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Research article

Distribución, estructura y diversidad de bosques de *Pseudotsuga menziesii* (Mirb.) Franco en la Sierra Madre Occidental en Chihuahua

Distribution, structure and diversity of *Pseudotsuga menziesii* (Mirb.) Franco forests in the *Sierra Madre Occidental* in *Chihuahua*

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Abstract

Pseudotsuga menziesii is "subject to special protection". In Mexico due to its restricted distribution in small and isolated populations in the *Sierra Madre Occidental* and *Oriental*, and some localities in Central Mexico. Currently, few ecological studies allow implementation strategies for its conservation. Therefore, the objective of the present study was to determine the distribution, structure and diversity of mixed forests with the presence of this species in *Chihuahua*. Using the Land Use and Vegetation Chart of *Chihuahua* State scale 1:50 000, geographical coordinates of the State Forest and Soil Inventory (*Iefys*) 2009-2014 and records of various locations, the map of its distribution in the state was prepared. With the information on the tree stratum of 11 *Iefys* locations, the Importance Value Index (*IVI*) and diversity were determined with the Shannon-Wiener index (*H'*) and Pielou's evenness index (*J'*); Hutcheson's *t-test* was used to obtain significant differences in *H'* and true diversity for the magnitude of their differences. 21 species were recorded, of which the most important are *Pinus durangensis*, *Pinus strobiformis*, *Pseudotsuga menziesii*, *Pinus arizonica* and *Quercus sideroxyla*. The species of interest is distributed in 23 municipalities of *Chihuahua*, and covers an approximate area of 17 000 ha. The values of *H'* (<2.00) and *J'* (>0.70) indicate low diversity and high evenness of their abundances. The present study will contribute to the State Strategy for the Conservation and Sustainable Use of the Biodiversity of species at risk.

Key words: Oregon pine, biological conservation, temperate ecosystems, Importance Value Index, *Pseudotsuga menziesii* (Mirb.) Franco, floristic richness.**Resumen**

En México, *Pseudotsuga menziesii* está "sujeta a protección especial" por su distribución restringida en poblaciones pequeñas y aisladas en las Sierras Madre Occidental y Oriental, y algunas localidades del Centro de

México. Actualmente, son escasos los estudios ecológicos que permitan implementar estrategias para su conservación. Por lo anterior, el objetivo del presente estudio fue determinar la distribución, estructura y diversidad de bosques mixtos con presencia de esta especie en Chihuahua. Mediante la Carta de Uso de Suelo y Vegetación de Chihuahua escala 1:50 000, coordenadas geográficas del Inventario Estatal Forestal y de Suelos (Iefys) 2009-2014 y registros de diversas localidades, se elaboró el mapa de su distribución en el estado. Con la información del estrato arbóreo de 11 localidades del Iefys se determinó el Índice de Valor de Importancia (*IVI*) y la diversidad con el Índice de *Shannon-Wiener* (*H'*) y de Equidad de *Pielou* (*J'*); la prueba de *t* de *Hutcheson* se utilizó para obtener diferencias significativas de *H'* y la diversidad verdadera para la magnitud de sus diferencias. Se registraron 21 especies, las de mayor importancia fueron *Pinus durangensis*, *Pinus strobiformis*, *Pseudotsuga menziesii*, *Pinus arizonica* y *Quercus sideroxyla*. La especie de interés se distribuye en 23 municipios de Chihuahua, y comprende una superficie aproximada de 17 000 ha. Los valores de *H'* (<2.00) y *J'* (>0.70) indican una baja diversidad y una alta equidad de sus abundancias. El presente estudio contribuirá a la Estrategia Estatal para la Conservación y Uso Sustentable de la Biodiversidad de especies en riesgo.

Palabras clave: Ayarín, conservación biológica, ecosistemas templados, Índice de Valor de Importancia, *Pseudotsuga menziesii* (Mirb.) Franco, riqueza florística.

Introduction

The state of *Chihuahua* is the largest in the Mexican Republic, it has a great diversity of species and ecosystems, and one of the most representative associations is its temperate forests, with an area of 7.4 million hectares (Inegi, 2021). They are distributed in the Northern part of the *Sierra Madre Occidental* (SMO), which has been recognized as a megacenter of diversity (Felger *et al.*, 1997). Numerous endemic species survive in these ecosystems, or within the NOM-059-SEMARNAT-2010 (Royo-Márquez *et al.*, 2014), such as *Pseudotsuga menziesii* (Mirb.) Franco, a species "subject to special protection" that lives in small discontinuous populations in the high parts of the mountains (Rzedowski, 2006; Mápula-Larreta *et al.*, 2007).

