Botanical Sciences 100 (1): 153-168. 2022
DOI: 10.17129/botsci.2859

Received: February 7, 2021, Accepted: June 17, 2021
First online: October 6, 2021

Ethnobotany / Etnobotánica

Uses and traditional knowledge of *Dendropogonella rufescens* (Bryophyta: Cryphaeaceae) in a Zapotec community of southeastern Mexico

Usos y conocimiento tradicional de *Dendropogonella rufescens* (Bryophyta: Cryphaeaceae) en una comunidad zapoteca del sureste de México

Enrique Hernández-Rodríguez[1]* and Jesús López-Santiago[2]

[1] Institut de Recherche sur les Forêts, Université du Québec en Abitibi-Témiscamingue, Rouyn-Noranda, Canada.
[2] Tropical Agricultural Research and Higher Education Center. Turrialba, Costa Rica.
*Author for correspondence: enrique.hernandezrodriguez@uqat.ca

Abstract

Background: Uses and traditional knowledge (TK) are essential for the protection and management of natural resources. There are extensive records of traditional uses involving mainly vascular plants, while for mosses are scarce. This study documents the TK and uses of *Dendropogonella rufescens* in San Juan Luvina, Oaxaca, Mexico.

Questions: For what purpose and how *D. rufescens* is used in San Juan Luvina? Can TK provide ecological information for this species? How is TK maintained among the members of the community?

Studied species: *Dendropogonella rufescens* (Schimp.) Britt. (Bryophyta).

Study site and dates: San Juan Luvina, Oaxaca, Mexico. March 2020.

Methods: We conducted interviews with inhabitants from three age categories (15-41, 42-68, and 69-95 years). Interviews included questions about the length of time the community has used the plant, harvesting practices, traditional use, and plant recycling after traditional use.

Results: We recorded around 40 traditional uses for *D. rufescens*. These include historical information about the use of the plant and TK grouped in seven categories (ceremonial, construction, craft, environmental, fuel, medicinal, and ornamental). These results include new reports of TK of bryophytes in Mexico.

Conclusions: For the uses and TK reported, *D. rufescens* is essential for the cultural identity of the community of San Juan Luvina. *D. rufescens* TK could be used to develop conservation strategies for bryophytes.

Keywords: Bryophytes, ethnobotany, ethnobryology, mosses, non-wood forest products, Oaxaca.

Resumen

Antecedentes: Los usos y el conocimiento tradicional (CT) son esenciales para la protección y el manejo de los recursos naturales. Existe un extenso registro de usos y CT que involucran principalmente plantas vasculares, mientras que para los musgos son escasos. Este estudio documenta los usos y el CT de *Dendropogonella rufescens* en San Juan Luvina, Oaxaca, México.

Preguntas: ¿Con qué finalidad y cómo se utiliza *D. rufescens* en San Juan Luvina? ¿Puede el CT proporcionar información ecológica para esta especie? ¿Cómo se mantiene este CT entre los miembros de la comunidad?

Especies de estudio: *Dendropogonella rufescens* (Schimp.) Britt. (Bryophyta).

Sitio y años de estudio: San Juan Luvina, Oaxaca, México. Marzo, 2020.

Métodos: Realizamos entrevistas a habitantes de tres categorías de edad (15-41, 42-68 y 69-95 años). Las entrevistas incluyeron preguntas sobre el tiempo que la comunidad ha usado la planta, las prácticas de cosecha, el uso tradicional *per se* y el reciclaje de la planta después de su uso.

Resultados: Registramos alrededor de 40 usos tradicionales para *D. rufescens***.** Estos resultados incluyen información histórica sobre el uso de la planta y su CT agrupados en siete categorías (artesanal, ambiental, ceremonial, combustible, construcción, medicinal y ornamental). Estos resultados incluyen nuevos registros de usos y CT de briofitas en México.

Conclusiones: Por los usos y el CT reportados, *D. rufescens* es esencial para la identidad cultural de la comunidad de San Juan Luvina. El CT de *D. rufescens* podría usarse para estrategias de conservación de briofitas.

Palabras clave: Briofitas, etnobotánica, etnobriología, musgos, Oaxaca, productos forestales no maderables.

