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EXTENDED DISTRIBUTION OF *VANDA WIGHTII* RCHB.F., AN ENDANGERED ORCHID OF WESTERN GHATS REVEALED BY ECOLOGICAL NICHE MODELLING

S William Decruse

Biotechnology Division, Jawaharlal Nehru Tropical Botanic Garden and Research Institute, Palode, Thiruvananthapuram-695 562, Kerala, India

Abstract

Vanda wightii Rchb.f., endemic to India and Sri Lanka and known to occur in 8 localities in Kerala, Karnataka and Tamil Nadu is an endangered orchid as notified by the Government of India. Preliminary survey based on climatic similarity followed by ecological niche modelling using Maxent software revealed extended distribution of the species over a distance of 405 kms, from Idukki district of Kerala to Dakshina Kannada district of Karnataka. Field surveys conducted in area revealed distribution of the species at 30-870 m altitudes in 31 distinct localities at 1km spatial resolution. New populations were discovered in Idukki, Malappuram, and Kasargod Districts of Kerala in addition to re-locating already known localities in Palakkad, Kannur, and Dakshina Kannada Districts. Precipitation during October-December, one of the climatic factors used for modelling, contributed 72.5% to the Maxent model and emerged as the most effective predictive variable. The model revealed distribution of the species mostly in inhabited areas or disturbed forests except those located in Idukki Wild Life sanctuary. The potential habitat distribution map provided here can help to discover new populations, identify top-priority survey sites, or to select translocation sites in protected areas close to natural populations (if in inhabited areas) for effective conservation of *V. wightii*.

Introduction

VANDA WIGHTII Rchb.f. (Fig. 1) reported from India and Sri-Lanka is one among the 40 species of *Vandas* distributed in the Indo-Malayan region (Limansela *et al.,* 2002). It is originally described by Reichenbach (1864) based on Robert Wight's collection from Vaulyar and Palghatcherry (1849) and Thwaite's collection from Sri Lanka (Sathish Kumar *et al.,* 2006). It is supposed to be extinct as it has not been re-sighted in the wild ever since Wight's collection (Limansela *et al.,* 2002). Later during 2000-02 period, the species was re-collected from Belthangady and Subramanya in Dakshina Kannada district of Karnataka; Nidiyanga in Kannur and Melattur near Palakkad district of Kerala (Sathish Kumar *et al.,* 2006). The species is described to be as distributed in narrow pockets with restricted numbers and later under section 38 of the Biological Diversity Act 2002, the Central Government notified that *V. wightii* is on the verge of extinction and prohibited/regulated collection along with other 25 plant species from Western Ghats (Ministry on Environment and Forests, Government of India, 2009). The ministry also called for studies on all aspects of the notified species for holistic understanding and propagation of the species for the purpose of *in situ* and *ex situ* conservation and rehabilitation.

The present study was framed to understand potential distribution of the species in localities other than that described earlier and the type localities as well as re-located sites. In such cases, plant distribution modelling/ecological niche modelling is known to have significant relevance as proved useful in several plant/animal species in predicting potential distributions based on a few occurrence records (Papes and Gaubert 2007;Siqueira *et al.,* 2009) and finding out new populations. There are several modelling algorithms in use and maxent model (Philip *et al.,* 2006) is reported to have more accuracy of prediction with small samples and narrow distribution (Aguirre-Gutierrez *et al.,* 2013; Papes and Gaubert 2007). The purpose of this paper was to document our experience with

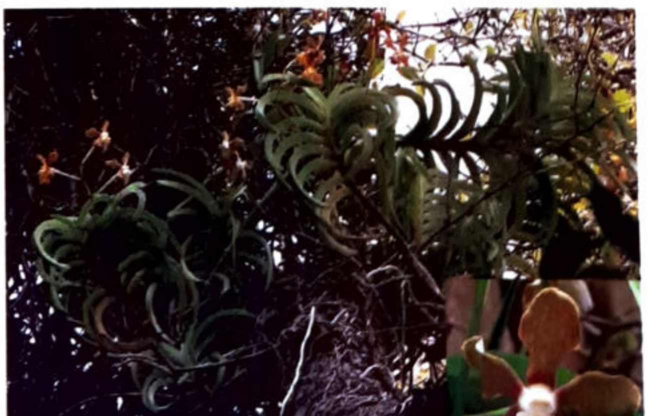

Fig.1. *Vanda wightii*, on its natural host

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combining ecological niche models (Maxent) and new field surveys towards discovery of additional populations of *Vanda wightii*.