To date, there are few works in Mexico with an ecological approach to species within any risk category (Pompa-García *et al.*, 2017), such as *Pseudotsuga menziesii*, which only brings together some works on diversity and structure in the *Sierra Madre Occidental* (Moreno *et al.*, 2018; García *et al*., 2020; García-García *et al.*,

2021; Molina-Marchan *et al.*, 2024a). Ventura *et al.* (2010) point out that more research is required on the distribution of these populations and their current status. Likewise, Martínez-Sifuentes *et al.* (2022) reaffirm the importance of the conservation of these habitats in the face of the effects of climate change and anthropogenic activities, and highlight the development of preservation measures based on their distribution, density and conditions in which they develop. These type of studies contribute to know the state of forests and their response to natural and anthropogenic impacts, in order to monitor and execute management and conservation plans (Spellerberg, 1991).

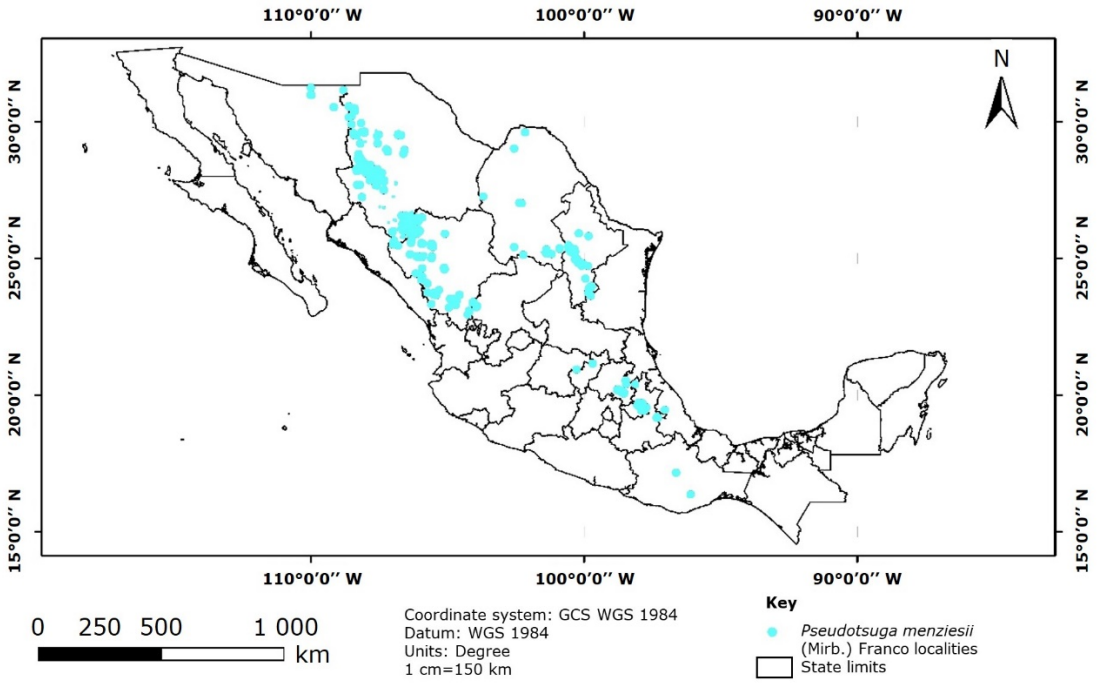
Therefore, the objective of this research was to determine the distribution, structure and diversity of the tree layer of the *Pseudotsuga menziesii* forests in the state of *Chihuahua*, in order to contribute to the State Strategy for the Conservation and Sustainable Use of the Biodiversity of the National Commission for Knowledge and Use of Biodiversity (Conabio) through strategic axes 1, 4 and 7 that correspond to scientific knowledge and information management for the protection, conservation and attention to threats to biodiversity (Cruz *et al.*, 2015).

Materials and Methods

Study area

Pseudotsuga forests on a national scale cover 57 000 ha distributed in the states of *Chihuahua*, *Coahuila*, *Durango*, *Guanajuato*, *Hidalgo*, *Nuevo León*, *Oaxaca*, *Puebla*,

Querétaro, *Sonora*, *Tamaulipas*, *Tlaxcala*, *Veracruz* and *Zacatecas* (Figure 1) (Molina-Marchan *et al.*, 2024b). According to García (2004) climate classification, the areas where most populations thrive are temperate sub-humid, with an average annual temperature between 10 and 14 °C and an average annual precipitation greater than 600 mm.



