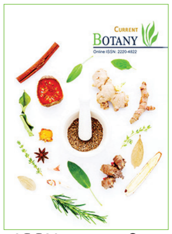
Current Botany 2022, 13: 81-88
doi: 10.25081/cb.2022.v13.7772
https://updatepublishing.com/journal/index.php/cb

Research Article



ISSN: 2220-4822

Potential distribution of six endemic species of *Stanhopea* (Orchidaceae) genus in Mexico

Mayra Hernández de la Cruz, José Luis Alanís-Méndez, Jorge Luis Chagoya-Fuentes, Oswaldo Javier Enciso-Díaz*

Facultad de Ciencias Biológicas y Agropecuarias, Universidad Veracruzana, Tuxpan Veracruz, Mexico

Received: June 11, 2022
Revised: November 15, 2022
Accepted: November 18, 2022
Published: December 12, 2022

***Corresponding author:**
Oswaldo Javier Enciso-Díaz
E-mail: oenciso@uv.mx

ABSTRACT

Stanhopea is an orchid's genus that includes 55 species distributed from Mexico to Argentina. However, due to its horticultural potential, a decrease in wild populations has been generated by the effect of over-collecting, further aggravated by the effect of habitat destruction, placing some species of *Stanhopea* from Mexico in some risk categories. In this work, the potential distribution areas of six endemic *Stanhopea* species in Mexico and in some Federal Natural Protected Area (ANP) were modeled with the use of the MaxEnt software. The potential distribution of the six endemic species in Mexico was obtained, in addition to the fact that it is possible to find one or more species within 74 ANPs.

KEYWORDS: Ecological niche, MaxEnt, Natural Protected Area, *Stanhopea*

INTRODUCTION

The Orchidaceae family in Mexico constitutes one of the most diverse plant groups since it includes around 1, 260 species, of which 60% are epiphytes and 40% are terrestrial (Soto-Arenas *et al*., 2007). In addition, 63% of them are endemic, even though not all of them are under the protection of the Norma Oficial Mexicana (Mexican Oficial Norm) NOM-059-SEMARNAT-2010 (SEMARNAT, 2019). The genus *Stanhopea* Frost ex Hook has gotten around 55 species and six natural hybrid ones (Jenny, 2010), distributed from Mexico (Northwest to the south of the country, mainly in the Sierra Madre Occidental, Sierra Madre Oriental, Sierra Madre del Sur and Sierra Madre of Chiapas) to northern Argentina (Dodson, 1963; Kennedy, 1975; Espejo-Serna & López-Ferrari, 1998; Hágsater, 2005; Soto-Arenas *et al*., 2007; Gerlach, 2010; Téllez-Velazco, 2011). Mexico has the second place of the diversity of the genus with fourteen recognized species and six of these (*Stanhopea hernandezii*, *S. intermedia*, *S. maculosa*, *S. martiana*, *S. Pseudoradiosa* and *S. tigrina*) are endemic within the territory (Jenny, 2010). Through many studies, it has been observed the existence of factors that affect the distribution of the species, and in recent studies about climate change there has been mention of the increase of the global temperature and how it affects biodiversity, which may impact: a) variations in the distribution intervals of the species and in the composition of the communities; b) altimetric and/or latitudinal displacements of vegetation communities and ecosystems and c) changes in the ecosystem functioning (Thuiller *et al*., 2005). at the species level, the changes could generate; displacement, adaptation or local extinction, due to the restricted geographical distribution (Thuiller *et al*., 2005). The models of the distribution of the species have had a wide development and are in expantion with new methods and strategies in the treatment and interpretation of biogeographic information (Mateo *et al*., 2011; Tsiftsis *et al*., 2019). They are cartographic representations of the suitability of an area for the presence of a species in relation to the variables used to generated such representation. Suitability is the mathematical or statistical relationship between the real known distribution and a set of independent variables that are used as indicators. These variables tend to be geological, topographical and climatic (Mateo *et al*., 2011). Thus far, the studies about the genus *Stanhopea* in relation to the potential distribution and the possible environmental conditions that favor the growth and distribution of their different species in the Mexican territory are limited, therefore and due to their ecological and economical relevance, the present work has as objective to determine the potential area of distribution of six endemic species of the genus *Stanhopea* (*S. hernandezii*, *S. intermedia*, *S. maculosa*, *S. martiana*, *S. pseudoradiosa* and *S. tigrina*) in Mexico using the algorithm MaxEnt, as well as to identify the percentage of Federal Protected Natural Areas (ANP) in which there is potential distribution, and that the obtained information can be used to propose models of conservation *in-situ* and *ex-situ*.

Copyright: © The authors. This article is open access and licensed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/) which permits unrestricted, use, distribution and reproduction in any medium, or format for any purpose, even commercially provided the work is properly cited. Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made.

MATERIALS AND METHODS

Location of Study

The present work included the Mexican territory, where a database about the six endemic species of the genus *Stanhopea* was elaborated, using information about the preserved specimens from the collections of national herbariums: herbarium AMO, Instituto Chinoín (AMO), Universidad Autónoma de México (MEXU), Chiapas herbarium (CHIP), Oaxaca herbarium (OAX), Instituto de Ecología (XAL), Universidad Veracruzana (XALU), Universidad Autónoma de Morelos (HUMO), Universidad Autónoma Metropolitana-Iztapalapa (UAM-I), Instituto de investigaciones biológicas de la Universidad Veracruzana's herbarium (CIB), Instituto de Ecología, A. C., Centro Regional del Bajío (IEB), Facultad de Estudios Superiores Iztacala (IZTA), biodiversity national Information system, (SNIB), Instituto Manantlán de Ecología y Conservación de la Biodiversidad y la Universidad de Guadalajara (ZEA). In addition, photographies from online data base from son foreign herbariums where reviewed, such as: Missouri Botanical Garden (www.missouribotanicalgarden.org), Arizona University herbarium (https://biokic.asu.edu/vascular-plant-herbarium) and Munich Nymphenburg botanical garden (http://sweetgum.nybg.org/science/collections/).