Uses and traditional knowledge (TK) provide a basis for the management and biodiversity protection, essential aspects for sustainable development (Gadgil *et al*. 1993). The study of the relationship between humans and plants through ethnobotany has allowed recording this knowledge worldwide, producing extensive literature about their role in social belief systems, natural resources management, and human culture (Young 2007, Casas *et al*. 2014). However, non-vascular plants such as bryophytes are a botanical group that does not receive the same attention in this field of study. Bryophytes have potential uses in horticulture and medicine because of their antibacterial, antifungal properties, as well as their antitumor activity (Ando & Matsuo 1984, Frahm 2004). Due to their genes related to stress tolerance, their use in biotechnology is continually developing (Beike *et al*. 2010). In addition, bryophytes are part of the traditional practices of native communities around the world (Harris 2008). The study of the relationship between humans and bryophytes is known as ethnobryology, but research in this area is scarce (Flowers 1957, Harris 2008).

In Mexico, few studies report the use and TK of bryophytes (Hernández-Rodríguez & Delgadillo 2021). Some works mentioned their importance in the traditional medicine of Aztecs and Huastecs and for bedding and padding material for Tzeltals (De la Cruz 1552, Berlin *et al.* 1974, Alcorn 1984). Nowadays, mosses are used as raw material for floral arrangements and as decorative material during the Christmas season (Delgadillo 2014). Some bryophyte species are used in traditional practices in southern Mexico regions, although this is poorly documented. Rees (1976) recorded five taxa of mosses sold in the Christmas market of Oaxaca city (Oaxaca state). One of them included the moss *Dendropogonella rufescens* (Schimp.) Britt. (Cryphaeaceae) which is used in many ways in the district of Sierra Juárez. In this region of northern Oaxaca state, *D. rufescens* is commonly found in small quantities or forming large colonies hanging from tree branches in pine-oak and cloud forests. In the area, Zapotec communities are responsible for the management and conservation of natural resources for their sustenance (Chapela 2007). They develop productive activities as sustainable management of their forests, ecotourism, and conservation strategies economically supported by national and international institutions (Bray 2020, Briones-Salas *et al*. 2016). These communities include *D. rufescens* in their cultural practices and customs. However, the traditional use of this moss has not been documented despite some ethnobotanical studies reporting an extensive checklist of useful plants (Ortiz 1970, Aguilar Santelises 2007, Camou-Guerrero *et al.* 2016). Since TK and uses related to bryophytes are rarely documented (Harris 2008), it is necessary to obtain ethnobotanical information about the ecology, conservation, and management of these plants while recording the biocultural heritage of a region.

The use of *D. rufescens* by indigenous communities in the Sierra Juárez represents an opportunity to answer basic ethnobotanical questions for bryophytes. For what purpose and how is this plant used? Can TK provide ecological information for this species? How is this knowledge maintained among the members of a community? To answer these questions, we proposed the following objectives: 1) document the uses and TK of *D. rufescens* in a locality of Sierra Juárez, Oaxaca, Mexico; 2) evaluate whether young members of the community preserved this information and 3) discuss the importance of bryophytes in ethnobiology research in the state of Oaxaca. To do that, we conducted interviews in the Zapotec locality of San Juan Luvina. Our results provide evidence that bryophytes can support research on uses and traditional knowledge of non-vascular plants, representing an antecedent to future ethnobryological studies in Latin America.

Materials and methods

Study area. The community of San Juan Luvina is in the district of Ixtlán de Juárez (Sierra Juárez), Oaxaca (17° 30′ 16.9″ N, 96° 32′ 56.1″ E; 2040 m asl; Figure 1). It has protected natural areas and for forest management and agriculture (Hernández-Rodríguez *et al.* 2019). The climate is temperate humid, with an average annual temperature between 16 and 20 °C (Trejo 2004). The community is part of an area of high biological, economic, and cultural importance (Mittermeier *et al.* 2004). The vegetation types in the region include pine-oak, oak-pine, and cloud forest that represent large non-fragmented areas with a high conservation level in Mexico (Arriaga-Cabrera *et al*. 2000, García-Mendoza *et al*. 2004). The main disturbances include forestry by local communities (Bray 1991, Chapela