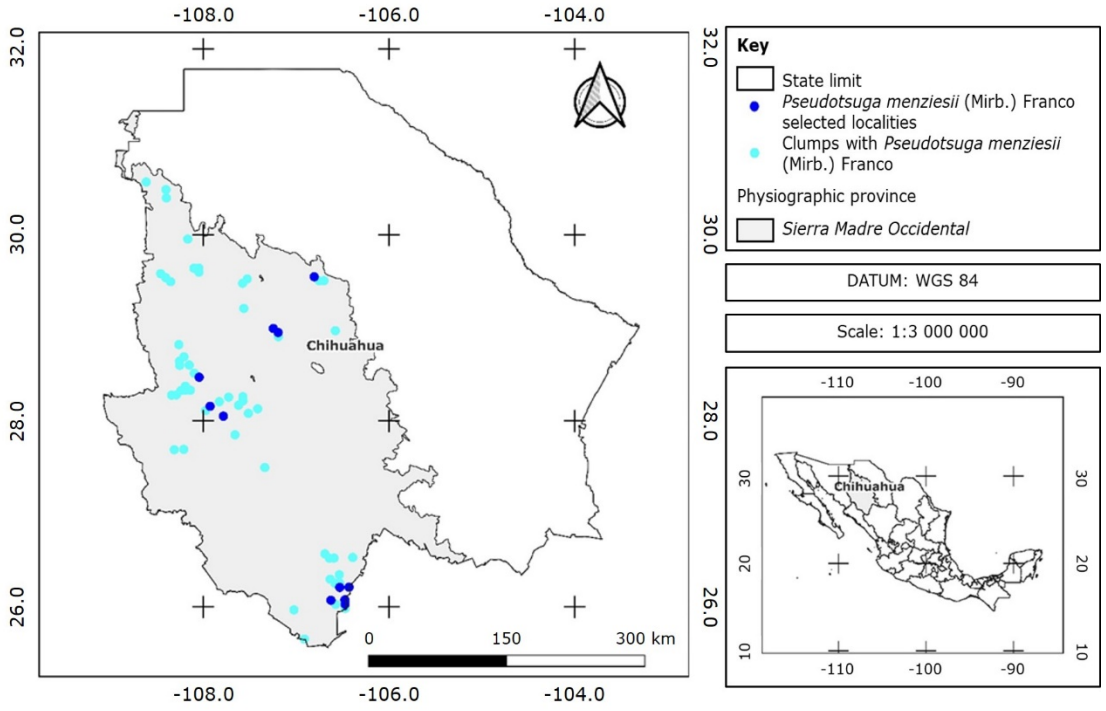
Source: Molina-Marchan *et al.* (2024b).

Figure 1. Modified map of the distribution of *Pseudotsuga menziesii* (Mirb.) Franco in Mexico.

In the SMO in *Chihuahua*, *Pseudotsuga* Carrière stands are concentrated at altitudes of 2 400 to 3 200 m, in North-facing exposures and moderate to steep slopes ranging from 15 to 72 %, conditions that are present in other regions of the country (Encina-Domínguez *et al.*, 2008; Ventura *et al.*, 2010).

The soils are of the Feozem, Regosol and Litosol type (INEGI, 2014), with depths between 10 and 60 cm, which indicates that they are low and medium depth soils (Conafor, 2014).

Information from the localities from the State Forest and Soil Inventory of the state of *Chihuahua* 2009-2014 (Conafor, 2014) was used, where each one is made up of four circular sites of 400 m^2 with the shape of an inverted *Y* in which the gender and species of all individuals with a normal diameter greater than or equal to 7.5 cm at a height of 1.30 m. Information was available from 62 localities with the presence of *Pseudotsuga menziesii* (Figure 2), and based on the analysis of the data, those that have an Importance Value Index greater than 5 % of the species were selected (Table 1).



Chihuahua = State of *Chihuahua*.

Figure 2. Geographic location of the 11 analyzed localities of *Pseudotsuga menziesii* (Mirb.) Franco.

Table 1. Description of the studied localities of *Pseudotsuga menziesii* (Mirb.) Franco in the state of *Chihuahua*.