Subsequently, all the information was integrated into a Microsoft Excel 2013 worksheet, where the information of the label of each specimen was captured: herbarium, scientific name, recollection date, collector's name, collection number, determiner's name, state, municipality, location, latitude, longitude, altitude, and vegetation. There were excluded those specimens that did not have the registration of the site of recollection, latitude, longitude or whose geographical coordinates were outside of the territory. Finally, one file was created with the geographical information of the species and it was saved with an extension. csv (comma-separated values).

Potential Distribution Model

Additionally, the altitude and a vectorial layer of land use and vegetation (INEGI, 2010) were used, where the protection to the geographical coordinates system was redefined WGS 1984. Subsequently, the layers to determine the Mexican territory where cut and the files were saved in the format ASCII raster, using the software ArcGIS 10.2 (ESRI, 2010).

Parameters and Evaluation of the Potential Distribution Model

The Maximum Entropy algorithm (close to the uniform) was made in the graphic version of the program MaxEnt v3.4.1 (Peterson *et al.*, 2008), using all the predetermined parameters, with the type of logistics output. 30 repetitions with 500 interactions were made for each species. The records of each species and the percentage of the model's training data are shown in Table 1. The remaining percentage corresponds to the validation data of each species. Receiver Operating Characteristic Curve (ROC) partial analysis for MaxEnt (Peterson *et al.*, 2008), was used for the evaluation of the models. When the partial value of the ratio of AUC (area under the curve) moves away from 1, the model improves in relation to an aleatory model.

Table 1: Environmental and topographic variables

	Topographic variables	
1.	Altitude (m)	(alt)
	Environmetal variables	
1.	Annual average temperature (°C)	(Bio1)
2.	Diurnal oscillation of temperature	(Bio2)
3.	Isothermality (quotient between variable BIO2 and BIO7)	(Bio3)
4.	Temperature seasonality (coefficient of variation, %)	(Bio4)
5.	Average maximum temperature of the warmest period (°C)	(Bio5)
6.	Average minimum temperature of the coldest period (°C)	(Bio6)
7.	Annual temperature interval (difference between BIO5 and BIO6)	(Bio7)
8.	Average temperature of the wettest quarter (°C)	(Bio8)
9.	Average temperature of the driest quarter (°C)	(Bio9)
10.	Average temperature of the warmest quarter (°C)	(Bio10)
11.	Average temperature of the coldest quarter (°C)	(Bio11)
12.	Annual rainfall (mm)	(Bio12)
13.	Precipitation of the wettest period (mm)	(Bio13)
14.	Precipitation of the driest period (mm)	(Bio14)
15.	Precipitation seasonality (coefficient of variation, %)	(Bio15)
16.	Precipitation of the wettest quarter (mm)	(Bio16)
17.	Precipitation of the driest quarter (mm)	(Bio17)
18.	Precipitation of the warmest quarter (mm)	(Bio18)
19.	Precipitation of the coldest quarter	(Bio19)

The statistics AUC is the area under the curve of the ROC, in this curve, the abscissa axis represents the rate of incorrectly classified presence (1 – specificity) and the ordinate axis represents the rate of correctly classified presence, or sensibility. The AUC is the integral defined by this curve by varying the cutoff thresholds (Peterson *et al.*, 2008). Furthermore, the statistic AUC takes the values between 0 and 1, where the values smaller than 0,7 indicate that the adjustment of the model is poor, 0,7 – 0,8 the quality of the model is – good, 0,8 – 0,9 the quality of the model is – very good, and the values higher than 0,9 indicate an excellent model quality (Mezaour, 2005).

Additionally, the tool Jackknife from MaxEnt was used for the selection of the variables of higher importance for the bioclimatic profile, which excludes a variable from the model and runs the model with the other variables. In this way, the model's profit with all its variables is compared with the model's profit with the excluded variable. The variable from the model that being considerably affects its efficiency, will be considered an important variable. The model is run with this only variable to see how much it contributes by itself (Peterson, 2006). Finally, to determine if the distribution of the modelled species is found within a protected natural area, layer of the priority zones for the conservation of the Natural Protected Areas National Comision (CONANP, for its initials in Spanish) of 2016 was used.

RESULTS

A total of 200 herbarium records (including 24 duplicates) were obtained for the six endemic species from the genus *Stanhopea*

(Table 2). Regarding the presence of the genus, it was identified that four of the six endemic species (*Stanhopea hernandezii*, *S. intermedia*, *S. martiana* and *S. pseudoradiosa*) are found in the state of Guerrero, particularly in the municipalities of Atoyac de Alvarez and Coyuca de Benítez (Table 3). Also, some of the species were identified as located in small patches of mesophyll forest of the mountain and pine-oak forest. Besides, the environmental variables that were highly correlated and that influenced the distribution model of the species were determined, which can be seen in Table 4.

