Patterns of orchid abundance and diversity in an elevation gradient in the Cloud Forest of Tezonapa, Veracruz, Mexico

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ABSTRACT

Objective: To analyze the orchid abundance and diversity in an elevation gradient in the tropical montane cloud forest (TMCF) of Tezonapa, Veracruz, Mexico.

Design/Methodology/Approach: Orchids were sampled in 100×20 m temporary transects, randomly distributed in an elevation gradient (T1=800-900, T2=901-1,000, T3=1,001-1,100, T4=1,101-1,200, and T5=1,201-1,300 m). Each specimen was georeferenced, species were identified, and the conservation status was determined.

Results: The diversity in the area reached 26 orchid species from 16 genera. The passport data of 204 specimens were recorded.

Study Limitations/Implications: The greatest abundance, richness, and diversity were recorded in T3. This result matches the favorable temperature and humidity conditions required for the development of orchids in a TMCF.

Findings/Conclusions: *Stanhopea tigrina* is in danger of extinction. Therefore, the following protocol is urgently required: *in vitro* propagation, release of individuals into the environment, and follow-up of wild populations for genetic improvement purposes.

Key words: Cloud Forest, NOM-059, Orchidaceae, orchid flora.

INTRODUCTION

Family Orchidaceae is composed of approximately 25,000 species and makes up 10% of the world floral diversity (Atwood, 1986). Mexico's diverse physiography and weather conditions have favored many biological families, particularly 167 genera and 1,296 species of family Orchidaceae (Rzendowski, 2006).

Orchid abundance is threatened by weather and anthropic factors that damage, destabilize, and carelessly exploit their populations, ultimately decimating them (Soto-Arenas *et al.*, 2007; Toledo *et al.*, 2020). Despite their environmental, industrial, medicinal, food, religious, and economic importance, at least 22 orchid species have become extinct in Mexico (Emeterio-Lara *et al.*, 2016). Wild orchids are informally sold in local markets or online, which increases the number of threatened specimens that are plundered, according to the NOM-059-SEMARNAT-2010 Mexican standard (Tejeda-Sartorius and Téllez-Velasco, 2017; SEMARNAT, 2010, 2019).

Most orchids are found in tropical ecosystems; however, the tropical montane cloud forest (TMCF) houses 60% of the Mexican orchid flora (Toledo *et al.*, 2020; CONABIO, 2022). The TMCF accounts for 18,534 km^2 (1%) of the Mexican territory and faces disturbance problems resulting from anthropogenic factors, leading to the loss of orchid biodiversity (Francisco-Ventura *et al.*, 2018; Toledo *et al.*, 2020; CONABIO, 2022).

The TMCFs record the highest orchid diversity in Mexico (443 species). Most of them (257 species from 93 genera) are found in the state of Veracruz (Villaseñor, 2010). Few researches have studied the abundance and diversity of orchids in the TMCFs of the state of Veracruz (Tejeda-Sartorius *et al.*, 2013; Tejeda-Sartorius and Téllez-Velasco, 2017). Díaz *et al.* (2012) reported that the main causes of the patterns of diversity and abundance are topography, slope, exposure to solar radiation, and altitude. Consequently, the patterns of orchid abundance and diversity were analyzed in an elevation gradient in the TMCF of Tezonapa, Veracruz, Mexico, to propose potential conservation and management plans (Tejeda-Sartorius and Téllez-Velasco, 2017).

MATERIALS AND METHODS

The work was carried out from July to December 2022, in the municipality of Tezonapa, Veracruz (Figure 1), which has a border to the north with the municipality of Zongolica, to the west with the municipality of Omealca and the state of Oaxaca, to the south with