Locality	Municipality	Longitude	Latitude	Altitude (m)	Type of vegetation
Catedral	*Guadalupe y Calvo*	-106.5296	26.2086696	2 220	QP
Chinatú	*Guadalupe y Calvo*	-106.625391	26.069766	2 879	PQ
La Hacienda	*Guadalupe y Calvo*	-106.474656	26.0741194	2 742	PQ
San Julián	*Guadalupe y Calvo*	-106.472878	26.0286592	2 557	PsP
Basogachi	*Ocampo*	-107.783333	28.049999	2 450	PQ
Ejido La Posta	*Temósachic*	-108.043216	28.4691792	2 666	QP
Ejido San Rafael (C1)	*Bachíniva*	-107.24631	28.9938805	2 461	PsP
Ejido San Rafael (C2)	*Cuauhtémoc*	-107.192979	28.9505128	2 614	P
Predio particular Álamo Mocho	*Guerrero*	-107.926481	28.1567	2 695	PQ
Río El Nido	*Buenaventura*	-106.804856	29.5495114	2 718	QPs
Río Verde	*Balleza*	-106.4294	26.2113318	2 635	PsP

P = *Pinus*; Q = *Quercus*; Ps = *Pseudotsuga*.

Data analysis

Distribution

The area and distribution of *Pseudotsuga menziesii* in the state was estimated using the database of the Land Use and Vegetation Chart Scale 1:50 000 (Stock

Informático, 2013), which favors greater accuracy for research studies and natural resources management (Stock Informático, 2013) and the records with coordinates of the State Forest and Soil Inventory of *Chihuahua* (Conafor, 2014) through the QGIS 3.30.2 program (QGIS Development Team, 2023). The localities registered by various authors were also considered (Villanueva *et al.*, 2000; Vargas-Hernández *et al.*, 2003; Cruz-Nicolás *et al.*, 2008; Sánchez *et al.*, 2012; Cibrián *et al.*, 2014; Conanp, 2017; García *et al.*, 2020).

Horizontal structure

The Importance Value Index (*IVI*) considers the absolute and relative values of abundance, dominance and frequency (Equation 1), it is a quantitative parameter of the horizontal structure and indicates the ecological weight of the species present in a community (Lozada, 2010).

$$IVI = \frac{Ar + Dr + Fr}{3} \quad (1)$$

Where:

IVI = Importance Value Index

Ar = Relative abundance

Dr = Relative dominance (basimetric area)

Fr = Relative frequency

Diversity indexes

Diversity was calculated using the Shannon-Wiener index (*H'*) which considers the abundance and richness of species. The more taxa the community and the more equitable has their abundances, the greater their diversity will be (Moreno, 2001). With the Pielou index (*J'*) the evenness between the abundances of the species was obtained, whose values vary between zero and one, and the latter represents maximum evenness (Magurran, 2004).

To determine if there is a significant difference between the communities studied, paired comparisons were made through Hutcheson's *t-test* ($p \leq 0.05$) with the following Equation (Hutcheson, 1970).

$$t = \frac{H'1 - H'2}{\frac{(varH'1 + varH'2)1}{2}} \qquad (2)$$

Where:

t = Hutcheson's *t* test

H'1 = Diversity of sample 1

H'2 = Diversity of sample 2

varH'1 = Variance of the diversity obtained for the sample 1

varH'2 = Variance of the diversity obtained for the sample 2

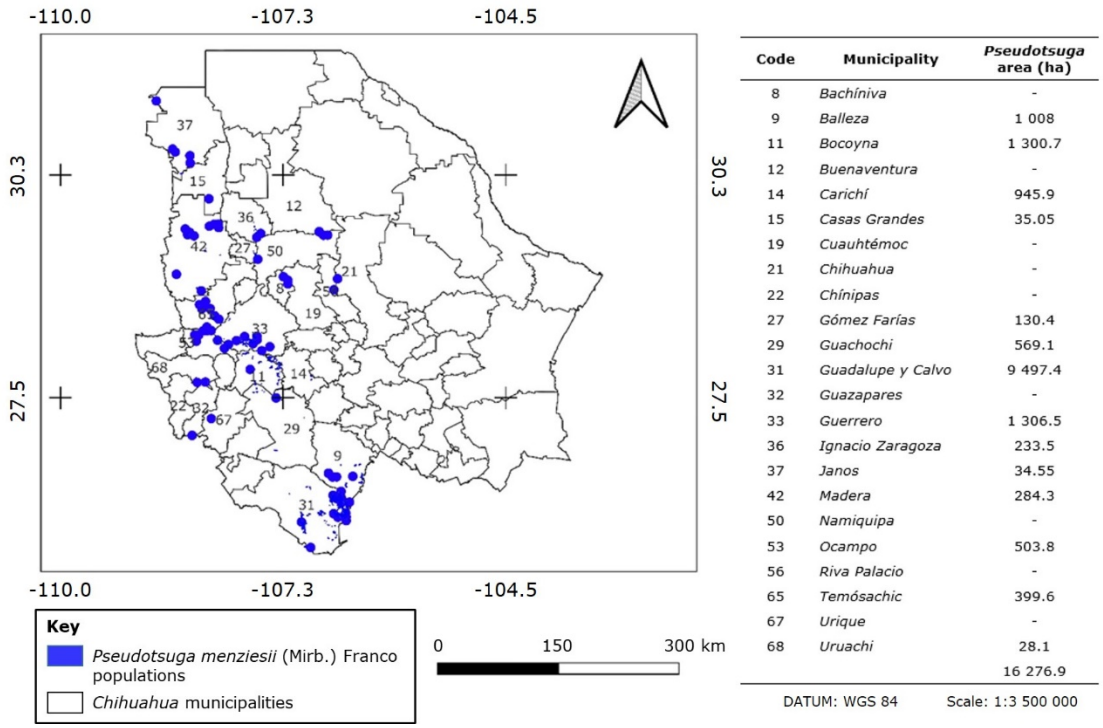
g. l. = Degrees of freedom needed to calculate the value of *t*