A) Potential distribution

Stanhopea hernandezii. The prediction of occurrence of the statistical analysis AUC from the model of the distribution obtained a value of 0.826, which indicates a high probability of finding this species. Its potential distribution is found mainly in the Neovolcanic Axis (east of Jalisco, south of Michoacan, Mexico state, Morelos, southwest of Puebla, center of Veracruz), followed by the Sierra Madre del Sur (west of Jalisco, west of Michoacan, Guerrero and Oaxaca) (Table 1, 3 and Figure 1). *Stanhopea intermedia*. Its potential distribution (AUC = 0.865), is found mainly in the Sierra Madre del Sur (west of Jalisco, Colima, West of Michoacan, Guerrero, Oaxaca, south of Mexico state), Pacific coastal plain (south of Sinaloa, west of Nayarit) and the Cordillera Centroamericana (southeast of Oaxaca and southwest of Chiapas) (Table 1, 3 and Figure 2). *Stanhopea maculosa*. It might be found mainly in the Sierra Madre del Sur (west of Jalisco, Colima, Michoacan, Guerrero, Oaxaca), Neovolcanic Axis (Jalisco, Michoacan, Mexico state), Sierra Madre Occidental (Jalisco, Nayarit, Sinaloa, Durango, Chichuahua, and south of Sonora) (AUC=0.873) (Table 1, 3 and Figure 3). *Stanhopea martiana*. Its potential distribution (AUC=0.840), it is found mainly in the Sierra Madre del Sur (West of Jalisco, Colima, Michoacan, Guerrero and Oaxaca), with high probability. In the Sierra Madre Occidental (Nayarit), Neovolcanic Axis (Jalisco, Michoacan, and Mexico state), Cordillera Centroamericana (Southeast of Oaxaca and southwest of Chiapas) and Sierra de Chiapas, with medium to low probability (Table 1, 3 and Figure 4). *Stanhopea pseudoradiosa*. Its potential distribution (AUC=0.829). It is found in the Sierra Madre del Sur (west of Jalisco, Colima, Michoacan, Guerrero and Oaxaca), with high probability. In the Sierra Madre Occidental (Nayarit), Neovolcanic Axis (South of Morelos), Cordillera Centroamericana (southeast of Oaxaca and southwest of Chiapas), and Sierra de Chiapas, with medium to low probability (Table 1, 3 and Figure 5). *Stanhopea tigrina*. The prediction of occurrence in the statistical analysis AUC of the model of distribution generated a value of 0.960, emphasizing that the probability of finding this species is high. Its potential distribution is found mainly in the Sierra Madre Oriental in the states of Queretaro, Hidalgo, Veracruz, Puebla, San Luis Potosí, Tamaulipas, south of Oaxaca, and south of Nuevo Leon (Table 1, 3 and Figure 6).

Table 2: Herbariums and consulted specimens records of the six species of the genus *Stanhopea*

Herbarium	Institution	Records
AMO	Asociación Mexicana de Orquideología, A. C.	52
AMNH	American Museum of Natural History	1
AMES	Harvard University	1
ARIZ	University of Arizona	6
CHIP	Herbario de Chiapas	1
FCME	Facultad de Ciencias, Universidad Nacional Autónoma de México	10
UAMIZ	Universidad Autónoma Metropolitana, Unidad Iztapalapa	24
HUMO	Centro de Investigación en Biodiversidad y Conservación, Universidad Autónoma del Estado de Morelos.	5
IEB	Instituto de Ecología, A. C., Centro Regional del Bajío	13
IZTA	Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México	1
K	Royal Botanic Gardens, Kew	1
MEXU	Instituto de Biología, Universidad Nacional Autónoma de México	18
MO	Missouri Botanical Garden	8
p	Muséum National d'Histoire Naturelle, Francia	2
SNIB	Sistema Nacional de Información sobre Biodiversidad, CONABIO	18
UAT	Instituto de Ecología y Alimentos, Universidad Autónoma de Tamaulipas	2
US	National Museum of Natural History, Smithsonian Institution	15
UCBG	University of California Botanical Garden, University of California, Berkeley	5
XAL	Instituto de Ecología, A. C., Xalapa	11
XALU	Facultad de Biología, Universidad Veracruzana, Xalapa.	1
ZEA	Instituto Manantlán de Ecología y Conservación de la Biodiversidad, Universidad de Guadalajara	5

B) Distribution in ANP

When overlapping the potential distribution map of the six endemic species of the genus *Stanhopea* on the layer of the Protected Natural Areas (ANP, for its initials in Spanish) system for the CONANP, it was observed that the 60% of the potential distribution of the *Stanhopea hernandezii* is not found within the poligone of an ANP. 90% of the potential distribution of *S. intermedia* is not found within an ANP. In the case of *S. maculosa* only 15% is found within an ANP, and 85% is found unprotected even in the areas with the highest probability. *S. martiana* is only covered in the areas with medium and low

Table 3: Known and potential distribution of the studied species of *Stanhopea* in Mexico

Species	Known Distribution	Potential Distribution
Stanhopea hernandezii	Edomex, Gro, Mor, Mich	Edomex, Gro, Mor, Mich, Oax, Pue, Gto.
Stanhopea intermedia	Nay, Jal, Mich, Col, Gro, Oax	Nay, Jal, Mich, Col, Gro, Oax, EdoMex, Sin, Chis.
Stanhopea maculosa	Col, Jal, Mich, Son	Col, Jal, Mich, Son, Chih, Sin, Dgo, Nay, Gro, EdoMex, Oax, Chis.
Stanhopea martiana	Gro, Jal, Nay, Oax	Gro, Jal, Nay, Oax, Mich, Col, Edomex.
Stanhopea psedoradiosa	Col, Gro, Oax	Col, Mich, Gro, Oax, Chis
Stanhopea tigrina	Tamps, SLP, Qro, Hgo, Pue, Ver, Oax.	Tamps, SLP, Qro, Hgo, Pue, Ver, Oax, NL.

probability (15%) within an ANP, in contrast with the areas of highest probability (85%) where it is not found within a poligon of an ANP. In the case of the *S. pseudoradiosa* it is observed that 10% of the model is within an ANP and finally *S. tigrina* only 3% of its potential distribution is covered within the poligon of an ANP (Figure 7).