Materials and Methods

The methodology include field survey, gathering of geo-referenced occurrence points, ecological niche modelling using freely available Maxent software version 3.1 (http.//www.cs.princeton.edu/~schapire/maxent/), confirmation of occurrence in more localities and preparation of a predictive model using all the 1km spatial occurrence records. Even though 9 occurrence points (Table. 1) are mentioned in the literature, none of them were geo-referenced.

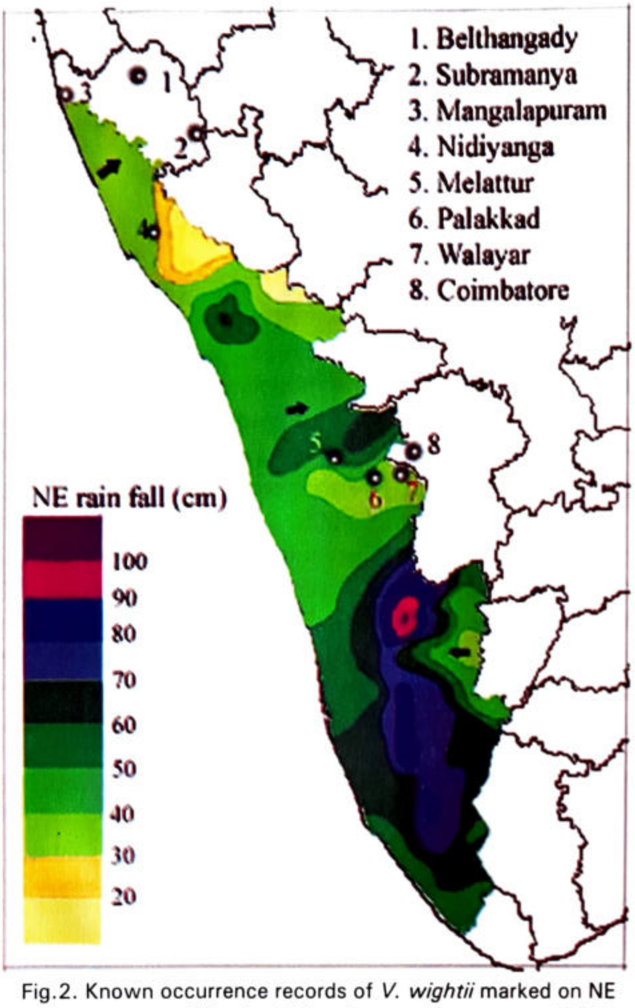

Fig.2. Known occurrence records of *V. wightii* marked on NE monsoon map of Kerala. (Climatic map data source: CESS, 1984); arrows indicate the regions of climatic similarity searched for *V. wightii*

Also, most of the reported localities are now major cities (Mangalapuram, Coimbatore, Belthangady, Palakkad) and or broader areas of diverse habitats (Ceylon). Thus, finding the most appropriate geo-referenced occurrence point from literary citing is difficult. Moreover, with the available records, typical ecological niche modelling approaches is