The magnitude of significant differences in diversity was established with the true diversity of order 1 (^{q}D) (Jost, 2006) as follows: when community *A* (*CA*) has greater diversity than community *B* (*CB*), the $\frac{CA}{CB}$ ratio reflects the times that *CA* is more diverse than *CB* (Moreno *et al.*, 2011). The diversity indices were carried out in the PAST statistical program version 4.16 (Hammer *et al.*, 2001).

Results and Discussion

Distribution

The results obtained from the analysis of the Land Use and Vegetation Cartography of the State of *Chihuahua* (Stock Informático, 2013) indicate that *Pseudotsuga menziesii* forests occupy an area of 16 276.9 ha distributed in 14 municipalities. However, the State Forest and Soil Inventory 2009-2014 recorded the presence of this species in 9 more municipalities (Figure 3). Therefore, it is estimated that the surface of these forests is around 17 000 ha, which are distributed throughout the SMO from the Southern part in the *Cerro Mohinora* Protected Natural Area (PNA) in *Guadalupe y Calvo*, to the North in the *Janos* PNA.



Code	Municipality	*Pseudotsuga* area (ha)
8	*Bachíniva*	-
9	*Balleza*	1 008
11	*Bocoyna*	1 300.7
12	*Buenaventura*	-
14	*Carichí*	945.9
15	*Casas Grandes*	35.05
19	*Cuauhtémoc*	-
21	*Chihuahua*	-
22	*Chínipas*	-
27	*Gómez Farías*	130.4
29	*Guachochi*	569.1
31	*Guadalupe y Calvo*	9 497.4
32	*Guazapares*	-
33	*Guerrero*	1 306.5
36	*Ignacio Zaragoza*	233.5
37	*Janos*	34.55
42	*Madera*	284.3
50	*Namiquipa*	-
53	*Ocampo*	503.8
56	*Riva Palacio*	-
65	*Temósachic*	399.6
67	*Urique*	-
68	*Uruachi*	28.1
		16 276.9

DATUM: WGS 84 Scale: 1:3 500 000

Figure 3. Area of *Pseudotsuga menziesii* (Mirb.) Franco by municipality in the state of *Chihuahua*.

Of the 23 municipalities where these communities are located, the most important are *Guadalupe y Calvo*, *Guerrero* and *Bocoyna* with 9 497.4 ha, 1 306.5 ha and 1 300.7 ha, respectively (Figure 3). The largest area was recorded in the *Guadalupe y Calvo* municipality, possibly related to biophysical conditions favorable for its development, such as the average annual precipitation greater than 1 000 mm, the variability of reliefs, cold temperatures, fertile soils and altitudes between 2 200 and 3 200 m (Rzedowski, 2006; Guerra *et al.*, 2012; Moreno *et al.*, 2018; García-García *et al.*, 2024); furthermore, in this area the *Cerro Mohinora* PNA is located, which is the highest part of the entity. These fir forests in *Guadalupe y Calvo* form an important biological corridor with the *Guanaceví* municipality, state of *Durango* (Molina-Marchan *et al.*, 2024a).

When this species is dominant or co-dominant in *Chihuahua*, its population density varies between 125 to 155 trees ha^{-1} (Conafor, 2014; García *et al.*, 2020), lower values than those reported by Domínguez-Calleros *et al.* (2014); if it occurs as a secondary species in pine-oak and oak-pine forests, its density accumulates between 30 and 70 trees ha^{-1}, which coincides with Ventura *et al.* (2010). *Picea martinezii* T. F. Patt. records similar figures as a dominant and secondary species with densities of 155 and 52 trees ha^{-1}, respectively (González *et al.*, 2018).