Table 4: Statistical results estadísticos for the *Stanhopea* species in México

Species		1	2	3	4	5	6
Grographical points*		64	11	22	22	11	73
Model data (%)		75	56	75	75	56	75
Interaction points		500	500	500	500	500	500
Average AUC**		0.826	0.865	0.873	0.840	0.829	0.960
% de contribution	Altitude	0	2.7	24.6	19.3	15.4	14.3
	Bio1	0	0	0	0	0	0
	Bio2	0	0	0	2.3	0.1	5
	Bio3	3.2	0	5.8	0	0	0
	Bio4	0	0	0	0	0	0
	Bio5	8.7	3.5	3.5	7	2.5	6.9
	Bio6	0	0	0	0	0	0.6
	Bio7	10.1	0	0	0	19.2	0
	Bio8	26.3	0	0	0.4	0	0
	Bio9	0	0	0	0	0	16.9
	Bio10	0.6	0	0	4.3	0	0
	Bio11	0	0	0	0	0	0.3
	Bio12	0	0	0	0	0	0
	Bio13	1.3	93.8	25.2	56.7	33.4	18.9
	Bio14	0	0	5.8	0.8	1.5	0
	Bio15	1.2	0	0	0	0	5
	Bio16	0	0	0.2	0	0	0
	Bio17	0	0	3.6	7.7	0	23.6
	Bio18	27.7	0	31.2	1.5	8.7	2.6
	Bio19	20.7	0	0	0	19.2	6

* Geographical points used for modeling

**Values of the AUC of the prediction model of each species, using the curve ROC. Species: 1, *Stanhopea hernandezii; 2, Stanhopea intermedia; 3, Stanhopea maculosa; 4, Stanhopea martiana; 5 Stanhopea pseudoradiosa; 6, Stanhopea tigrina*

DISCUSSION

The modelling of the potential distribution of the species by algorithms such as MaxEnt is an effective tool to identify possible ecological niches of the species that are of interest. In relevance to the above, the models of potential distribution generated for the six endemic species of the genus *Stanhopea* suggest that possibly there are new locations where there haven't been recollections. The study of the genus by the use of specimens from herbariums is complex and sometimes it is not possible to properly identify the species since the flowers can be deformed. For that reason, it is advisable to study the field to have an adequate identification of the species. However, because the flores of the *Stanhopea* last only a few days, it is more likely to find species in the sterile state, so their identification in the field is not easy, being necessary to do several excursions during the corresponding flowering season to be able to find them in the reproductive state, and at the same time do not dismiss other complementary studies such as analysis of molecular biology. The models for each species had a good performance and they can be considered vigorous, the records of presence varied from 11 to 73 among the species, which, according to several authors, is appropriate to do the modelling of species with the algorithm of MaxEnt (Pearson *et al.*, 2007; Shcheglovitova & Anderson, 2013; Boria *et al.*, 2014). The variables with a higher contribution in the models for the six endemic species of *Stanhopea* agreed on three variables; Bio 13 (Precipitation of the wettest period), Bio 19 (Precipitation of the coldest quarter) and altitude. These results confirm that the humidity, precipitation and altitude variables determine the presence and