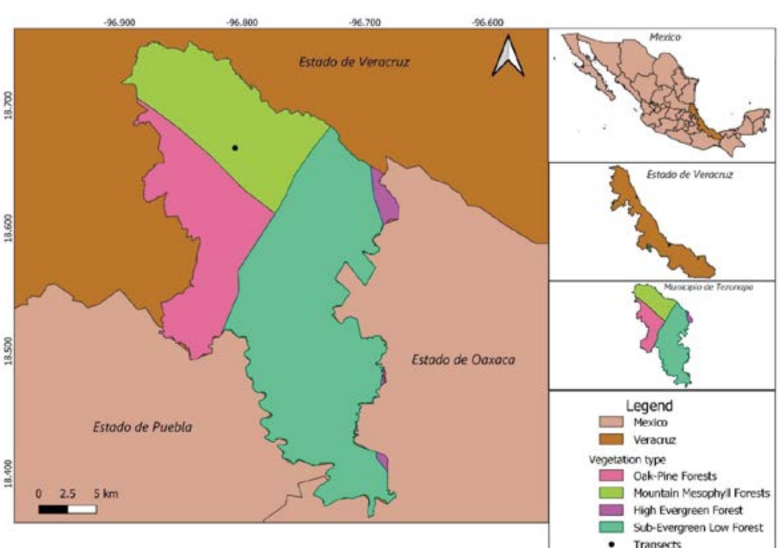

Figure 1. Orchid sampling area in the TMCF of Tezonapa, Veracruz (CONABIO, 2001).

the states of Oaxaca and Puebla, and to the west with the municipality of Zongolica and the state of Puebla. The municipality is located between 18.366° and 18.75° N and 96.666° and 96.916° W, at an altitude between 60 and 1,500 m. The average temperature ranges from 18 to 26 °C, while the mean annual rainfall ranges from 2,400 to 3,100 mm (SIEGVER, 2020; INEGI, 2021). The vegetation includes oak and pine forest, tropical montane cloud forest, montane tropical evergreen forest, and lowland subperennifolious tropical forest; meanwhile, the soils include humic acrisols, orthic acrisols, chromic luvisols, orthic luvisols, chromic vertisols, pellic vertisols, and lithosols (CONABIO, 2001; INIFAP-CONABIO, 1995).

The orchids were collected following the Hágsater-Stewart method (1986) and the sampling was carried out in 100×20 m temporary transects (Mostacedo and Fredericksen, 2000), randomly distributed in an elevation gradient (T1=800-900, T2=901-1,000, T3=1,001-1,100, T4=1,101-1,200, and T5=1,201-1,300 m). Each specimen was labeled with its collection number, transect number, and habitat; the georeferenced coordinates were recorded with a Garmin eTrex® 10 GPS. The collected plants were taken to the nursery of the Instituto Tecnológico de Zongolica for their conservation and taxonomic identification.

The orchids were identified according to Pridgeon *et al.* (2005, 2009), Blanco *et al.* (2007), Soto-Arenas *et al.* (2007), and Chase *et al.* (2015). The data were checked with the information available in virtual herbaria (AMO) and digital platforms (CONABIO, iNaturalista, Missouri Botanical Garden, and Global Biodiversity Information Facility (GBIF)). Additionally, the conservation status was determined according to the NOM-059-SEMARNAT-2010 (SEMARNAT, 2010, 2019).

The richness and abundance of the orchid species recorded at different altitudes were compared with the species cumulative curve analysis. The curves were developed using the iNEXT software, based on the number of individuals and species reported for each sample (Chao *et al.*, 2016). When confidence intervals overlap, there is no significant differences in richness and/or abundance (Cumming *et al.*, 2007).

The species inventory completeness was determined calculating the coverage estimation of the sample, which indicates the ratio of the plant community represented by the collected species. When the sample coverage approaches 100%, the sampling has been completed, considering the collection effort and technologies employed. In addition, the values of the effective number of species (q^0 or abundance, q^1 or abundant species, and q^2 or very rare species) can be therefore compared (Chao and Jost, 2012) with sets whose inventory has a similar completeness level (Magurran and Henderson, 2010). A Principal Component Analysis (PCA) was likewise applied, using the abundance correlation matrix for each classified species for the altitude range. The orchid species were classified based on the classification criteria of epiphytic plants; their frequency was determined with the Infostat software (2021), based on the elevation gradient.

