BIODIVERSITAS
Volume 16, Number 2, October 2015
Pages: 109-115

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d160201

Potential distribution of *Monotropa uniflora* as a surrogate for range of Monotropoideae (Ericaceae) in South Asia

PRAKASH PRADHAN
West Bengal Biodiversity Board, Department of Environment, Government of West Bengal, Salt Lake, Sector-III, FD415A, Poura Bhawan, 4th Floor, Kolkata, West Bengal, India, 700 106. Tel.+91 8013126863, ♥email: shresthambj@gmail.com.

Manuscript received: 12 February 2015. Revision accepted: 13 May 2015.

Abstract. *Pradhan P. 2015. Potential distribution of* Monotropa uniflora *as a surrogate for range of Monotropoideae (Ericaceae) in South Asia. Biodiversitas 16: 109-115.* Monotropoideae is a mycoheterotrophic subfamily of Ericaceae. Its members are highly specific to a particular fungal family, which has attributed to the rarity and limited distribution of Monotropoideae. In the past two decades, there are considerable developments in understanding their biology and biogeography, among which, the distribution of *Monotropa uniflora* L. and *M. hypopitys* L. has been extensively studied. In this contribution, Ecological Niche Modeling of *M. uniflora* has been conducted to test its earlier proposed distribution in South Asia, to test the spatial scale of the said proposal, to test its potential distribution as a surrogate for range of Monotropoideae in South Asia and to prioritize conservation areas for *M. uniflora* in the region. The model was built with five occurrence details of the rare plant *M. uniflora* in Western and Eastern Himalaya, in relation to 19 bioclimatic explanatory variables, performed in MaxEnt. The results show the good performance of the model with the training AUC of 0.994. 1,50,316 square Km. of suitable areas have been predicted for the growth of *M. uniflora* (IHS ≥0.5) in South Asia, many areas of which is in line with earlier distributional reports. The bioclimatic variables are able to predict and suitably justify the spatial distribution of *M. uniflora*. The predicted range of the species could be established for potential distribution of other Asian Monotropoids like *Monotropastrum* and *Cheilotheca*.

Key words: Ecological Niche Modeling, Himalaya, MaxEnt, Mycoheterotrophy, Russulaceae
Abbreviations: IHS = Index of Habitat Suitability; Bio = Bioclimatic variable

INTRODUCTION

Mycoheterotrophy includes an obligatory reliance of achlorophyllous and non-photosynthetic plants upon specialized mycorrhizal associates for carbon influx (Klooster and Culley 2009). Monotropoideae is a mycoheterotrophic subfamily of Ericaceae, consisting of 10 genera and 15 species (Wallace 1975). Leake (1994) has reported 260 species of Mycoheterotrophic plants as endemic to Palaeotropics, extending from India in the West to Papua-New Guinea and Japan in the East. Endemic taxa of Monotropoideae have been reported from Western North America (seven species) and Asia (two *Monotropastrum* species and two *Cheilotheca* species and a variety) (Tsukaya et al. 2008), preferring to grow mostly in shady old growth forests (Min et al. 2012). Their endemism and narrow geographic range have been linked to limited distribution of their taxa specific mycorrhizal fungal partners (Kruckeberg and Rabinowitz 1985; Bidartondo and Bruns 2001), and such trophic structure has left the subfamily with very isolated and rare taxa (Klooster and Culley 2009). *Monotropa uniflora* L. and *M. hypopitys* L. though distantly related but are the only species within Monotropoideae which are distributed across Neotropics and Palaeotropics (Leake 1994). Although Leake (1994) has indicated broad range of genus *Monotropa* in Indian subcontinent, *M. uniflora* is considered regionally rare in Indian states of West Bengal (WBBB 2012; FRLHT 2015) and Meghalaya (Mir et al. 2014).

Suitability of climate and presence of dense and shaded forest habitat has been attributed for the evolution of heterotrophy in paleotropics and neotropics (Leake 1994). Similarly, Ecological Niche/climate modeling has been proposed to act as a successful marker to infer the phylogeographic and demographic histories of mycoheterotrophic plants by Taylor et al. (2013). In this regard, paleo-distribution modeling of *M. hypopitys* in North America has been successfully conducted in MaxEnt using bioclimatic variables (Beatty and Provan 2011), however no study has been focused on Monotropoideae as a whole or any species therein in South Asia regarding their distribution in bioclimatic envelope. For planning suitable conservation action for Monotropoideae in this region, prime necessity is to prioritize areas for conservation having high suitability of the ecological niche of the taxa.

In this contribution, Ecological Niche Modeling of *M. uniflora* has been conducted to test earlier proposed distribution of the species in South Asia, to test the spatial scale of the said proposal, to test potential distribution of the species as a surrogate for range of Monotropoideae in South Asia and to prioritize conservation areas for *M. uniflora* in the region.