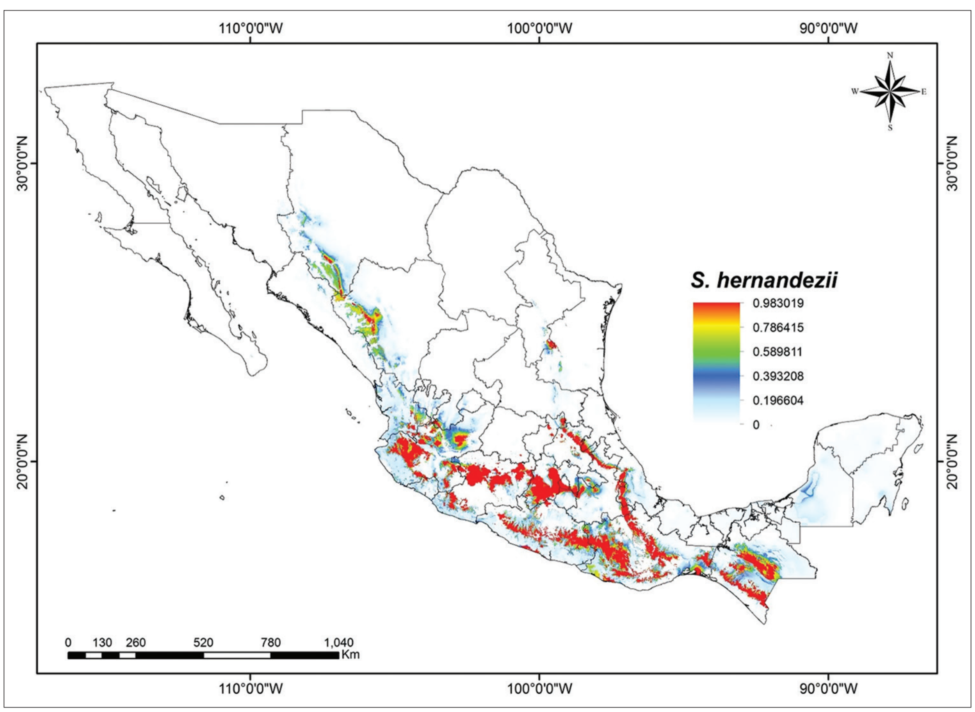


Figure 1: Potential distribution of *Stanhopea hernandezii* in Mexico

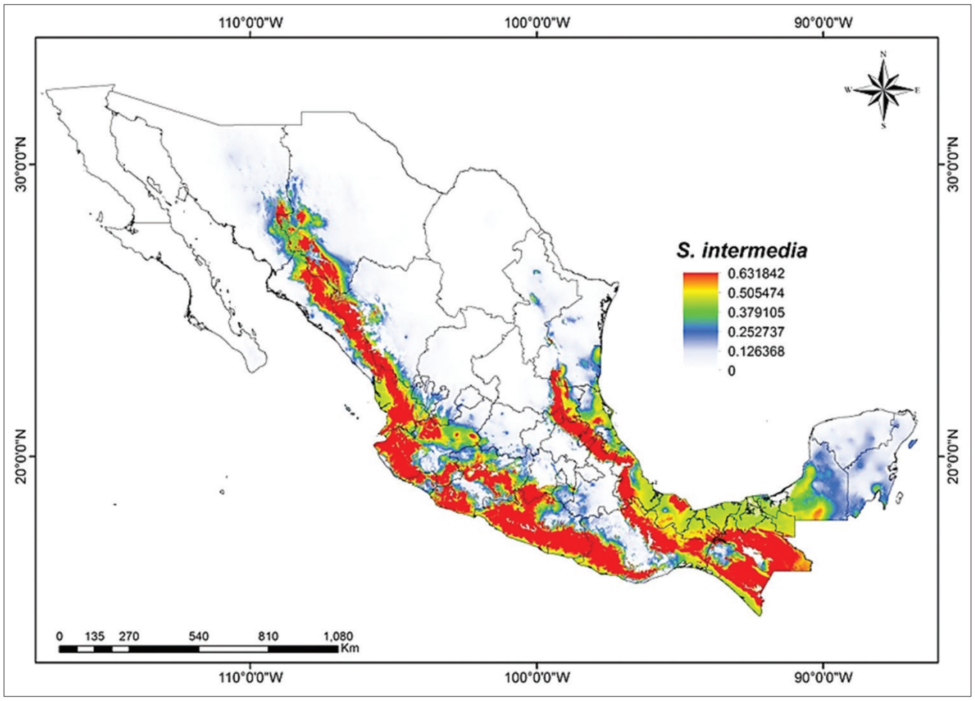


Figure 2: Potential distribution of *Stanhopea intermedia* in Mexico

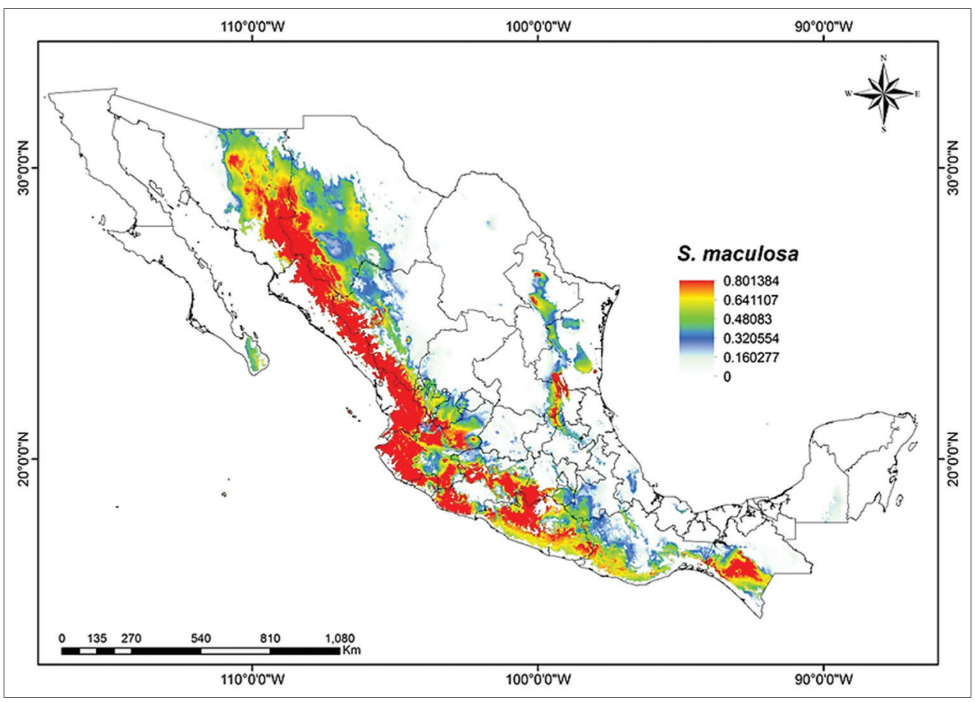


Figure 3: Potential distribution of *Stanhopea maculosa* in Mexico

establishment of orchid populations (Hágsater *et al*., 2005; Téllez-Velazco, 2011).

It should be emphasized that the models where developed in bioclimatic layers obtained from Worldclim2 product from the collection of 50 years of annual seasonal variation and with the use of the statistical analysis of MaxEnt, it was possible to determine the variables that influence the potential distribution of each species. In addition, it is essential to emphasize that the potential distribution models only show areas where there is a probability of finding the species only because they comply with the environmental or topographical characteristics for their growth, but it does not mean that they will actually be seen. The above is due to: 1) the geographical area of the distribution has changed with time (destruction of the habitat for change in the soil), so it can be considered the extinction of the species