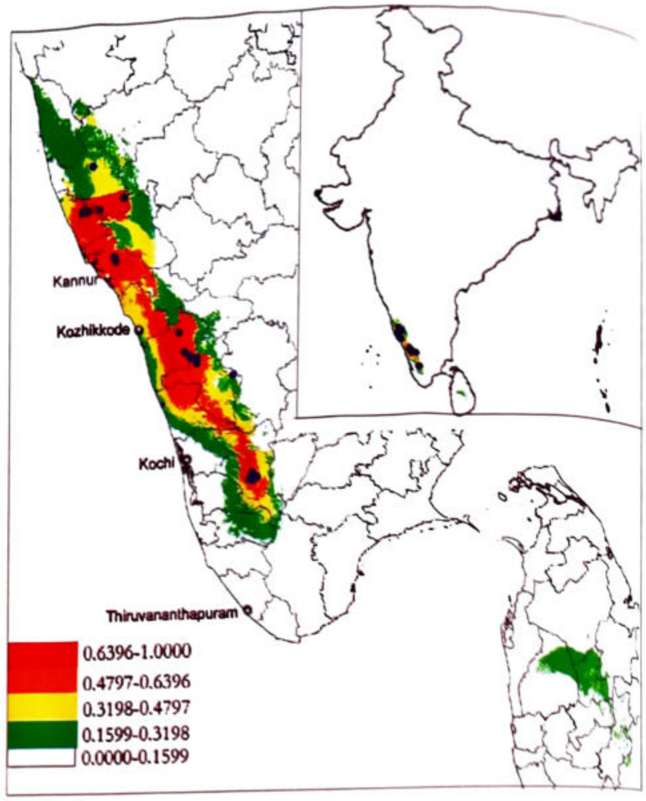

Fig. 3. Predicted potential suitable habitat for *V. wightii* in India and Sri Lanka

inapplicable, as they require at least minimal sample sizes to function appropriately (Wisz *et al.*, 2008). As a consequence, we used a very simple measure of climatic similarity and known host ranges to prioritize initial field efforts.

Study Area

The study area was initially confined to middle land in Western Ghats region of Kerala as the reported localities were at 60-80 m altitudinal ranges. This region presents marginal seasonality of temperatures, with coldest months averaging 22°C, and warmest months 34°C. Kerala as a whole receives an average 300 cm annual precipitation and exhibits significant variation

Fig. 4. Results of jackknife evaluations of relative importance of predictor variables for *V. wightii* Maxent model (See Table 3 for definition of variables).

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Table. 1. Distribution of *V. wightii*.

Locality	State/Country	Citation/collection
Vaulyar = Walayar	Kerala, India	1849
Palghatcherry = Palakkad	Kerala, India	1849
Ceylon	Sri Lanka	Prior to 1864
Coimbatore	Tamil Nadu, India	1849
Nidiyanga	Kerala, India	2001,2002
Belthangady	Karnataka, India	2003
Subramanya	Karnataka, India	2000
Melattur	Kerala, India	2006
Mangalapuram	Karnataka, India	2006

Source : (Sathish Kumar *et al.*, 2006.)

between seasons and regions. Northern regions receive higher precipitation during SouthWest monsoon and Southern region receive higher during NorthEast season. Winters are generally dry, and summers rainy, particularly in the middle land. The region is mainly inhabited land with occasional and highly fragmented deciduous forests.

Field Survey based on Climatic Similarity

To find out sufficient geo-referenced occurrence points, the five reported localities in Kerala are marked on different climatic resource maps of Kerala (CESS, 1984) *i.e.*, annual precipitation, SouthWest monsoon precipitation, NorthEast (NE) monsoon precipitation and annual mean temperature. Incidentally, most of the occurrence records in Kerala fell into the low rain fall (30-50 cm) area of NE monsoon precipitation. Three localities reported are in Dakshina Kannada district receiving average 26.4cm precipitation during October-December. Therefore, the reported localities in Kerala (Palakkad, Walayar, Melattur, Nidiyanga) and random locations in the said precipitation zones are surveyed to record geographical co-ordinates of occurrence points. This includes inhabited land and forest segments in the districts of Idukki (Idukki and Chinnar wild life sanctuary), Palakkad, Malappuram, Kannur, Kasaragod and Dakshina Kannada. Searching for the species in the inhabited land is much difficult and thus, age old host trees (*Alstonia scholaris, Artocarpus integrifolia, Ficus bengalensis, Mangifera indica,, Strychnos-nux-vomica, Tamarindus indicus, Terminalia paniculta*), along highways in the latter districts were observed for the potential presence of *V. wightii*.

Environmental Variables

Fourteen bioclimatic variables (Table 2; Mean diurnal range, Isothermality, Temperature Seasonality, Minimum Temperature of Coldest Period, Temperature

Table 2. Selected environmental variables and their per cent contribution in Maxent model for *V. wightii* in India and Sri Lanka.