RESULTS AND DISCUSSION

Orchid abundance is made up of 204 specimens, 26 species, and 16 genera. Figure 2 includes some of the most representative species. *Epidendrum* was the genus with the highest number of species (*E. amphistomum*, *E. melistagum*, *E. paranthicum*, *E. radicans*, *E.*

ramosum, and *E. rogidum*), followed by *Campylocenthum* (*C. micranthum* and *C. schiedei*), *Dichaea* (*D. glauca* and *D. muricatoides*), *Isochilus* (*I. unirantiacus* and *I. aurantiacus*), and *Prosthechea* (*P. ochracea* and *P. cochleata*). According to the distribution per habit, the most abundant species are: epiphytes (93%), ground and epiphytes (6%), and lithophytes and epiphytes (1%). Tejeda-Sartorius and Téllez-Velasco (2017) reported a similar diversity in their study of a TMCF in the state of Veracruz; they identified 36 orchid species from 25 genera, the most diverse of which was *Epidendrum* (7). The orchid abundance reported in this study accounts for 5.86% and 10.11% of the orchid flora of Mexico and the state of Veracruz, respectively (Villaseñor and Gual-Díaz, 2014; Villaseñor, 2010).

T3 (1,001-1,100 m, the intermediate elevation stratum) recorded greater abundance and richness than the other strata (Table 1). However, Díaz *et al*. (2012) reported different results: they found greater diversity and abundance of plant species at higher than at lower altitudes. They attributed this result to the intensive management, easy access, and high rates of resource exploitation.

The T3 altitude recorded the highest diversity of species and abundance of individuals per species. Meanwhile, T5 was significantly similar recorded the same number of species, but highest abundance (Figure 3).