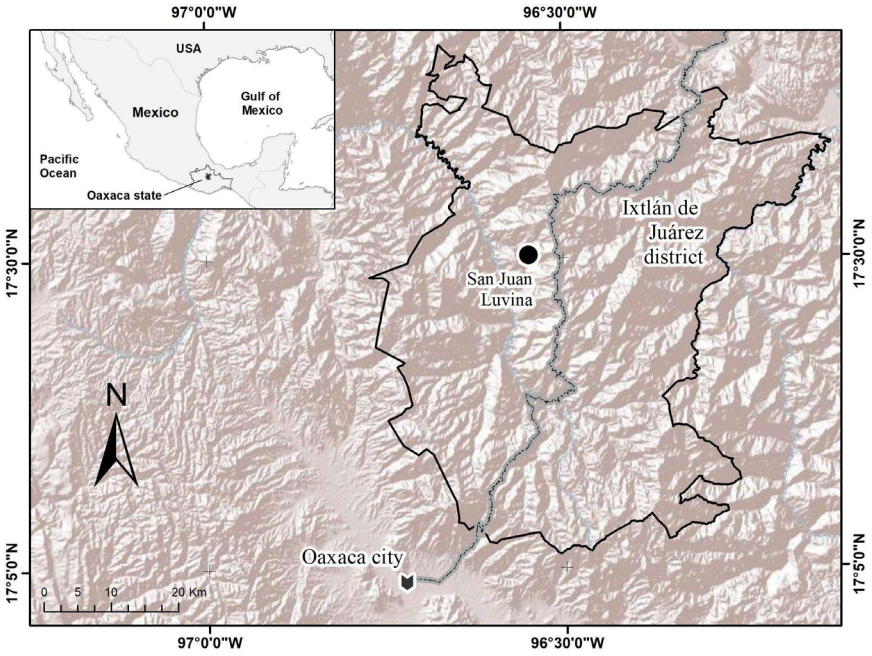

Figure 1. Location of San Juan Luvina in the district of Ixtlán de Juárez (Sierra Juárez), Oaxaca, Mexico. The dotted line indicates highway 175 Oaxaca-Tuxtepec.

2007, Álvarez & Rubio 2013) and deforestation for crops and cattle pastures. San Juan Luvina has a population of approximately 560 inhabitants, whose native language is Zapotec. San Juan Luvina was chosen for our study because it retains many traditions, and according to López-Santiago (2015), there is an extensive traditional knowledge of more than 200 vascular plants.

Dendropogonella rufescens. *D. rufescens* is an epiphytic moss whose stems can exceed 30 cm in length with irregular pinnate branches up to 3 cm long reddish-brown or green in color, with thin and soft texture (Manuel 1994). It grows on different tree species as conifers and oaks at an altitude between 200 to 2,800 m (Figure 2). Its neotropical distribution includes Guatemala, El Salvador, Honduras, Costa Rica, Panama, Venezuela, and Brazil. In Mexico, in addition to Oaxaca, its distribution consists of the states of Veracruz, Puebla, and Chiapas (Gradstein *et al.* 2001).

Data collection. We interviewed 90 people in three age categories to identify generational differences in the TK among community members: 15-41 (youth), 42-68 (adult), and 69-95 years (old). Each age category included 15 men and 15 women. We established these age categories based on the social roles of community members and their possible influence on the knowledge and use of their natural resources. People between 15 and 41 years of age perform roles related to agriculture and forestry. Those between 42 and 68 years of age carry out work of exploitation of timber and non-timber resources and hunting activities. Finally, people between 69 and 95 years old are guides for people in the second category in forest management because they have greater knowledge about the area and distribution of natural resources. We selected informants randomly through home visits. In the interviews, we avoid forming groups of individuals that could bias in the informant responses.

The interviews included questions about the beginning of the use of *D. rufescens* by the community, how people used it, collected it, and recycled or disposed of it after use. For the interviews, we brought moss parts, and we showed photos of the plant in its natural habitat to guarantee that people could reliably identify it. We also show interviewees photos of different bryophytes (mosses and liverworts) from the area to avoid confusion with other species used.

Figure 2. *Dendropogonella rufescens* (Schimp.) E. Britton in the Sierra Juárez, Oaxaca. A) Habitat and life form in an ecotone of cloud forest and oak-pine forest; B) *D. rufescens* usually grows on the branches of young pine trees where its stems can reach 50 cm in length.

We did the interviews in the Zapotec language during March 2020 (Appendix 1). Interviews in the native language are useful in reducing confusion among interviewees regarding the taxa investigated and enriching the data quality with a more precise description of the knowelge and traditional uses (Berlin & Berlin 2005). For the interviews, we requested permission from the municipal authorities in charge of the environment and wildlife and the local social affairs office (Presidency of the locality).

