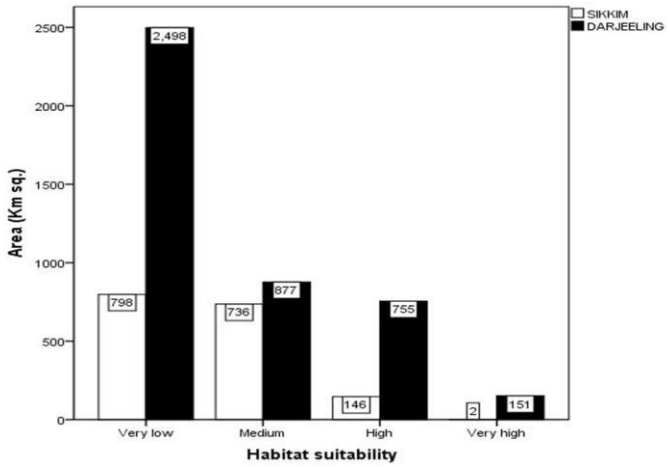

Fig. 3. Area under different suitability grades for the optimal average model. The figures at the top of each bar represent the area.

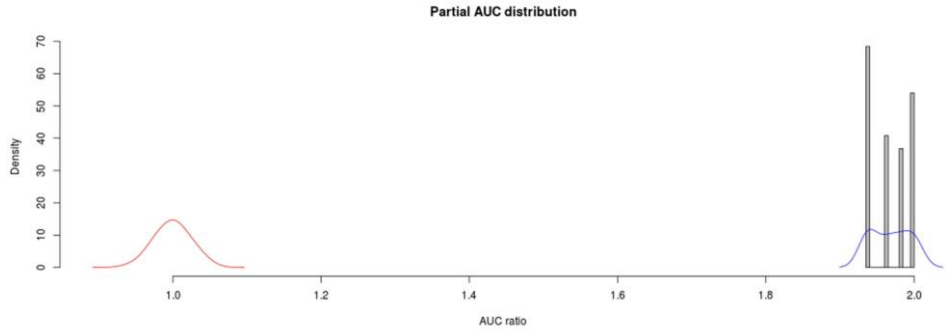

Fig. 4. Partial AUC distribution for *P. unguifer* generated after 500 iterations with 0.05 proportion of omission in the ROC space.

Discussion

The updated Koppen-Geiger climate classification system includes the state of Sikkim and Darjeeling district of West Bengal into warm temperate to subtropical climate with dry winter and warm summer. The larger part of the area falls in the thirds category (i.e. Group C) of Koppen-Geiger classification where the average maximum monthly temperature is below 22°C and average minimum monthly temperature below 10°C, with average annual precipitation of more than 60mm with constant variation in monthly rainfall with maximum rainfall occurring during the month of July and August. Interestingly plant flowers during August and hence this characteristic of constant variation in monthly precipitation and high average rainfall may have restricted its distribution to this region. A total of 5963km^2 was predicted to be suitable for *P. unguifer* in Sikkim Himalaya (i.e. Darjeeling and Sikkim). Most of the area falls in the low suitability category and covering an area of about 3296km^2. The area with very high suitability was very much restricted to about 153km^2. The area with high and medium suitability was restricted to 901km^2 and 1613km^2 respectively. The total area covered in different thresholds within the state of Sikkim and Darjeeling district of West Bengal is given in figure 3. The potential distribution was found to be more in the Darjeeling district of West Bengal compared to Sikkim (Fig. 3). Only two km^2 areas were predicted to be very suitable for the species in the state of Sikkim (i.e. South district) which is in accordance with the report of *Zanan & Nadaf* [15] where they have reported its distribution in Sikkim. Therefore this result further validate the model output and also indicates the importance of ENM in predicting the habitat suitability of the species. The restricted distribution of *P. unguifer* indicates its narrow endemism. The herbarium records, past field survey and published articles also validate that species do not occur beyond the South district of Sikkim and Darjeeling district of West Bengal [25, 26]. The superimposed map on Google Earth satellite imageries also informs that the areas with very high and high habitat suitability class mostly exist in the South district of Sikkim and the area is largely dominated by human and cultivated land. Moreover, the areas predicted with very high suitability towards Darjeeling district of West Bengal are mostly under tea and *Cinchona* plantation. However, areas predicted with very high and high suitability towards South districts of Sikkim are less human populated with the dense forest canopy. One such site predicted suitable in the South district of Sikkim is a local tourist destination locally known as *Taray Bhir*. Such a site makes an ideal destination for species reintroduction, as it brings both awareness and attraction to the visitors.

Conclusion

The present study establishes the fact that ENM is of significant importance in predicting the potential habitats of threatened species and with the use of Google Earth one can make an assessment of habitat prediction through ENM and plan conservation strategy accordingly. The results obtained could be useful for conservation enthusiasts, natural resource managers in the management of this species and conserving overall biological diversity in the region. The habitat of *P. unguifer* within the region is increasingly exposed to disturbance as it falls along the trekking corridor of human settlement. Resource extraction due to felling of trees for fodder and small timber, and activities like road-widening, agricultural expansion, construction of a building are the other causative factors threatening the existence of the species in its natural habitat, the species might be extinct soon, unless adequate conservation measures for the species is taken. Therefore urgent conservation initiatives are required to protect the existing endangered endemic species richness of this region. From a conservation point of view, identification of potential distribution areas would help locate sites suitable for reintroduction programs. Characterization of natural populations will help to identify the areas for *in situ* conservation of the species, and will also help in the cultivation of such species because of known niche breadth.

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