MATERIALS AND METHODS

Occurrence records and site characteristics

Occurrence records were obtained with the help of Garmin Etrex GPS machine for the locations of Jorepokhari (Figure 1); data from Rachela were obtained from Divisional Forest Office (Research Division), Darjeeling; occurrences in Phedkhal, Jakholi and Mandal of Uttarakhand were derived from Semwal et al. (2014) and in communication with Dr. Semwal (Figure 2). All the occurrence sites have montane topography. Vegetation wise, Rachela and Phedkhal have Oak dominated vegetation, Jakholi has mixed woodlands, Mandal has mixed forest with Oak, Birch and Cedrus, while Jorepokhari has mixed woodlands of *Cryptomeria japonica*, Oak and Bamboos. The geographical features of the occurrence sites are shown in Table 1.

Figure 2. *Monotropa uniflora* plants observed in Jorepokhari, Darjeeling District, West Bengal, India

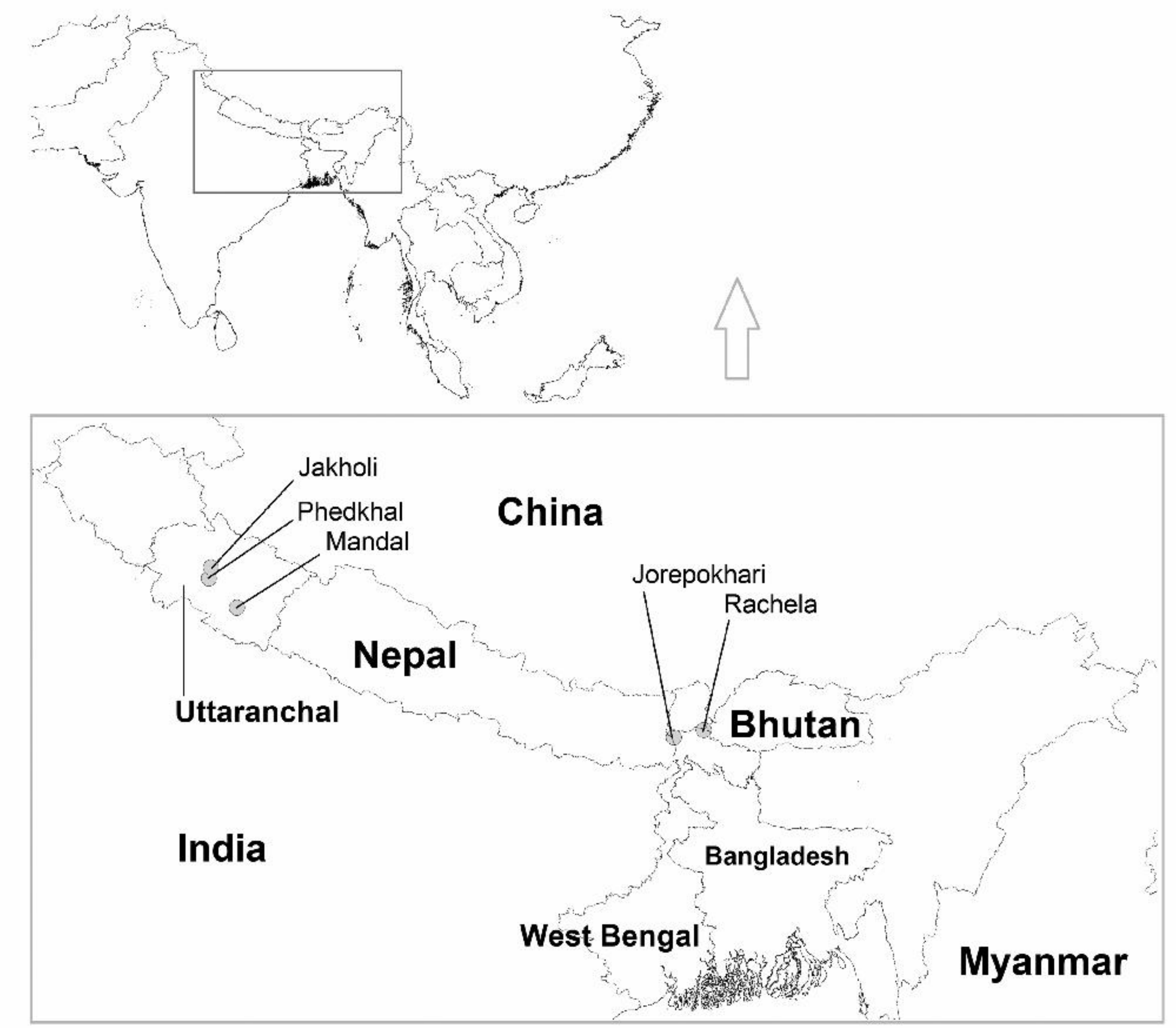

Figure 1. Occurrence records utilized for modelling potential distribution of *Monotropa uniflora*

Table 1. Geographical and climatic features of the occurrence sites; Tmin=mean monthly minimum temperature, Tmax=mean monthly maximum temperature, PPT=annual precipitation.

