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DISTRIBUTION MAPPING AND CONSERVATION OF *Bruguiera sexangula* (LOUR.) POIR., KERALA, INDIA

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Abstract: **The study was conducted to identify the potential distribution of *Bruguiera sexangula*, a threatened mangrove species in the Kerala region using ecological niche modelling. Of the 19 bioclimatic and six topographic variables, only three variables viz., Annual Precipitation, Dem and Mean Diurnal Range positively influence the distribution of this mangrove species. The potential distribution is found to be high in the backwater areas in Alapuzha and Ernakulam districts especially the mangrove patches of Chellanam, Panangad, Vypin, Pattanakkad, Ezhupunna, Eramallur and Thuravur areas. The potential predicted distribution information of this species can be helpful in planning, conservation of existing populations, identification of survey sites, and to set priorities for the restoration in natural habitats.**

Keywords: **Ecological niche modelling, *Bruguiera sexangula*, Distribution, Maxent**

1. INTRODUCTION

Modelling distribution of species is an important tool for the biogeography and conservation biology which is widely used for calculating the potential distribution of species (Bombi *et al.*, 2009; Britto *et al*., 2009), to evaluate the effects of climate change on species distribution (Araujo *et al.*, 2006), suitable habitat and species range estimates (Chefaoui *et al*., 2005; Gaubert *et al*., 2006), to identify the suitability of protected areas (Garcia, 2006; Doko *et al.*, 2011) and the effects of habitat disturbance on species distributions (Banks *et al.,* 2005; Sanchez-Cordero *et al*., 2005; Rhodes *et al*., 2006). Method involving ground surveys covering entire study regions are either not possible or time consuming in most cases and moreover the conventional approaches fail to synthesize the minuscule distribution details of certain species. New Geographical Information System (GIS) approaches have been developed to address this limitation by combing the known occurrence localities and environmental coverage that describes the study region. This approach has been explored under the rubric of 'ecological niche modelling' (ENM) which produces potential distribution maps by establishing a relation between the known presence localities and background information (Soberson & Peterson, 2005). Ecological niche models has been created with the known distribution data by calculating the possible prediction algorithms by the base of different environmental variables such as climate data sets, topographical data and habitat data (Peterson and Soberon, 2012). In India, this technique was widely applied for identification of the environmental niches of Himalayan birch (Singth *et al.,* 2013), Malabar nut (Yang *et al*., 2013), *Coscinium fenestratum* (Thriveni *et al*., 2015) etc.,

The genus *Bruguiera* which belongs to the family Rhizhophoraceae (Hou, 1958; Tomlinson, 1986; Hogarth, 1999) and it comprise a small group of six mangrove species of the Indian and west Pacific Ocean region. Its range extending from east Africa and Madagascar through coastal India, Sri Lanka and South east Asia to northern Australia, Melanesia and Polynesia (Hou,1958). The species are *Bruguiera gymnorhiza* (L.) Lam., *B. sexangula* (Lour.) Poir., *B.. exaristata* Ding Hou, *B.hainesii* C. G. Rogers, *B. cylindrica* (L.) Bl., and *B. paviflora* Wight and Arnold ex Griffith (Tomlinson, 1986). Among these, four *Bruguiera* species viz. *Bruguiera cylindrica*, *B. gymnorrhiza, B. parviflora*, *B. sexangula* are present in India (Raghavan *et al.*, 2016). *Bruguiera sexangula* is a very rare middle zone mangrove in Kerala, and it is restricted to a few localities in Puduvypin area of Ernakulum and Neendakara region of Kollam district especially in private land or along the coastal roads. Road widening and other developmental activities are the major threat and special attention is required for the conservation of this mangrove species (Sujanapal and Sasidharan, 2014). According to Vidyasagaran and Madhusoodanan (2015), *B. sexangula* is confined to few places wherein their population is facing further decline and noted as Endangered. But as per the IUCN status (IUCN, 2018), it is reported as Least Concern.

Ecological Niche Modelling technique was used to construct the potential distribution *B. sexangula* in the Kerala region and Maxent has been known to produce accurate distribution predictions for numerous rare and threatened species in a restricted study region (Elith *et al.* 2006; Pearson *et al.* 2007). An attempt was made here to produce accurate distribution map of *B. sexangula* using ecological niche modelling framework especially for understanding local distribution pattern and habitat requirements which is a fundamental goal of modern biogeography.