It should be noted that the distribution of species changes over time, since they are strongly influenced by environmental conditions and anthropogenic activities, which can put the existence of some taxa at risk and favor the permanence and distribution areas of others (Conabio, 2023). An example of this is the forecasts of Martínez-Sifuentes *et al.* (2022) who point out that the potential distribution areas of *Pseudotsuga* under different climate scenarios will be reduced by more than 50 % by 2040. To this it should be added the fact that these areas in Mexico are currently affected by land use change, fires and clandestine logging (Mápula-Larreta *et al.*, 2007; Velasco-García *et al.*, 2007). In addition to the above, in *Chihuahua* and other Northern entities, the *Dendroctonus pseudotsugae* Hopkins pest has been detected, which mainly damages mature forests of this conifer (Sánchez *et al.*, 2012).

Several species included in NOM-059-SEMARNAT-2010 do not develop in an PNA as mentioned by Luna-Vega *et al.* (2010); or their representation is scarce, such as the Douglas fir forests that in *Chihuahua* only comprise 2 928.95 ha (18 %) within an PNA (Table 2).

Table 2. Area of *Pseudotsuga menziesii* (Mirb.) Franco in Protected Natural Areas of *Chihuahua*.

PNA	Management category	Area (ha)
Papigochic	Flora and Fauna Protection Area	1 283.50
Cerro Mohinora	Flora and Fauna Protection Area	663.60
Tutuaca	Flora and Fauna Protection Area	423.10
Santuario Cotorra Serrana Occidental	Sanctuary	420
Campo Verde	Flora and Fauna Protection Area	104.20
Janos	Biosphere Reserve	34.55
Total		2 928.95

Therefore, it is considered of great relevance that with the elements provided by this work, more surface area of these communities is included within an PNA and strategies are implemented to monitor the effect of climate change and anthropogenic activities on current populations for the conservation of these High Conservation Value forests.

Horizontal structure

In the present study, 6 families, 7 genera and 18 species were recorded. The Pinaceae and Fagaceae families were the most important, both with seven species, which together amount to 77.77 % of the total taxa. *Pseudotsuga* communities bring together a floristic richness of between 3 and 11 species; the most

outstanding localities were *Basogachi*, *P. P. Álamo Mocho* and *Chinatú* with 11, 10 and 9 taxa, respectively, similar numbers to those of Domínguez (2004) and González (2019). In addition to the species recorded in this study, others that share the same habitat are: *Picea chihuahuana* Martínez and *Abies durangensis* Martínez (García *et al.*, 2020), in the PNA of the *Cotorra Serrana Occidental* Sanctuary in *Madera*; in addition to *Pseudotsuga menziesii*, the main species that make up this community are *Abies concolor* (Gordon & Glend.) Lindl. *ex* Hildebr., *Pinus strobiformis* Engelm., *Populus tremuloides* Michx., *Pinus arizonica* Engelm. and *Quercus sideroxyla* Bonpl. (Conanp, 2023; Molina-Marchan *et al.*, 2024a). The state's Northernmost town of *Pseudotsuga* is located on *Janos* in a "sky island"; it is considered an ancient forest and has the greatest floristic richness with 16 species (Cortés *et al.*, 2012).

The *IVI* of *Pseudotsuga menziesii* in the studied localities varied between 6 and 41 % (Figure 4), values closely related to natural and anthropogenic disturbances, the succession stage and environmental conditions such as latitude, altitude, precipitation and exposure (Stirling and Wilsey, 2001; Asquith, 2002). In *Chihuahua* the highest *IVI* values for this species occur in the *Madera* PNA with 42 % (Molina-Marchan *et al.*, 2024a); and in the forests of the *Cerro Mohinora* PNA, from 2 600 m onwards *Abies* Mill. and *Pseudotsuga* concentrate 62 to 74 % of the relative abundances (García-García *et al.*, 2024), these results are similar to those reported by Guerra *et al.* (2012) and González (2019) and possibly the greater presence of *Abies* and *Pseudotsuga* in these localities is due to the boreal origin of these genera that find their most favorable environmental conditions for their development in the high parts of the mountains with low temperatures, high humidity and slopes with orientations North (Rzedowski, 2006).