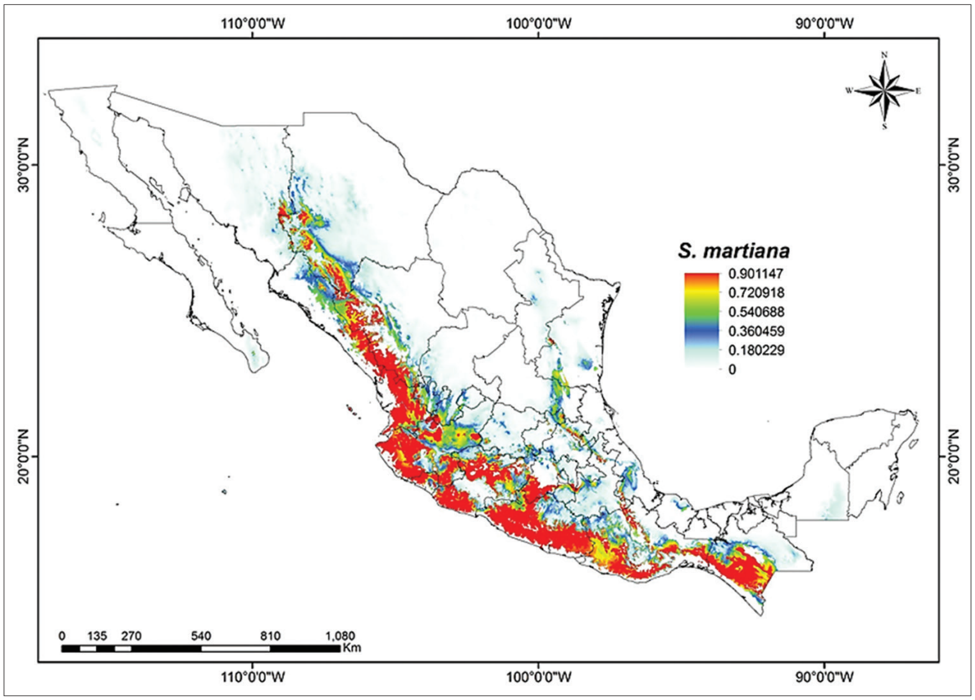


Figure 4: Potential distribution of *Stanhopea martiana* in Mexico

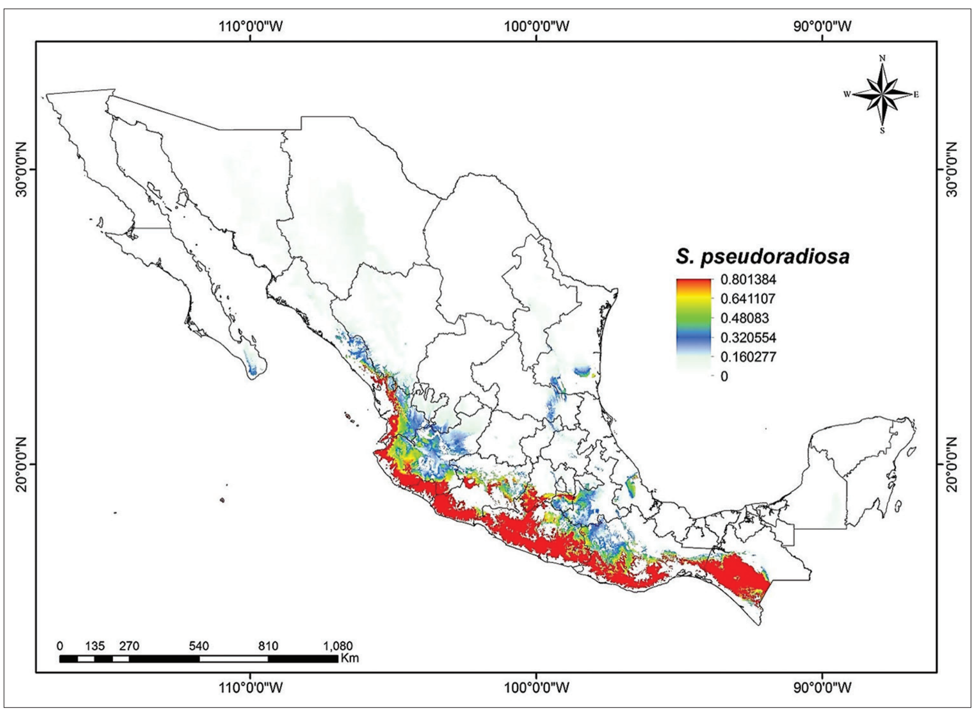


Figure 5: Potential distribution of de *Stanhopea pseudoradiosa* in Mexico

in that area. 2) The species in question is not distributed in a given area in its biogeographical history. It is important to consider those zones where the ideal conditions for the growth and development of several species comply as strategic points to propose areas of conservation *in situ* (as can be observed in Figure 7, in the area of Guerrero where different species of *Stanhopea* converge) or *ex situ* in the areas where, although the species are not distributed biogeographically, but there are the necessary conditions for the establishment of living collection, as it is the case of Oaxaca and Chiapas where in the Figures 1 - 6 can be observed several areas where the variables of distribution of different *Stanhopea* comply.

As for the participation of the Federal ANPs, it is observed that only a few percentages of the species of the studied *Stanhopea* have distribution in any ANP. The above is worrisome because