Data analysis. To assess uses richness in each age category, we performed rarefaction/extrapolation (R/E) curves with the Hill number 0 for incidence data (Begossi 1996, Chao *et al.* 2014). The curves were performed with an extrapolation twice the number of informants per age category (60), 999 bootstrap replications, and 95 % confidence intervals. We did the R/E curves in the R languaje (R Core Team 2021) using the iNext package (Hsieh *et al*. 2016). To evaluate the TK of *D. rufescens*, the uses mentioned in the interviews were classified according to the plant use categories proposed by Bernal-Ramírez *et al.* (2019) (Table 1). We counted the number of people in each age category who mentioned uses in each category. This number was divided by 30 (total number of people in each age category) and multiplied by one hundred to determine a percentage that indicates the representativeness of traditional uses between the age categories.

Table 1. Plant use categories for *D. rufescens* according to Bernal-Ramírez *et al*. (2019).

	Category	Description
1)	Craft	It involves the elaboration of objects for daily chores and recreation (*e.g*., crafts, toys, or rustic tools).
2)	Ceremonial	When the plant is part of magical-religious events such as traditional rituals or local festivities, or in the treatment of psychosomatic diseases.
3)	Construction	When the plant is directly employed in the assembly and formation of structures that function as houses or warehouses.
4)	Environmental	It refers to the plants that indicate the presence of water, conserved environments or conducive to conservation.
5)	Fuel	It consists of using the plant for obtaining or maintaining the fire.
6)	Medicinal	When part of the plant, or its derivatives, is used to cure or treat diseases.
7)	Ornamental	The entire plant is used as decoration material or when it is part of the flora of the home gardens.

Results

All people interviewed visually recognized *D. rufescens*, despite having different names for it. It is known principally as *Begachi yaa'xia* (from Zapotec *Begachi* = moss and *yaa'xia* = yellow), or *pastle amarillo* (from *pastle* a variant word from Náhuatl *pachtli* = herb that grows and hangs from trees and Spanish *amarillo* = yellow). Other less commonly used Spanish names include cortinas amarillas (yellow curtains), barba de los árboles (tree beard), and musgo amarillo (yellow moss) (Figure 2).

Over the years, *D. rufescens* has been managed only locally by residents, meaning no selling or exchanging with other communities. It was not possible to precisely learn the year in which the community began using it. However, people in the oldest age category (69-95 years) indicated that their parents and grandparents were familiar with using this plant. Although there are no written records or photographs, community knowledge has been preserved through oral transmission over generations. Therefore, we estimated that the historical use of *D. rufescens* in the community of San Juan Luvina dates to at least 100 years.

Harvesting is done manually, and when located high up in trees, people use wooden hooks to reach the moss. Bags are used for storage and transport to the population center. According to the interviews, people previously conducted harvesting near the community, but presently they go further into the forest to obtain it.

For *D. rufescens*, we recorded around 40 traditional uses classified into seven categories (Figure 3) (Table 2). According to the R/E curves, there are no significant differences in the number of uses by age category. For category 1 (15-41 years) and 3 (69-95 years), the asymptotic tendencies in the curves suggest we recorded almost all the uses. However, more sampling is needed for category 2 (42-68 years) to record unfrequent uses of *D. rufescens* (Figure 4).

The uses recorded for *D. rufescens* are:

1) Ceremonial: This is the category most recognized in San Juan Luvina, where *D. rufescens* is used mainly as decoration in religious events. These events include weddings, Christmas (December), Easter (between March and April), Virgin of Guadalupe (December 12th), or Day of the Dead (November 2th). The local church's interior is decorated for these occasions. In the San Juan Bautista celebration (June 24), which is the most important in the community, arches made of stems of *Arundo donax* L. (Poaceae) are entirely covered by the moss and decorated with floral arrangements of *Dasylirion lucidum* Rose (Asparagaceae). These structures measure approximately 3 m high by 2 m wide and are placed at the local church main entrance (Figure 5A, B).