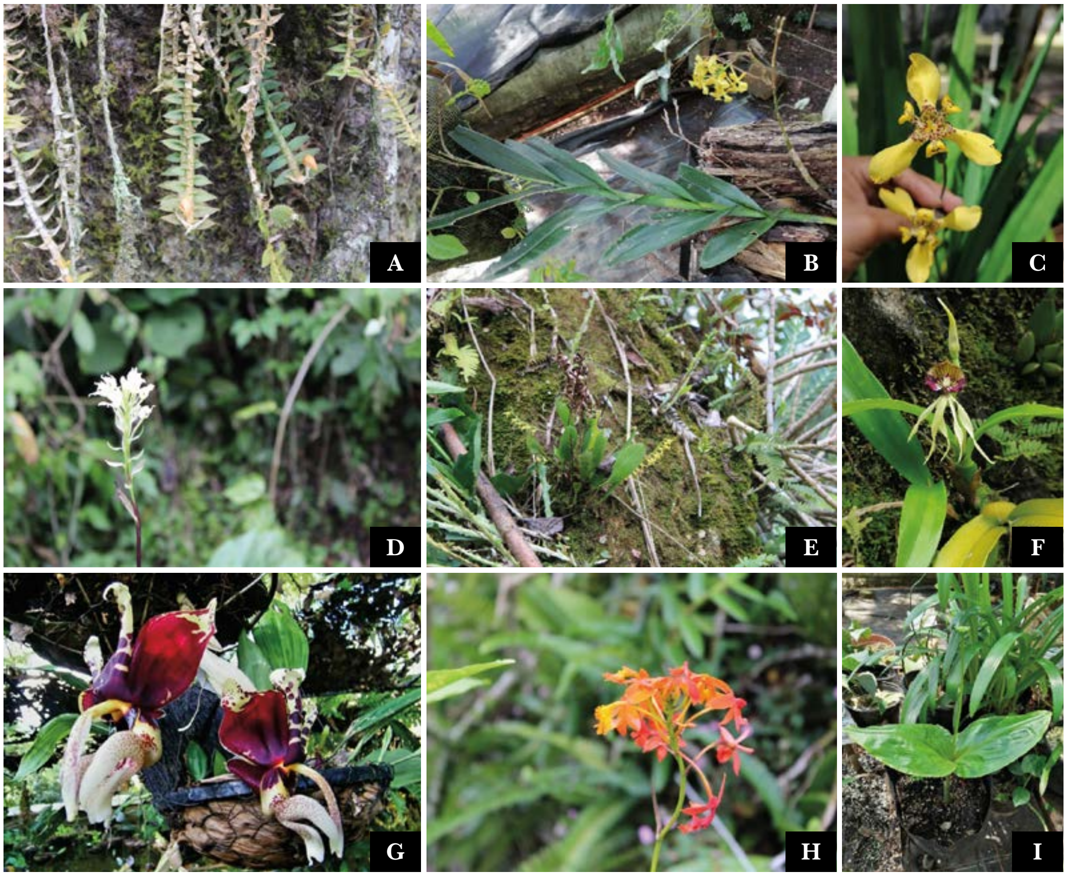

Figure 2. Representative orchid species of the TMCF of Tezonapa, Veracruz. A) *Dichaea muricatoides*, B) *Epidendrum amphistomum*, C) *Trimezia steyermarkii*, D) *Govenia alba*, E) *Stelis platystylis*, F) *Prosthechea cochleata*, G) *Stanhopea tigrina*, H) *Epidendrum radicans*, and I) *Malaxis excavata*.

Table 1. Indicators of the effective number of orchid species at various altitudes in a TMCF.

Indicator	**Abundance Species richness Sample coverage**				
	T1 (800-900)	**T2 (901-1000)**	**T3 (1001-1100)**	**T4 (1101-1200)**	**T5 (1201-1300)**
Abundance	4	52	61	53	34
Species richness	2	9	14	9	9
Sample coverage	1.0	0.9	0.9	0.9	0.9
q^0	2	9	14	9	9
q^1	1.7	6.6	11	7.3	6.7
q^2	1.6	5.4	9	6.6	5.5

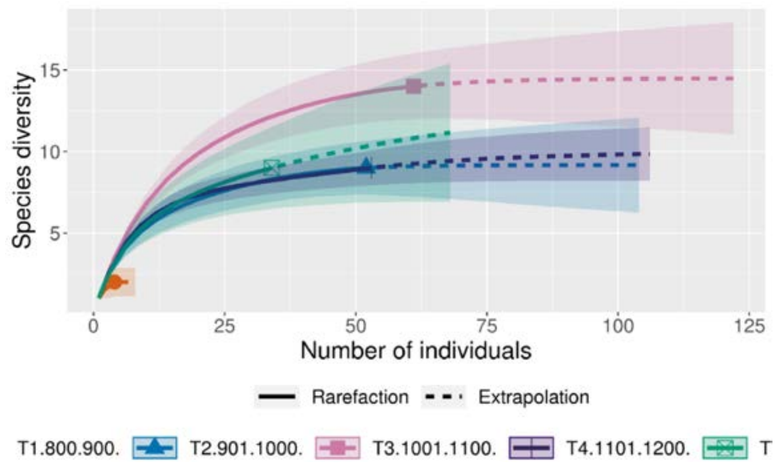

Figure 3. Rarefaction and extrapolation curves of the orchid diversity and number of individuals found at various elevation ranges in the TMCF of Tezonapa, Veracruz, México.

The T3 altitude community had the highest abundance of species and the greatest number of abundant species and rare orchid species, indicating that its diversity is structurally stable (Figure 4). Figure 4 shows that T1 had an unstable structure and a low abundance (two common species and one rare species). Its proximity to human settlements and agricultural and livestock areas fragments the ecosystem and the diversity of orchids. Baltazar and Solano (2020) recorded a q^1 of 7.1 orchid species, attributing this diversity to temperature, humidity, and tree canopy.

The first two PCs show a cumulative variance of 61% (Figure 5), while PC3 has an 82% variance. In this sense, 82% of the orchid species can be found at three altitudes: 14 species at T3 and 9 species each at T2, T3, and T5. The remaining altitudes had a lower variation (*e.g.*, T1 only had two orchid species). Finally, the two species with the greatest variation in T3 were *M. densa* and *L. aurantiacus*.