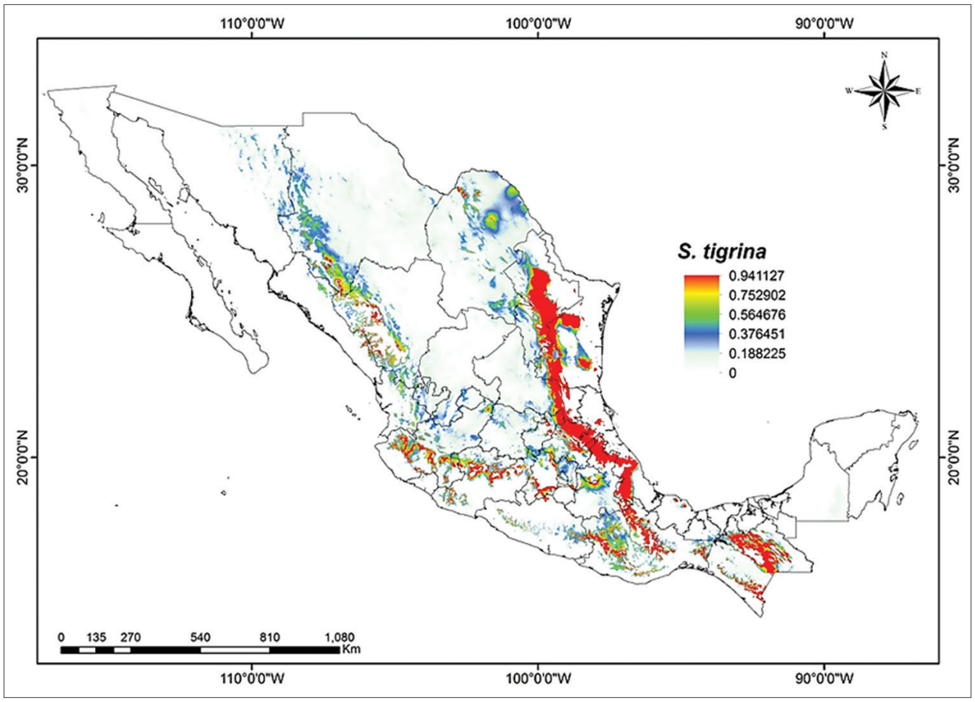


Figure 6: Potential distribution of *Stanhopea tigrina* in Mexico

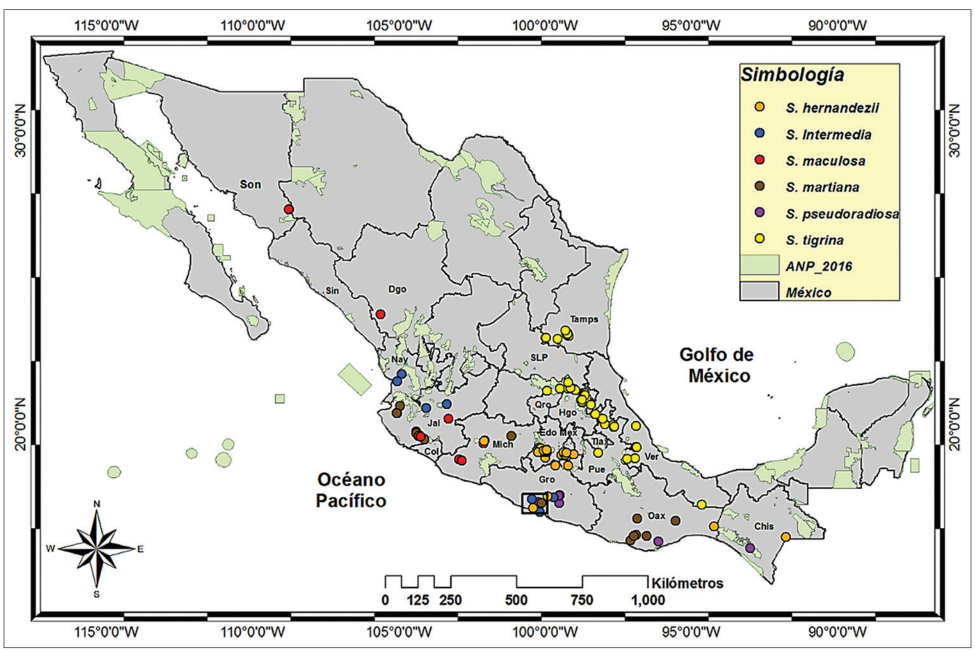


Figure 7: Potential distribution of *Stanhopea* in the ANP

the six species in this study are endemic to Mexico, and therefore, they should be protected by the national system of ANPs. For that reason and based on the fact that orchids stand out for the color and shape of their flowers, as well as the threat to their populations in the natural habitat, the change in the use of the land and the illegal collection of plants to sell as ornamental plants, there should be a search for other kinds of strategies for the care and/or use as controlled crop either *in vitro* or in rustic nurseries, which could lead to an inclusion of the civil society that inhabits in the areas where the orchids are distributed. On the other hand, the selection of some species associated with the mesophyll forest (diagnosed or endemic) is important to justify the maintenance of their habitat and also to propose an integrated plan to protect natural areas in megadiverse countries, such as the case of Mexico. In Mexico, Alanís-Méndez in 2012, generated several models of the potential distribution of orchids in the Protected Natural Area (ANP) "Sierra de Otontepec" and determined the climatic variables of higher importance for their distribution, using the programs Bioclim and Diva Gis. Additionally, with the use of the program, MaxEnt obtained the modelling of the ecological niche of the species *Cyclopogon comosus*, *Encyclia dickinsoniana*, *Encyclia parviflora*, *Oncidium sphacelatum* and *Prosthechea mariae*, which were selected as bioindicators. Based on the generation of models of distribution on the species level, it was proved that wild orchids are essential for the conservation of this ANP in the North of the state of Veracruz.

CONCLUSIONS

It can be emphasized that the resulting maps in this study are useful as a base to propose fieldwork in specific sites, where the presence of the species has been suggested for the model; in addition, specific areas with suitable biotic conditions for the growth and development with the purpose of propagation, reintroduction and preservation of orchids can be proposed. Furthermore, the areas with a higher potential richness of the species were identified to be related to the areas of mesophyll forest of the mountain, which must be protected in Mexico due to the great diversity of species that it harbours (Villaseñor, 2010). Finally, the information on the genus *Stanhopea* in Mexico is scarce, which is why it is necessary to carry out demographic and ecological studies, *in vitro* spread, *ex situ* preservation in botanical gardens and the recognition of where these species are concentrated in order to include them in future conservation plans at the national level.