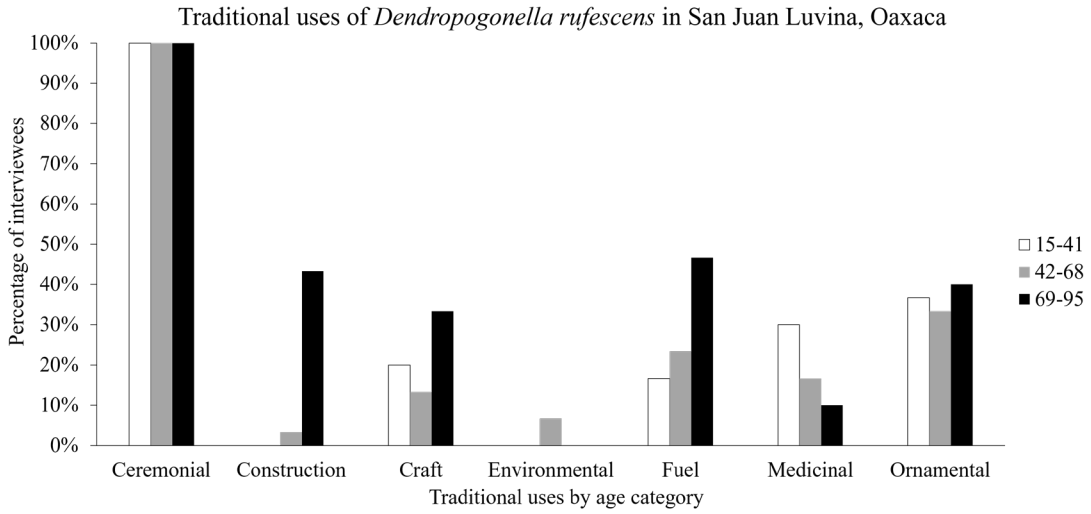

Figure 3. Proportion of traditional uses recognized by inhabitants of San Juan Luvina by age category.

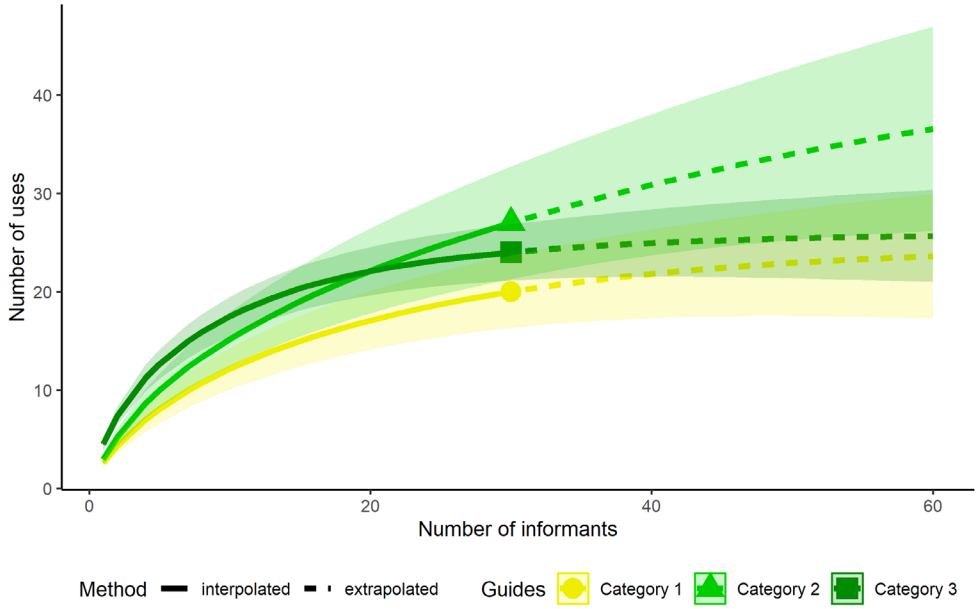

Figure 4. Number of traditional uses curves by age category with intrapolation/extrapolation. Each curve has confidence intervals of 95 %. Confidence intervals overlapping indicate no significant differences in the number of uses observed and estimated between age categories.

2) Construction: This category includes uses no longer practiced as material in the construction of household roofs and tombs. For the roofs, a dense layer of branches was padded with *D. rufescens*. Later, this process evolved to sandwiching a layer of the moss between two layers of "tejamanil" (long thin sheets of wood of *Pinus* L.) so that rainwater did not seep into the house. For tombs, portions of *D. rufescens* were placed next to the deceased person, along with offerings consisting of food and flowers. Subsequently, everything was covered with smooth stones. The use of the moss and rocks was to prevent odors from being released by decomposition. This knowledge is maintained mainly by people in the third age category and was not recorded in youth.