Site	Longitude	Latitude	Altitude (m)	Tmin avg (˚C)	Tmax avg (˚C)	PPT (mm)	Aspect
Jorepokhari	88.1490	26.9877	2239	9.3	16.1	2268	351.92 (N)
Rachela	88.7414	27.1378	3124	1.7	12.8	1068	312.45 (NW)
Phedkhal	78.8704	30.1682	1842	10.3	19.4	1634	308.95 (NW)
Jakholi	78.9080	30.3862	1706	10.9	20.4	1467	117.88 (SE)
Mandal	79.4331	29.5789	1621	9.6	19.5	1784	56.97 (NE)

Table 2. Range of Index of Habitat Suitability (IHS) along with predicted area and the respective percentage of the total suitable area.

IHS	Predicted area km^2	% of total suitable area
0.5 - 0.599	1,50,316	35.06
0.6 - 0.699	98,045	22.87
0.7 - 0.799	76,717	17.89
0.8 - 0.899	63,697	14.86
0.9 - 1	39,968	9.32

Modeling species distribution - Modeling method

MaxEnt program version 3.3.3 k (Phillips et al. 2006; Phillips and Dudik 2008) is a maximum entropy based general-purpose machine learning method and it was used for modeling species distribution in geographic space and creation of habitat suitability maps. Entropy in the context of probability theory and statistics measures the amount of information that is contained in a random variable or unknown quantity. MaxEnt uses the basic set of information to model the distribution of a species, i.e., a set of samples (species presence) available from a geographical region, which is linked to a set of explanatory variables (e.g. climatic).

Explanatory variables

Climatic variables of monthly precipitation and monthly mean, minimum and maximum temperature at a spatial resolution of 30 arc seconds (~1 × 1 km resolution) were derived from WORLDCLIM (Hijmans et al. 2005) (tile 18, 19, 28 and 29) which includes interpolation of climatic records from global network of 4000 climate stations, with time series of 1950–2000. Current investigation doesn't incorporate climatic information of tile 110 and 210 of WORLDCLIM, hence geographic space of East Asian countries like Taiwan, Japan etc. are excluded for potential species distribution. Using DIVA-GIS version 7.5 (Hijmans et al. 2001), tile data were converted into 19 bioclimatic variables i.e., annual mean temperature [Bio1], mean monthly temperature range [Bio2], isothermality [Bio3], temperature seasonality [Bio4], max temperature of warmest month [Bio5], min temperature of coldest month [Bio6], temperature annual range [Bio7], mean temperature of wettest quarter [Bio8], mean temperature of driest quarter [Bio9], mean temperature of warmest quarter [Bio10], mean temperature of coldest quarter [Bio11], annual precipitation [Bio12], precipitation of wettest month [Bio13], precipitation of driest month [Bio14], precipitation seasonality [Bio15], precipitation of wettest quarter [Bio16], precipitation of driest quarter [Bio17], precipitation of warmest quarter [Bio18], precipitation of coldest quarter [Bio19] (Busby 1986; Nix 1986; Hijmans et al. 2005) in ESRI ASC format for use in MaxEnt program. These bioclimatic variables express spatial variation in annual means, seasonality and extreme or limiting climatic factors and represent biologically meaningful parameters for characterizing species distributions (Saatchi et al. 2008) hence they were used as explanatory variables.

Model building and evaluation

Presence-only data were used for model building. However, in order to evaluate models on the basis of error rates, absence details are needed. To overcome this, 25,000 random points throughout the study area were assumed as absence 'pseudo-absence' (Zaniewski et al. 2002). Linear regularization feature was used for model building; default value of 1 for β regularization which gives consistent AUC peaks (Phillips et al., 2004) was used; prevalence or the probability of presence was taken to be 0.5.

Threshold-independent analysis

In the threshold-independent analysis, model performance/strength (the power to discriminate between sites where a species is present, versus those where it is absent) was evaluated using the Area under the Curve (AUC) of the Receiver Operating Characteristic (ROC) curve (Fielding and Bell 1997; Elith and Burgman 2002). The AUC statistic ranges from 0 to 1, where a score of 0.5 implies discrimination that is no better than random, and a score of 1 indicates perfect discrimination (Fielding and Bell 1997; Pearce and Ferrier 2000).