2. MATERIALS AND METHODS

A total of 9 spatially unique points of *B. sexangula* were recorded during field surveys with Global Positioning System (GPS). All points were further geo-rectified with the Survey of India topographic sheets and Google Earth (Google, Mountain View, CA, USA) to obtain accurate coordinates to be used in the modelling. The background environmental data is given in the form of nineteen bioclimatic and six topographic variables. The bioclimatic variables are from the Worldclim dataset developed by Hijmans *et al.* (2005) available at a resolution of 1 km^2 (http://www.worldclim.org). The variables of annual and monthly values of mean temperature, precipitation and seasonality were derived. The topographic variables include elevation, slope, aspect, flow accumulation, flow direction and compound topographic index (a measure of tendency of water to pool). The topographic variables were derived from Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (http://topex.ucsd.edu/WWW html/srtm30 plus.html) available at 30 meter resolution.

2.1 Ecological Niche Modelling:

Species distribution model (Franklin 2009) or Maximum entropy (Maxent) modelling was chosen to predict the potential distribution of the *B.sexangula* in the Kerala region. Maxent is a machine learning method which has its origin in the statistical mechanics. It is a general purpose method which makes predictions from incomplete information. The probability distribution of maximum entropy (closest to the uniform), subject to a set of constraints that represent the incomplete information about the target distribution (Phillips *et al.* 2006; Peterson *et al.* 2011). Maxent has shown to produce competitive results when compared with other general purpose modelling methods used in predicting the potential geographical distribution of a species (Elith *et al.* 2006; Wisz *et al.* 2008). Maxent version 3.3.2e (http://www.cs.princeton.edu/~schapire/maxent/) was used to run the models. In the program, 500 iterations were run with a convergence threshold of 0.00001 and a maximum of 10,000 background points and algorithm parameters were set to auto features (Phillips & Dudik 2008). Only the random test percentage in the settings was turned to 20% in order to test the model robustness through the Area under Curve (AUC). In addition to that, an external test was done through a jackknife test. By leaving one occurrence point at a time and running the model, it was allowed to predict the excluded point and the accuracy was tested through a simple probability test. Maxent produces predictions in the form of real numbers between 0 and 100 representing the cumulative probability of occurrence. The cumulative output raster data set format is chosen and the values were imported into ArcGIS as integer grids for further analysis, reclassify values, comparison and preparing final map outputs.

3. RESULTS AND DISCUSSION

The simple probability test conducted from the jackknife test confirmed that the prediction is significantly better than at random as shown in Figure 1 ($P < 0.05$). The test and training Area under Curve (AUC) values were also higher (Training Area under Curve (AUC) value – 0.991, Test AUC – 0.996) which indicates that the model is accurate and justifies the construction of final niche model with all the available points. The prediction was good because the final niche model includes all the occurrence points in the Kerala. The predicted potential distribution *B. sexangula* is provided in Figure 2. The potential distribution is found to be high in the backwater areas in Alapuzha and Ernakulam districts. The mangrove patches of Chellanam, Thirunettur, Panambukad, Mangalavanam, Panangad, Kadamakkudy, Vypin areas in Ernakulam district, and Pattanakkad, Ezhupunna, Eramallur, Thuravur areas in Alapuzha district showed high potential distribution of *B. sexangula*. Medium prediction was found Pallam, Kumbalapuzha and Mogral, Poyya and Shiriya areas in Kasaragod district. Of the 19 bioclimatic and six topographic variables, only three variables viz., Annual Precipitation, Dem and Mean Diurnal Range positively influence the distribution of this mangrove species (Table 1). Katrien *et al*., (Unpublished) investigated influence of temperature at the different mangrove latitudinal range limits and observed that there is not one isotherm that coincides with mangrove latitudinal limits: monthly air and sea surface temperature are highly variable among congeneric mangrove limits. The larger distribution of the genus *Avicennia* compared to the genus *Rhizophora* is reflected in the temperature requirements and *Avicennia* limits are colder than *Rhizophora* limits (Quisthoudt *et al.*, 2012) and the high temperature variation among limits can be due to partial range filling towards the latitudinal limits. Anupama and Sivadasan (2004) reported *B. sexangula* from Panangad and Pudvyppin areas in Ernakulum District and considered as very rare. Similarly, Vidyasagaran and madhusoodanan (2015) treated this mangrove as Endangered in Kerala. Of the 9 reported localities of *B. sexangula* used in the present study, two were from Kollam district, and other districts like Kottayam, Thrissur, Ernakulam, Kannur, Alapuzha, Malapuram and Kasaragod are represented with only single locality.