Environmental variable	Per cent contribution	Permuation importance
Precipitation of coldest quarter (bio19_28)	72.5	0.4
Precipitation of warmest quarter (bio18_28)	7.4	20.7
Annual Precipitation (bio12_28)	6.6	0.6
Precipitation of driest period (bio14_28)	3.4	0.6
Isothermality (Annual mean temperature/Temperature Annual Range) ~100 (bio3_28)	2.6	0.0
Temperature annual range (Max Temperature of Warmest Period - Min Temperature of Coldest Period) (bio7_28)	2.2	1.2
Precipitation of wettest period (bio13_28)	2.1	3.3
Precipitation of driest quarter (bio17_28)	1.3	0.3
Temperature seasonality (Coefficient of Variation) (bio4_28)	1.2	71.9
Min temperature of coldest period (bio6_28)	0.8	0.1
Mean temperature of coldest quarter (bio11_28)	0.2	0.1
Precipitation of wettest quarter (bio16_28)	0.1	0.1
Mean temperature of wettest quarter (bio8_28)	0.1	0.6
Mean diurnal range (max temp – min temp) (monthly average) (bio2_28)	0	0

Annual Range, Mean Temperature of Wettest Quarter, Mean Temperature of Coldest Quarter, Annual Precipitation, Precipitation of Wettest Period, Precipitation of Driest Period, Precipitation of Wettest Quarter, Precipitation of Driest Quarter, Precipitation of Warmest Quarter and Precipitation of Coldest Quarter) biologically more meaningful to define eco-physiological tolerances of a species (Graham and Hijmans, 2006; Murienne *et al.*, 2009) obtained from WorldClim dataset (Hijmans *et al.*, 2005; *http://www.worldclim.org/ bioclim.htm)* are used as environmental variables for modelling studies. The environmental variables confined to zone 28 at 30 are S ~ 1KM spatial resolution (bio28_30s) were downloaded to use as environmental layers.

Modelling Procedure

We used maximum entropy distribution or Maxent modelling method which has been found to perform best among many different modelling methods and may remain effective despite small sample sizes (Aguirre-Gutierrez *et al.*, 2013; Benito *et al.*, 2009, Hernandez *et al.*, 2006; Papes and Gaubert, 2007; Pearson *et al.*, 2007; Sunil Kumar and Stohlgren 2009; Wisz *et al.*, 2008). Maxent is a maximum entropy based machine learning program that estimates the probability distribution for a species occurrence based on environmental constraints (Phillips *et al.*, 2004; 2006). It requires only species presence data (not absence) and environmental variable (continuous or categorical) layers for the study area. We used the freely available Maxent software, version 3.1, which generates an estimate of probability of presence of the species that varies from 0 to 1, where 0 being the lowest and 1 the highest probability. The 31 occurrence records gathered during our preliminary search and 14 environmental predictors were used in Maxent to model potential habitat distribution for *V. wightii*. We used auto features and maintained other settings as default (Phillips *et al.*, 2004), but trying a replicated modelling procedure with 5 replications. After running the analysis and obtaining prediction as grd file, Diva-Gis was used to edit the species distribution map such that administrative layers and occurrence points were merged with the prediction map.

Results

Survey Based on Climatic Similarity

The reported localities of *Vanda wightii* marked on climatic maps revealed a significant coincidence of receiving low precipitation (30-60 cm) during NorthEast monsoon season in Kerala (Fig. 2). Four points outside Kerala (Mangalapuram, Coimbatore, Belthangady and Subramanya) are very close to Kerala and also receive 20-40 cm rains during the latter season. Search in reported localities and similar climatic zones in Idukki and Kasaragod district of Kerala and Dakshina Kannada district of Karnataka enabled us to gather about 141 occurrence points, of which, 31 points were separated by one to several kilometers (Table 3). Also, the altitude of *V. wightii* habitats ranged from 34-871 m above msl. A few occurrence points in Sullia, Palakkad and Idikki districts were identified after preparing a pilot distribution model, created using about 15 occurrence records gathered based on preliminary search in areas of climatic similarity and also reported localities (Mangalapuram and Coimbatore excluded).