Explanatory variable importance

The importance of each bioclimatic factors explaining the distribution of species was determined by Jackknife analysis of the average gain with training and test data. 500 iterations were conducted for training algorithm, the increase or decrease in regularized gain was added or subtracted, respectively, to the input of the corresponding variable, giving a heuristic estimate of bioclimatic variable contribution for the model (Phillips et al. 2006).

Model output and Mapping

Logistic format was selected which categorizes estimates of probability of occurrence or Index of Habitat Suitability (IHS) within 0-1 (Anderson et al. 2003; Baldwin 2009). In DIVA-GIS, the logistic output grid was reclassified and exported to raster. IHS regions < 0.5 were discarded as random prediction, > 0.5 IHS were treated as suitable areas of species distribution, ≥ 0.7 IHS were treated as the core areas of species distribution (Kuemmerle et al. 2010), and prioritized areas for conservation were taken for IHS ≥0.9.

RESULTS AND DISCUSSION

The potential distribution of *Monotropa uniflora* in South Asia have been found to be in the longitudinal range of 68.94-117.8 decimal degrees and latitudinal range of 6.76-36.81 decimal degrees, covering 1,50,316 square Km (Table 2). Suitable areas for the growth of the species (IHS ≥0.5) have been found in the countries of Tajikistan, Afghanistan, Pakistan, India, Nepal, China, Bangladesh, Myanmar, Srilanka, Laos and Vietnam. Whereas, conservation areas that could be prioritized (IHS ≥0.9) have been found in India, Nepal, China, Afghanistan, Sri Lanka, Myanmar and Vietnam covering are of 39,968 square Km (Figure 3).

The model performed well with the training AUC value above 0.9 (0.994) with the training omission rate of zero for evaluation localities. The jackknife test of variable importance showed the environmental variable with the highest gain when used in isolation (which has the most useful information by itself) to be temperature annual range [Bio7] (maximum temperature of the warmest month - minimum temperature of the coldest month). The environmental variable that decreases the gain the most when it is omitted is precipitation of driest quarter [Bio17], which therefore appears to have the most information that isn't present in the other variables.