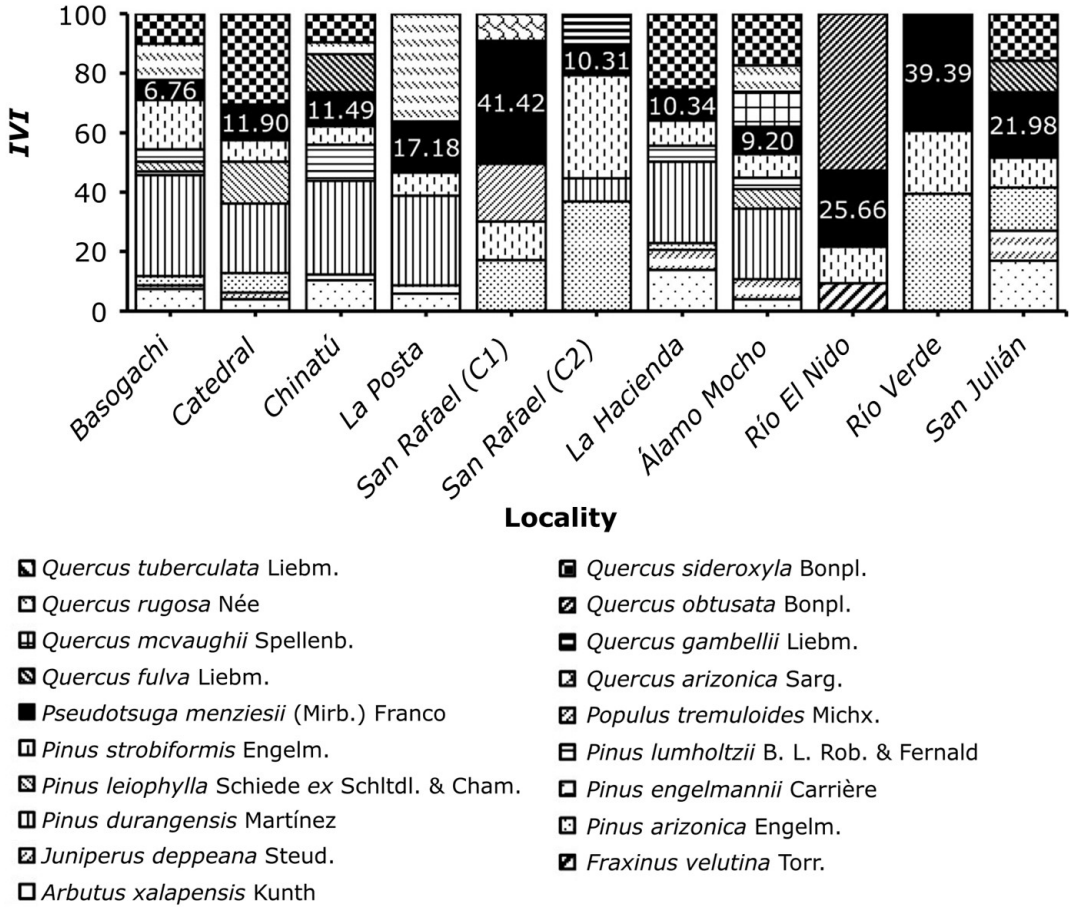


Figure 4. Importance Value Index (*IVI*) in the studied localities of *Pseudotsuga menziesii* (Mirb.) Franco.

According to Criterion 1 of the Forest Stewardship Council (Brown *et al.*, 2013), *Pseudotsuga* forests are considered Areas of High Conservation Value because it cohabits with endemic species such as *Quercus fulva* Liebm., *Quercus obtusata* Bonpl., *Pinus durangensis* Martínez, *Pinus lumholtzii* B. L. Rob. & Fernald and *Quercus sideroxyla*, and in NOM-059-SEMARNAT-2010 as *Pseudotsuga menziesii*, *Pinus strobiformis*, *Picea chihuahuana* and *Abies concolor*.

Pinus strobiformis, *P. durangensis*, *Pseudotsuga menziesii*, *Quercus sideroxyla* and *Pinus arizonica* were the taxa with the greatest ecological weight within the forests

analyzed. *Pinus strobiformis* frequently coexists in Douglas fir communities, because they share similar environmental requirements in the high, humid parts of the mountains (González *et al.*, 2006); similar results have been recorded by García and González (2003).

Diversity

Based on the Shannon-Wiener index (*H'*), it was obtained that the diversity of the tree layer of the *Pseudotsuga* communities is low since the range of values for *H'* were from 0.78 to 2.04; these results are similar to those reported by Encina-Domínguez *et al.* (2008), González (2019) and García *et al.* (2020) for these communities, and coincide with those of Méndez *et al.* (2018) and Graciano-Ávila *et al.* (2020) for temperate mixed forests of Mexico. The low diversity of the tree layer in these ecosystems is possibly because they are located in the highest altitudinal gradients of the mountains and, according to Boyle (1996) and Hemp (2005), there is a negative relationship between altitude and diversity of tree species. Challenger and Soberón (2008) and McCain and Grytnes (2010) document that in forests at higher elevations there is a decrease in temperature that generates adverse conditions and only allows the dominance of a small number of taxa. Regarding the Pielou index, the results show that the evenness of their relative abundances is high from 0.71 to 0.97 (Table 3).