Modelling Studies

Modelling studies revealed potential distribution (31.56 to 47.52% probability) of *V. wightii* in a distance of over 405 km extending from Idukki district of Kerala to Dakshina Kannada district of Karnataka (Fig 3). Climatic condition (15.77-31.56% probability) also seems to be good to support *V. wightii* survival in Pathanamthitta district of Kerala and Uduppi district of Karnataka. Besides, Central province in Sri Lanka also appears to possess suitable habitats for *V. wightii*. All the occurrence records fell in the predicted areas; 16 in the 47.52 64-100% probable area, 13 in the 47.5-64% probable area and only 2 in the less suitable areas (0-47.5% probability). The major environmental variables contributing to the Maxent model (Table 3) are precipitation in the coldest quarter (bio 19; 72.5%), precipitation in the warmest quarter (bio 18; 7.4%) and annual precipitation (bio 12; 6.6%). However, internal jackknife test revealed (Fig. 4) bio 4 (Temperature seasonality (Coefficient of Variation) and bio 7 (Temperature annual range = Max Temperature of warmest period - Min temperature of coldest period) also possessed high training gain equal to precipitation. Mean omission on test data was also very close to predicted omission.

Discussion

Distribution data on threatened and endangered species are often sparse and clustered making it difficult to model their suitable habitat distribution using commonly used modelling approaches (Sunil Kumar and Stohlgren, 2009). Particularly, in such cases of sparse data, environmental matching approach has been applied to trace potential occurrences in other localities (Siqueira *et al.*, 2009) as a prerequisite to gather sufficient data for modeling. *V. wightii* is a similar species having sparse data to find out potential presence in other localities through modeling studies. However, search based on climatic similarity enabled

Table 3. Geo-reference points (~1 KM spatial data) of *Vanda wightii* occurrence in Kerala and Karnataka

Population	Latitude	Longitude	Geographical area	District	Altitude(m)
1	9.753211	76.98285	Idukki WLS	Idukki	790
2	9.763739	77.00232	Idukki WLS	Idukki	819
3	9.774333	76.99353	Idukki WLS	Idukki	814
4	9.827003	77.01376	Idukki IL	Idukki	850
5	9.780394	77.0612	Ayyappankovil RS	Idukki	871
6	9.775372	77.07055	Ayyappankovil RS	Idukki	870
7	9.742683	77.02115	Ayyappankovil RS	Idukki	768
8	9.756842	76.98212	Idukki WLS	Idukki	810
9	10.8134	76.79857	Walayar IL[1]	Palakkad	176
10	10.95212	76.40689	Kottoppadam IL	Palakkad	95
11	10.99267	76.40973	Kottoppadam IL	Palakkad	94
12	11.0248	76.32975	Alanallur IL	Palakkad	70
13	10.99415	76.40357	Kottoppadam IL	Palakkad	95
14	11.02283	76.336	Palakkuzhy IL	Palakkad	79
15	10.99527	76.40118	Kottoppadam IL	Palakkad	95
16	11.07522	76.26647	Melattur IL[2]	Malappuram	60
17	11.26552	76.20888	Vadapuram FF	Malappuram	34
18	12.02377	75.52562	Srikantapuram IL	Kannur	28
19	12.06847	75.51473	Srikantapuram IL[2]	Kannur	117
20	12.068	75.50135	Srikantapuram IL	Kannur	109
21	12.54825	75.16505	Karadukka FF	Kasaragod	183
22	12.53663	75.16028	Karadukka FF	Kasaragod	178
23	12.53662	75.15915	Karadukka FF	Kasaragod	174
24	12.53242	75.15928	Karadukka FF	Kasaragod	181
25	12.53043	75.21662	Bandadka RS	Kasaragod	114
26	12.53535	75.2035	Bandadka RS	Kasaragod	221
27	12.52468	75.20712	Bandadka RS	Kasaragod	203
28	12.53535	75.2035	Bandadka RS	Kasaragod	202
29	12.55158	75.34815	Sullia IL	Dakshina Kannada	92
30	12.98543	75.27697	Belthangadi [3]	Dakshina Kannada	~80
31	12.67065	75.60648	Subramanya[3]	Dakshina Kannada	~80