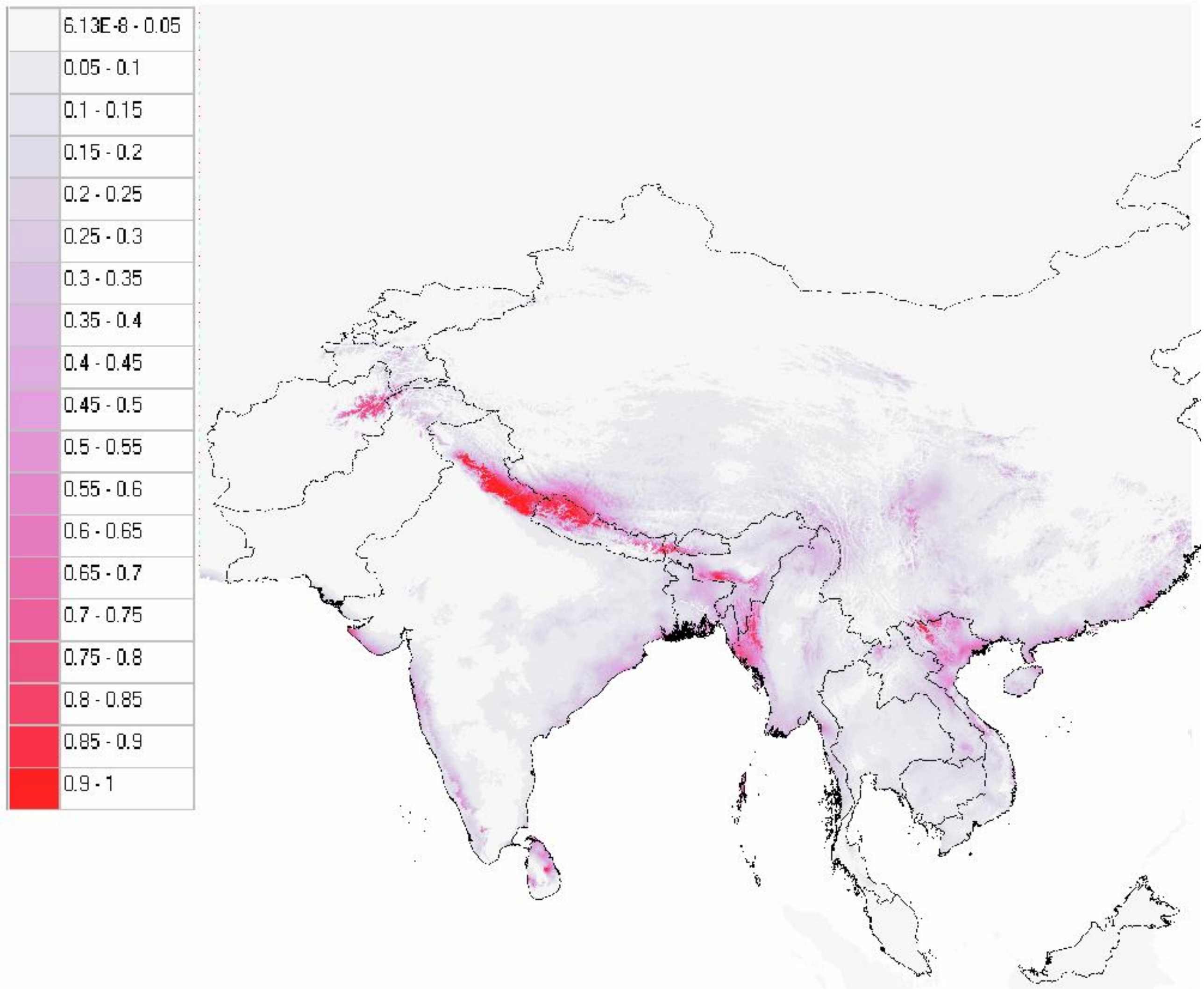

Figure 3. Potential distribution of *Monotropa uniflora* in South Asia with graded Index of Habitat Suitability; warmer colour are indicative of more suitable areas.

Potential conservation areas for *M. uniflora* (IHS ≥0.9) in India are predicted in Eastern Kathua in the state of Jammu and Kashmir; Charua, Chamba, Dalhousie, Kangra, Brahmaur, Dharmshala, Palampur, Baijnath, Kullu, Mandi, Thunag, Chachyot, Karsog, Banjar, Nermand, Ani, Rampur, Rohru, Kotkhai, Theog, Rajgarh, Chaupal, Renuka, Shilla, Jubbal, Paonta in the state of Himachal Pradesh; Chakrata, Purola, Rajgarhi, Dunda, Tehri Garhwal, Dehradun, Northern Lansdown, Pauri, Pauri Garhwal, Devprayag, Narendranagar, Chamoli, Karnaprayag, Ranikhet, Naini Tal, Almora, Champawat, Bageshwar, Southern Joshimath in the state of Uttaranchal; Darjeeling, Kurseong and Kalimpong subdivisions of Darjeeling District in the state of West Bengal; South Eastern Nongstoin area of West Khasi Hills, South Eastern area of Shillong in the state of Meghalaya.

IHS ≥0.9 have been predicted in the Kuran Wa Munjan and Wakhan areas of Afghanistan; Chitral of N.W.F.P. in Pakistan; Central and Northern Matupi, Southern Thlangtlang areas of Myanmar; Baitadi, Dadeldhura, Doti, Western Darchula, Bajhang, Bajura, Kalikot, Northern Jajarkot, South Eastern Jumla, Mugu, South Eastern Humla, Western Dolpa, Northern Myagdi, Northern Rapti, Southern Manang, Northern Kaski, Eastern Ilam of Nepal; Elahera, Thamankadua, Dimbulagala of Sri Lanka; Eastern Lai Chau and Western Lao Cai areas of Vietnam.

Suitable areas (IHS ≥0.5) in China are predicted mostly in South-Central and South-Western China with IHS ranging upto 0.80 in Yunnan, 0.81 in Sichuan and 0.94 in Xizang provinces. Wenshan, Pingbiang Miao, Hekou Yao, Maguan, Malipo, Jinping Yao, Miao and Dai areas of Yunnan province are predicted in continuum of the potential areas from Northern Vietnam; Zanda, Burang and Zhongba area of Xizang province are in continuum of Western and Central Himalaya; Kangding, Luding, Hongya, Hanyuan, Meishan, Ebian Yi, Meigu, Mabian Yi, Ganluo, Jinkouhe areas of Sichuan have been predicted as potential habitats in central China.

Not only is the present prediction takes into account for high altitude habitats, but also coastal vegetation with IHS ranging upto 0.82 in Sagar Island, West Bengal, India. Possibility of suitable habitats of the taxa in coastal areas (IHS ≥0.5) which await prioritized inventory are presently predicted along the coast of Western India, Western Ghats, Bay of Bengal, Gujrat in India; Maungtaw, Buthidaung, Sitwe, Chaungzon, Mudon, Paung, Moulmein areas of Myanmar, Patuakhali, Noakhali, Cox's Bazar, Bandarbon areas of Bangladesh; Thua Thien - Hue, Nghe An, Thai Binh, Hai Phong, Quang Ninh area of Vietnam; Hainan, Haikou, Zhanjiang, Maoming, Yangjiang, Jiangmen, Zhuhai, Zhangzhou areas of China.