Table 3. Diversity indexes and Hutcheson's *t* test in *Pseudotsuga menziesii* (Mirb.) Franco localities.

Locality	Taxons	Shannon index (*H'*)	Pielou index (J)	Hutcheson's *t* test	Real diversity (effective species)
P. P. Álamo Mocho	10	2.04	0.88	a	7.66
San Julián	7	1.88	0.97	b	6.57
Chinatú	9	1.82	0.83	bc	6.16
La Hacienda	8	1.78	0.86	cd	5.93
Basogachi	11	1.70	0.71	de	5.49
Catedral	8	1.66	0.80	e	5.28
Ej. San Rafael (C1)	5	1.43	0.89	f	4.16
Ej. San Rafael (C2)	5	1.42	0.88	f	4.12
Ej. La Posta	6	1.42	0.79	f	4.12
Río Verde	3	1.07	0.97	g	2.91
Río El Nido	3	0.78	0.71	h	2.18

Different letters indicate significant difference based on Hutcheson's *t* test ($p \leq 0.05$).

In general, the *IVI* and the high evenness of the relative abundances of the species that make up these communities show that there is no defined dominance of one or several species, which suggests a more efficient distribution of resources (Guzmán, 2009), through niche differentiation, which increases ecosystem productivity and functionality (Harrison *et al.*, 2019).

The forests studied show significant differences in diversity according to the *t* test (Hutcheson) (Table 3). *P. P. Álamo Mocho* with *H'* of 2.04 was the one with the highest value due to its high species richness and high evenness in its abundances. The analysis of true diversity indicates that this locality with 7.6 effective species is 1.17 and 3.51 times more diverse than *San Julián* and *Rio El Nido*, which occupied the second and last place in diversity, respectively. Forests with higher indices are more heterogeneous and have a greater complexity of ecological

interactions, which favors the stability and resilience of the ecosystem. On the other hand, those localities with a low diversity of species are the most susceptible to effects, such as pests and diseases (Thompson, 2011; Keesing and Ostfeld, 2024); likewise, a poor use of light or soil resources is generated, which establishes a lower diversity of niches (Huuskonen *et al.*, 2021).

Regarding regeneration, approximately 50 % of the localities did not present repopulation of *P. menziesii*, which is similar to what was described by Velasco-García *et al.* (2007) and Ventura *et al.* (2010), due to inbreeding and low germination rate (Cruz-Nicolás *et al.*, 2008); it may also be due to cone and seed pests, interspecific competition, and ecological site conditions.

Current forestry must have a comprehensive approach that includes ecological criteria such as *IVI*, biomass and species diversity. Likewise, conservation must be a main component of management in order to maintain the functional and structural relationships of the ecosystem, as well as adequate repopulation of the species (Vargas, 2013; Jardel, 2015). The above will allow more stable and resilient ecosystems in the face of disturbance events and climate change.

Conclusions

Chihuahua is one of the states in the country with the largest extension of *Pseudotsuga menziesii* forests, which are currently under special protection and coexist with other species in some risk categories, according to NOM-059-SEMARNAT-2010. These communities have a low tree diversity that is common in the high and cold parts of the mountains, and their structure has a high evenness in their abundances. Due to their specific ecological requirements, these communities are susceptible to climate change and it is expected that in a period of 20 to 30

years their distribution areas will be drastically reduced. Other factors that are affecting their populations are anthropogenic activities and the *Dendroctonus pseudotsugae* pest. For these reasons, it is important to monitor the sites of the National Forest and Soil Inventory, and to establish permanent research sites, to evaluate the dynamics and resilience of these communities over time. The inclusion of more surface area of these forests within PNAs is recommended, as well as the implementation of demographic or ecological studies such as this contribution, which allow the implementation of better strategies for conserving these Areas of High Conservation Value.

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Conflict of interests

The authors have no conflict of interest.

Contribution by author

Emanuel Molina Marchan: preparation of the manuscript, data analysis, and preparation of cartography; Raúl Narváez Flores: review and preparation of the

manuscript, support in data analysis and application of corrections; Jesús Miguel Olivas García: review and application of corrections; Javier Hernández Salas: review and support in data analysis; Aldo Saúl Mojica Guerrero: analysis of the *Iefys* database.

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