REFERENCES

Alanís-Méndez, J. L. (2012). *Distribución espacial de las orquídeas silvestres de la Reserva Ecológica "Sierra de Otontepec "Veracruz, México*. Doctoral Dissertation. Universidad de Xalapa.

Boria, R. A., Olson, L. E., Goodman, S. M., & Anderson, R. P. (2014). Spatial filtering to reduce sampling bias can improve the performance of ecological niche models. *Ecological Modelling, 275*, 73-77. https://doi.org/10.1016/j.ecolmodel.2013.12.012

Dodson, C. H. (1963). The Mexican Stanhopea. *American Orchid Society Bulletin, 32*(2), 115-129.

Espejo-Serna, A., & López-Ferrari, A. R. (1998). *Las monocotiledóneas mexicanas, una sinopsis florística.* I. Lista de referencia. Partes VII. UAM-CONABIO, México, D. F.: Consejo nacional de la Flora de México A.C.

ESRI. (2010). Enviromental Systems Research Institute. ArcMap 10.0. Redlands, CA, EEUU.

Gerlach, G. (2010). Stanhopeinae mesoamericane, V. El aroma floral de las Stanhopeas de México. *Lankesteriana: International Journal on Orchidology, 9*(3), 431-442. https://doi.org/10.15517/lank.v0i0.12105

Hágsater, E., Soto-Arenas, M. A., Salazar-Chávez, G. A., Jiménez-Machorro, R., López-Rosas, M. A., & Dressler, R. L. (2005). *Las Orquídeas de México.* México, D. F.: Instituto Chinoin.

INEGI. (2010). *Altitude and a vectorial layer of land use and vegetation*. Retrieved from https://www.inegi.org.mx/temas/usosuelo/#Mapa

Jenny, R. (2010). *The Stanhopea Book.* Allmendingen, Switzerland.

Kennedy, C. C. (1975). The Stanhopeas of Mexico. *Orchid Digest*, *39*(5), 115-129.

Mateo, R. G., Felicísimo, Á. M., & Muñoz, J. (2011). Modelos de distribución de especies: Una revisión sintética. *Revista Chilena de Historia Natural*, *84*(2), 217-240. https://doi.org/10.4067/S0716-078X2011000200008

Mezaour, A.-D. (2005). Filtering Web Documents for a Thematic Warehouse Case Study: eDot a Food Risk Data Warehouse (extended) In M. A. Kłopotek, S. T. Wierzchoń & K. Trojanowski (Eds.), *Intelligent Information Processing and Web Mining: Advances in Soft Computing* (Vol. 31, pp. 269-278) Berlin, Heidelberg: Springer. https://doi.org/10.1007/3-540-32392-9_28

Pearson, R. G., Raxworthy, C. J., Nakamura, M., & Peterson, A. T. (2007). Predicting species distributions from small numbers of occurrence records: a test case using cryptic geckos in Madagascar. *Journal of Biogeography, 34*(1), 102-117. https://doi.org/10.1111/j.1365-2699.2006.01594.x

Peterson, A. T. (2006). Uses and requirements of ecological niche models and related distributional models. *Biodiversity Informatics, 3*, 59-72. https://doi.org/10.17161/bi.v3i0.29

Peterson, A. T., Papes, M., & Soberón, J. (2008). Rethinking receiver operating characteristic analysis applications in ecological niche modeling. *Ecological Modelling, 213*(1), 63-72. https://doi.org/10.1016/j.ecolmodel.2007.11.008

SEMARNAT. 2019. Secretaría del Medio Ambiente y Recursos Naturales. NORMA Oficial Mexicana NOM-059-SEMARNAT-2010. Protección ambiental-Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-Lista de especies en riesgo. Diario Oficial de la Federación. Cd. Mx., México. Obtenido de http://biblioteca.semarnat.gob.mx/janium/Documentos/Ciga/agenda/DOFsr/DO2454.pdf

Shcheglovitova, M., & Anderson, R. P. (2013). Estimating optimal complexity for ecological niche models: a jackknife approach for species with small sample sizes. *Ecological Modelling, 269*, 9-17. https://doi.org/10.1016/j.ecolmodel.2013.08.011

Soto-Arenas, M. A., Hágsater, E., Jiménez-Machorro, R., & Solano-Gómez, R. (2007). Orquídeas de México. Herbario AMO-Instituto Chinoín, A.C. y Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional-Unidad-Oaxaca, Instituto Politécnico Nacional. Informe final SNIB-CONABIO proyecto No. P107. México D. F.

Téllez-Velazco, M. A. A. (2011). Análisis del diagnóstico de la familia Orchidaceae en México. Universidad Autónoma de Chapingo. México. https://www.gob.mx/cms/uploads/attachment/file/225080/Analisis_del_diagnostico_de_la_familia_orchidaceae_en_mexico.pdf

Thuiller, W., Lavorel, S., Araújo, M. B., Sykes, M. T., & Prentice, I. C. (2005). Climate change threats to plant diversity in Europe. *Proceedings of the National Academy of Sciences of the United States of America, 102*(23), 8245-8250. https://doi.org/10.1073/pnas.0409902102

Tsiftsis, S., Štípková, Z., & Kindlmann, P. (2019). Role of way of life, latitude, elevation and climate on the richness and distribution of orchid species. *Biodiversity and Conservation, 28*, 75–96. https://doi.org/10.1007/s10531-018-1637-4

Villaseñor, J. L. (2010). El bosque húmedo de montaña de México y sus plantas vasculares: catálogo florístico-taxonómico. UNAM/CONABIO. México, D. F. https://www.biodiversidad.gob.mx/publicaciones/librosDig/pdf/Bosque%20humedo%20de%20montana.pdf