Genus *Monotropa* was represented by Leake (1994) to cover Indian, Nepalese and Chinese part of Western, Central, Eastern Himalaya and coastal Indian Subcontinent including other parts of India and Bangladesh and Japan in the east as well. Some of the Monotropoideae reported from Asia include *Cheilotheca malayana* from Japan (Matsuda and Yamada 2003); *M. uniflora* L. from damp deciduous or mixed forests of Anhui, Gansu, Guizhou, Hubei, Jiangxi, Qinghai, Shaanxi, Shanxi, Sichuan, Xizang, Yunnan, Zhejiang regions of China (100-1500 m), Bangladesh, Bhutan, India, Korea, Myanmar, Nepal, Sikkim (FOC 2014; Min et al. 2012); Japan (Bidartondo and Bruns 2001); Murree hills in Pakistan (33.9043˚ N, 73.3942˚ E) (FOP 2014); *Monotropa hypopitys* L. from India (Barik et al. 2009), Japan (Bidartondo and Bruns 2001); *Monotropastrum humile* (D. Don) Hara from Himalaya (East Asia) to Japan (Kitamura et al. 1975; Bidartondo and Bruns 2001), Yunnan, China. (Min et al. 2012), *M. humile* var. *humile* from Fengshan, Chi-Tou Region of Taiwan, Mt. Mirokusan of Korea, Shioupuri, Kathmandu, Nepal (Tsukaya et al. 2008); *Monotropastrum sciaphilum* from Yunnan, China (Min et al. 2012); *Monotropastrum macrocarpum* from Eastern Himalaya (Maheshwari 1969) etc. The potential distribution of *M. uniflora* is in line with the reported distribution of other Monotropoids. Large tracts of Central and Western Himalayas are predicted to be bioclimatically suitable for *M. uniflora*, with disjunct distribution in various countries reaffirming previous reports. However, many areas viz. Zhejiang, Fujian, Guangdong and Hainan of China are predicted in addition to earlier reports (E floras 2014a). Previously, members of Monotropoideae were reported to grow in coastal dunes in the Pacific North West USA with prostrate *Arctostaphylos* mats (Leake 1994). Current prediction of *M. uniflora* in many coastal areas of South Asia therefore necessitates further insight into such habitat of the species. Though temperature annual range have singly important role to play in *M. uniflora* distribution, precipitation of driest quarter may be important in density dependent feedback of fungal biomass in the substratum of mycorrhizal partner of *M. uniflora* (Krivtsov et al. 2006).

Monotropastrum humile and *Cheilotheca malayana* which are distributed in South East Asia from the Himalaya to Japan (Wallace 1975; Kitamura et al. 1975) are similar to *M. uniflora* regarding specialization to fungal family Russulaceae (Young et al. 2002; Matsuda and Yamada 2003). In fact, *M. humile* has been shown to be phylogenetically close to *M. uniflora*, therefore current potential distribution of *M. uniflora* could be functionally predictive for the said species of Monotropoideae. However, currently described potential distribution should be carefully applied to derive cross-continent inference for the species, as collections of *M. uniflora* from Asia, North America, and Central America are indicated to be molecularly diverged and phylogenetically distinct (Bidartondo and Bruns 2001; Neyland and Hennigan 2004).

Monotropa uniflora has been reported in association with *Lithocarpus fenestrata* (Roxb.) Rehd., from temperate forests of Meghalaya and adjoining forests of Shillong plateau, Nagaland, Mizo and Mikir Hills (1800-3500 m.) during winter season from November to March (Singh et al. 2002). Report of *M. hypopitys* L. from North Eastern India (Barik et al. 2009) has indicated that this belt might indeed be abode for the Genera. The projected range of *Monotropa* in Northeast Hills (Meghalaya and Mizoram-Manipur-Kachin forest zones) has also been proposed for prioritized conservation of amphibians and reptiles, highlighting importance of said areas for conservation, which are yet currently out of protected area network (Pawar et al. 2007). One of the collection sites (Jorepokhari) of *M. uniflora* in the present study is located within plantation of *Cryptomeria japonica* (introduced from Japan), while collection of *M. humile* by Matsuda et al. (2011) from ecotone of natural forests of *Cryptomeria japonica* in Tateyama, Japan indicates prevalence and competence of Monotropoideae in allelopathic environment.

The climatic relationship of Monotropoid distribution predicted by earlier workers is in line with the present work and the present study is able to justify the same by refining spatial extent of their distribution in climatically suitable areas. The congruence of the potential range of the *M. uniflora* and other Asian Monotropoids like *Monotropastrum* and *Cheilotheca*, indicates that the potential distribution of *M. uniflora* could act as a surrogate for understanding the range of the Monotropoideae (Ericaceae) in South Asia. The identified novel distributional areas may add to the effective conservation efforts of the subfamily in the region.