Recollection from type locality[1], other known localities[2] or known locality[3] but not surveyed at present. WLS-Wild Life Sanctuary; RS- reserve forest; FF- Forest Fragment; IL-Inhabited land (trees in temple, along highways or private land).

to find additional populations and thus to gather sufficient geo-referenced records. Despite the study did not include herbarium preparation and documentation, live collection of samples from all the localities maintained at JNTBGRI flowered in 2-3 consecutive years to confirm their identity. *V. wightii* is an epiphytic orchid, inhabiting on *Ficus religiosa* as host at 60-80 m altitudes as per the reports

(Satheeshkumar *et al.*, 2006). Nevertheless, the present study revealed their distribution at altitudes extending to 870m inhabiting on diverse hosts common to deciduous forests, like *Dalbergia latifolia, Ficus bengalensis, Mangifera indica, Stereospermum colais, Strychnos nux-vomica, Tectona grandis,* and populations of *V. wightii* noticed in sanctuary, fragmented forests and inhabited lands in the present study indicate that the species remained unknown probably due to misidentification rather than sincere efforts to trace them. The species is much similar to *Vanda tessellata,* once common to lower altitudes of Western Ghats. Therefore, earlier flora workers probably treated them as *V. tessellata* as those collected from Vadapuram, Nilambur (Sivarajan and Mathew ,1997). The sample we collected from the latter locality is nothing but *V. wightii.* Eventually, we could not locate any *V. tesssellata* from Nilambur. The herbarium documented by earlier flora workers (Sivarajan and Mathew,1997) is in fact, needed to verify for final conclusion. Although Ceylon is one of the type locality of *V. wightii* (Satheeshkumar *et al.,* 2006) we could not assign a probable geo-reference point for the locality as there is no report after the original collection. Now, it is evident from the created model, that the central province in Sri Lanka possess suitable habitat for *V. wightii.* But due to habitat destruction and fragmentation, spreading of the species to presently available forest land in Sri Lanka had not happened as observed in Kerala and Karnataka. Thus the species is supposed to be extinct in Sri Lanka.

The results of the potential distribution model for *V. wightii* (Fig. 3) suggest that this species can grow in regions of Central province of Sri Lanka to Uduppi district of Karnataka in India. Their higher probabilities of occurrence are in the deciduous forests in Malappuram, Kannur and Kasaragod districts of Kerala and Dakshina Kannada District of Karnataka. The model has a good predictability, with AUC = 0.997. The results of relative contributions of the environmental variables show that precipitation in the coldest quarter is the variables with highest per cent contribution (72.5), while temperature seasonality showed highest permutation importance (71.9) to the Maxent model. Precipitation of warmest quarter show higher contribution (7.4) as well as permutation importance (20.7) to the model. Moreover, highest training gain acquired by the environmental variables as temperature seasonality, temperature annual range and precipitation coldest quarter as evidenced in jackknife test suggest that the latter three can be considered as predictor variables and that this species may present higher occurrence probabilities in habitats where the precipitation in coldest quarter (October-December) is between 30-60 cm and little variation in temperature throughout the year. However, the most appropriate predictor variable could not be identified in the Maxent model as results of percent contribution, permutation importance and training gain are not matching. This problem of inefficiency is addressed earlier and proved that Maxent model is not good enough to select predictive environmental variable (Aguirre-Gutierrez *et al.*, 2013) even though is the most efficient modelling tool with small sample (Aguirre-Gutierrez *et al.*, 2013; Moraes *et al.*, 2014; Sunil Kumar and Stohlgren, 2009).

Present studies indicate that the habitat distribution patterns for threatened and endangered plant species such as *V. wightii* can be modelled using a small number of occurrence records and environmental variables using Maxent. The study provides the first predicted potential habitat distribution map for a plant species in Kerala, India. The potential habitat distribution map for *V. wightii* can help to discover new populations, identify top-priority survey sites, or to select translocation sites in protected areas close to natural populations (wherever it is in inhabited areas) for more effective conservation.

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