TABLE-1 Variable Contribution - Maxent

Variable	Percent contribution	Permutation importance
Annual Precipitation	40.8	72.9
Dem	34.5	24.9
Mean Diurnal Range	19.6	0
Precipitation of Wettest Month	3.1	2.2
Slope	1.9	0

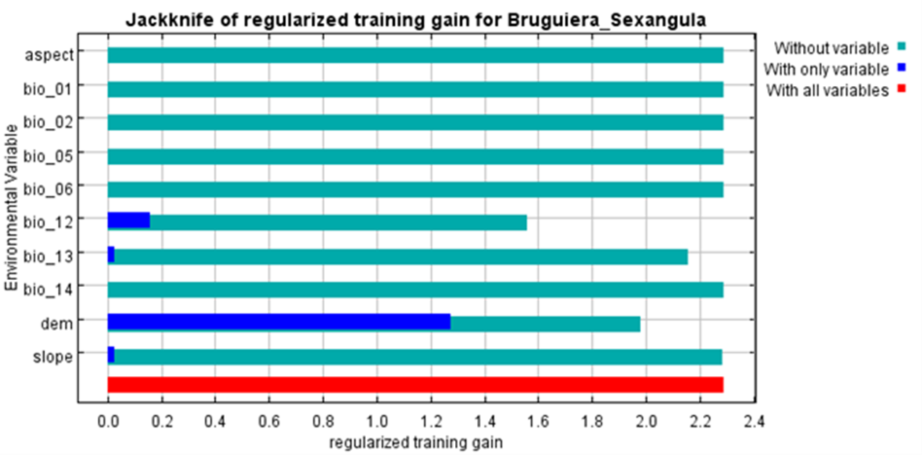

Fig - 1 Jackknife of regularized training gain of *Bruguiera sexangula*

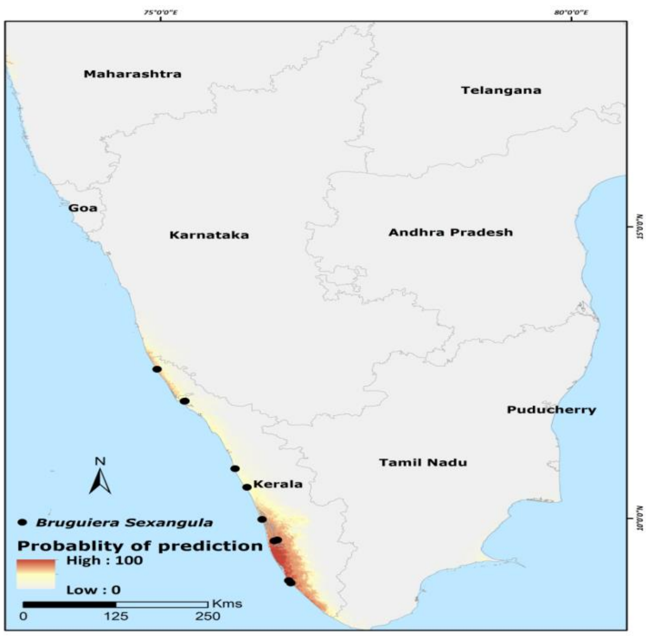

Fig - 2 Potential Distribution of *Bruguiera sexangula*

4. CONCLUSIONS

ENM is a useful tool in outlining and understanding the species distributions and serve as an application to focus on the conservation issues like suitable habitat and range estimation of species and biodiversity conservation especially in the protected area prioritization and network design. The prediction of distribution ranges of *B. sexangula* was good because the final niche model includes all the nine occurrence points in the Kerala. Our findings can be applied in various ways such as the identification of additional localities where *B. sexangula* may already exist, has yet to be investigated using more ground surveys. Similarly the potential predicted distribution information of this species will be helpful in planning, conservation of existing populations, identification of survey sites, and to set priorities for the restoration of natural habitats for more effective conservation. Further to develop species specific conservation programmes, a detailed study on population structure, spatial ecology, reproductive phenology and seed dispersal are also recommended

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