One of the prerequisite of realizing niche of a mycoheterotrophic species is the range maps of many ectomycorrhizal host trees, which unfortunately are of limited availability in public domain of a developing nation. Furthermore, modeling species distribution with more occurrence records would be helpful in refining spatial scale of suitable areas. Therefore the currently predicted distribution of Monotropoideae in South Asia has to be further tested with more occurrence records and calibrated with the range maps of ectomycorrhizal fungi and their host trees for consolidation.

ACKNOWLEDGEMENTS

Author would like to share his heartfelt gratitude to Dr. K.C. Semwal (Mekelle University, Ethiopia) and S. Suratna Sherpa, IFS (Divisional Forest Officer, Research Division, Darjeeling, India) for providing inputs to the occurrence records of *Monotropa uniflora*.

REFERENCES

Anderson RP, Lew D, Peterson AT. 2003. Evaluating predictive models of species distributions: criteria for selecting optimal models. Ecol Model 162: 211-232.

Baldwin RA. 2009. Use of maximum entropy modelling in wildlife reserve research. Entropy 11: 854-866.

Barik SK, Lakadong NJ, Baishya R, Chettri A, Das P, Kayang H, Marbaniang D. 2009. A New record of *Monotropa hypopitys* L., A myco-heterotrophic plant from India. J Bombay Nat Hist Soc 106 (1): 127-129.

Beatty GE, Provan J. 2011. Phylogeographic analysis of North American populations of the parasitic herbaceous plant *Monotropa hypopitys* L. reveals a complex history of range expansion from multiple late glacial refugia. J Biogeogr 38: 1585-1599.

Bidartondo MI, Bruns TD. 2001. Extreme specificity in epiparasitic Monotropoideae (Ericaceae): widespread phylogenetic and geographical structure. Mol Ecol 10: 2285-2295.

Busby JR. 1986. A biogeographical analysis of *Nothofagus cunninghamii* (Hook.) Oerst. in southeastern Australia. Aust J Ecol 11: 1-7.

Elith J, Burgman M. 2002. Predictions and their validation: rare plants in the central highlands, Victoria, Australia. In: Scott, JM, Heglund, PJ, Morrison, ML, Haufler, JB, Raphael, MG, Wall, WA and Samson, FB (Eds). Predicting Species Occurrences: Issues of Accuracy and Scale. Island Press, Washington, DC.

Fielding AH, Bell JF. 1997. A review of methods for the assessment of prediction errors in conservation presence/absence models. Environ Conserv 24 (1): 38-49.

FOC [Flora of China]. 2014. *Monotropa uniflora* Linnaeus, Sp. Pl. 1: 387. 1753. Flora of China 14: 256 http://www.efloras.org/florataxon.aspx?flora_id=2&taxon_id=200016137 [30.12.2014]

FOP [Flora of Pakistan]. 2014. *Monotropa uniflora* L., Sp. Pl. 387. 1753. Clarke in Hk. f., I.c. Flora of Pakistan. http://www.efloras.org/florataxon.aspx?flora_id=5 &taxon_id=200016137 [30.12.2014]

FRLHT [Foundation for Revitalisation of Local Health Traditions]. 2015. Medicinal Plants of West Bengal. Foundation for Revitalisation of Local Health Traditions, Bangalore http://envis.frlht.org/checklist/WestBengal.pdf [14.01.2015].

Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A. 2005. Very high resolution interpolated climate surfaces for global land areas. Int J Clim 25: 1965-1978.

Hijmans RJ, Guarino L, Cruz M, Rojas E. 2001. Computer tools for spatial analysis of plant genetic resources data: 1. DIVA-GIS. Plant Genet Resour Newsl 127: 15-19.

Kitamura S, Mutata G, Hori M. 1975. Coloured illustrations of herbaceous plants of Japan (Sympetalae). Osaka: Hoikusha. 297 p.

Klooster MR, Culley TM. 2009. Comparative analysis of the reproductive ecology of *Monotropa* and *Monotropsis*: Two mycoheterotrophic genera in the Monotropoideae (Ericaceae). Am J Bot 96 (7): 1337-1347.

Krivtsov V, Bezginova T, Salmond R, Liddell K, Garside A, Thompson J, Palfreyman JW, Staines HJ, Brendler A, Griffiths B, Watling R. 2006. Ecological interactions between fungi, other biota and forest litter composition in a unique Scottish woodland. Forestry 79 (2): 201-216.