Stanhopea tigrina is included in NOM-059-SEMARNAT-2010 as a category A species (endangered). Nevertheless, the TMCF in which that species was found is not included among the Federal Protected Natural Areas of Mexico (CONANP, 2023). Therefore, according to Tejeda-Sartorius and Téllez-Velasco (2017), the orchid flora of Veracruz

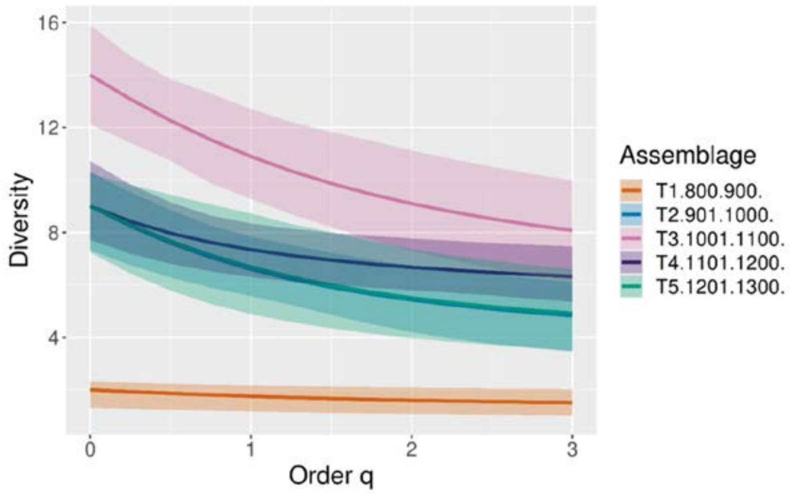

Figure 4. Comparison of the effective number of orchid species of order q^0, q^1, and q^2 of the community in the elevation gradient of the TMCF of Tezonapa, Veracruz, México.

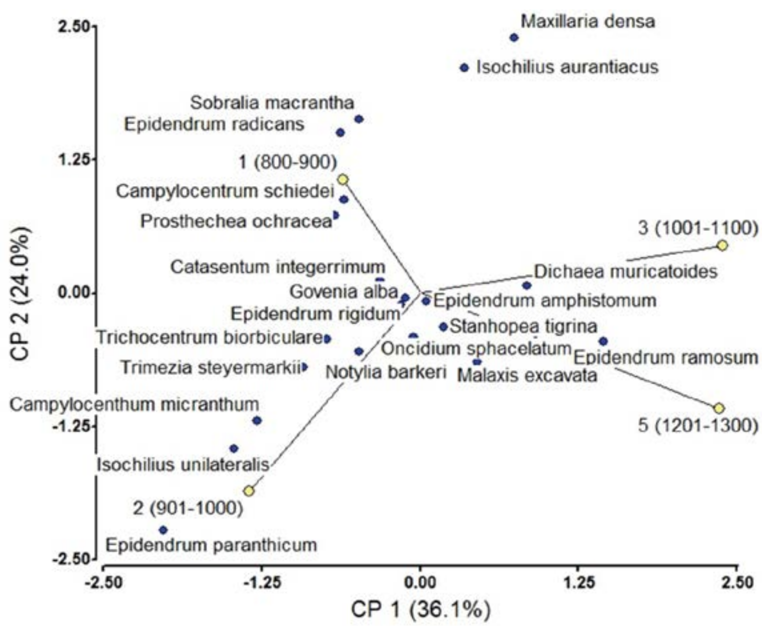

Figure 5. Elevation variation of the diversity of orchid species in the TMCF.

requires further studies to develop public policies for the conservation and management of the TMCF.

CONCLUSIONS

The tropical montane cloud forest of Tezonapa, Veracruz proves the important relationship between this plant community and the orchid flora, recording an abundance of 204 specimens from 26 species. The greatest abundance and diversity were recorded at an altitude of 1,001 to 1,100 m, which favors the development of orchids. *S. tigrina* is an endangered species that requires an urgent protocol that should include *in vitro* propagation, the release of individuals into the environment, and follow-up of wild populations.

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