Kuemmerle T, Perzanowski K, Chaskovskyy O, Ostapowicz L, Halada L, Bashta A-T, Kruhlov I, Hostert P, Waller DM, Radeloff VC. 2010. European Bison habitat in the Carpathian Mountains. Biol Conserv 143: 908-916.

Leake JR. 1994. Tansley Review No. 69. The Biology of Myco-Heterotrophic ('Saprophytic') Plants. New Phytol 127 (2): 171-216.

Maheshwari JK. 1969. The need for Conservation of Flora and Floral Provinces in South East Asia. In: Holloway CW (ed.) Papers and Proceedings: Eleventh technical meeting, Third Session: Survival Service Commission: Problems of Threatened Species. IUCN Publications new series No. 18, New Delhi, India.

Matsuda Y, Okochi S, Katayama T, Yamada A, Ito S-I. 2011. Mycorrhizal fungi associated with *Monotropastrum humile* (Ericaceae) in central Japan. Mycorrhiza 21: 569-576.

Matsuda Y, Yamada A. 2003. Mycorrhizal morphology of *Monotropastrum humile* collected from six different forests in central Japan. Mycol 95: 993-997.

Min S, Chang-Qin Z, Yong-Peng M, Welti S, Moreau P-A, Selosse M-A. 2012. Mycorrhizal features and fungal partners of four mycoheterotrophic Monotropoideae (Ericaceae) species from Yunnan, China. Symbiosis. DOI: 10.1007/s13199-012-0180-4

Mir AH, Upadhaya K, Choudhury H. 2014. Diversity of endemic and threatened ethnomedicinal plant species in Meghalaya, North-East India. Int Res J Environ Sci 3 (12): 64-78.

Neyland R, Hennigan MK. 2004. A Cladistic Analysis of *Monotropa uniflora* (Ericaceae) Inferred from Large Ribosomal Subunit (26S) rRNA Gene Sequences. Castanea 69 (4):265-271.

Nix H. 1986. A biogeographic analysis of Australian elapid snakes. Atlas of Elapid Snakes of Australia. Australian Government Publishing Service, Canberra, Australia.

Pawar S, Koo MS, Kelley C, Ahmed MF, Chaudhuri S, Sarkar S. 2007. Conservation assessment and prioritization of areas in Northeast India: Priorities for amphibians and reptiles. Biol Conserv 136: 346-361.

Pearce J, Ferrier S. 2000. Evaluating the predictive performance of habitat models developed using logistic regression. Ecol Model 133 (3): 225-245.

Phillips SJ, Anderson RP, Schapire RE. 2006. Maximum entropy modeling of species geographic distributions. Ecol Model 190 (3-4): 231-259.

Phillips SJ, Dudík M. 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography 31: 161-175.

Saatchi S, Buermann W, ter Steege H, Mori S, Smith TB. 2008. Modeling distribution of Amazonian tree species and diversity using remote sensing measurements. Remote Sens Environ 112: 2000-2017.

Semwal KC, Stephenson SL, Bhatt VK, Bhatt RP. 2014 - Edible mushrooms of the Northwestern Himalaya, India: a study of indigenous knowledge, distribution and diversity. Mycosphere 5 (3): 440-461.

Singh MP, Singh BS, Dey S. 2002. Plant Biodiversity and Taxonomy. Daya Publishing House, New Delhi, India.

Taylor DL, Barrett CF, Beatty GE, Hopkins SE, Kennedy AH, Klooster MR. 2013. Progress and Prospects for the Ecological Genetics of Mycoheterotrophs. In: Merckx VSFT (ed.). Mycoheterotrophy: The Biology of Plants Living on Fungi. Springer Science and Business Media, New York.

Tsukaya H, Yokoyama J, Imaichi R, Ohba H. 2008. Taxonomic status of *Monotropastrum humile*, with special reference to *M. humile* var. *glaberrimum* (Ericaceae, Monotropoideae). J Plant Res 121 (3): 271-278.

Wallace GD. 1975. Studies of the Monotropoideae (Ericaceae): taxonomy and distribution. Wasmann J Biol 33: 1-88.

WBBB [West Bengal Biodiversity Board] 2012. Threatened Plants of West Bengal. Official database of West Bengal Biodiversity Board, Department of Environment Government of West Bengal, India, www.wbbb.nic.in.

Young BW, Massicotte HB, Tackaberry LE, Baldwin QF, Egger KN. 2002. Monotropa uniflora: Morphological and molecular assessment of mycorrhizae retrieved from sites in the Sub-Boreal Spruce biogeoclimatic zone in central British Columbia. Mycorrhiza 12: 75-82.

Zaniewski AE, Lehmann A, Overton McC J. 2002. Predicting species spatial distributions using presence-only data: a case study of native New Zealand ferns. Ecol Model 157: 261-280.