3) Craft: The plant is used to elaborate beds for dogs, poultry nests, school models, toys (stuffing for dolls and

Table 2. Traditional uses of *D. rufescens* checklist recorded for three age categories (1 = 15-41 years, 2 = 42-68 years, 3 = 69-95 years) in the community of San Juan Luvina, Oaxaca, Mexico. The ● indicate that the use is reported in the age category. The * indicate uses not more longer practiced.

Uses categories	Age categories		
1. **Ceremonial**	1	2	3
Posada navideña, a typical Christmas festival that is celebrated from December 16 to 24.	●	●	●
Nativity scene.	●	●	●
Christmas Eve.	●	●	●
Three Kings celebration (January 6).	●	●	
15 years celebration.		●	
Weddings.		●	
Virgin of Guadalupe (December 12).		●	●
Easter week.	●	●	●
Altars of Saints in homes.	●		
Day of the Dead (November 2).		●	
San Juan Bautista celebration (June 24).	●	●	●
2. **Construction**			
Household roofs.*		●	●
Tombs.*			●
3. **Craft**			
Poultry nests.	●		
Rug for domestic dogs and their puppies.	●		
School models.	●		
Padding material for pillows. *		●	●
Rug for rest in the forest.		●	●
Hats for cold in winter season. *			●
Confection of petates, a type of traditional rug. *		●	●
Costume items (wigs and mustaches) in local carnivals.	●		
Flower arrangements with pine branches (*Pinus* sp.).		●	●
4. **Environmental**			
Indicator of conserved areas.		●	
Indicator of the presence of water or humid areas.		●	
5. **Fuel**			
To create bonfires.	●	●	
To get fire in local garbage burners.	●	●	
6. **Medicinal**			
Treatment for the discomfort of women after childbirth. *			●
To pain relief to the body and bones. *		●	●
For kidney health.			●

Uses categories	Age categories		
For lung health.			●
For treatment of diabetes-related ailments.			●
For treatment blindness.			●
To whet the appetite.			●
7. **Ornamental**			
In family gardens.	●	●	●
In family celebrations.	●	●	
In home entrances, and in living spaces.	●	●	●
In School graduations.	●	●	
In inauguration of local government authorities (January 1).		●	●
Mother's Day (May 10).	●	●	
In national holidays (September 15 and 16).	●	●	●
Total of traditional uses recorded by age category	19	27	24

balls), costume items (wigs and mustaches) in local carnivals, and flower arrangements with pine branches (*Pinus* sp.) (Figure 5C, D). In the past, the moss was an important material to make "petates," a traditional rug used for a quick rest in the forest. To make these items, people collected thin stems of *A. donax* from streams that were joined with "ixtle," a fiber obtained from *Agave americana* L. subsp. *americana* (Asparagaceae). Finally, they added a layer of *D. rufescens* to the rug as a coating. Another option was to spread a dense layer of *D. rufescens* directly on the ground like a carpet to provide comfort while resting and maintaining body heat. Also, because of its soft texture, it has been used as padding material for pillows. Hats made with this moss show that it was also incorporated into garments. The process consisted of molding the moss until it obtained a hat shape, which then served as head protection in the winter season.

4) Environmental: People use *D. rufescens* as an indicator of humid areas as it is a plant that captures, maintains, and provides water. Also, reducing the moss population has been useful to detect environmental impact in the forest caused by local silvicultural management and wildfires. The environmental use category received the fewest mentions and was only recognized by men of the second age category.

5) Fuel: The plant is employed for forest rangers to create bonfires. It is useful to get fire in local garbage burners.

6) Medicinal: According to people in the third category, before the arrival of modern medicine (the 1960s), the moss provided treatment for the discomfort of women after childbirth. The moss was boiled and cooled a little before a patch was placed on the woman's abdomen. The therapy was repeated until the patient felt better. Another treatment gave pain relief to the body and bones. In this case, the moss was used with other plant parts that included corn ear styles and the central maguey stalk (*Agave americana* L. (Asparagaceae)). Patients breathed the smoke created by burning these three ingredients. Nowadays, *D. rufescens* is served as a drink to whet the appetite, for kidney and lung health, as well as for treatment of diabetes-related ailments, blindness, or only for quenching thirst. The infusion is consumed either warm or cold at any time of the day.

7) Ornamental: The moss is found as ornamental on trees in family gardens, but also as an ornament for tables, home entrances, and in living spaces, hung on strings. Furthermore, it serves as a decoration material for festivities such as Mother's Day (May 10), national holidays (September 15 and 16), and the inauguration of government authorities (January 1) in the main square of the community. In the square, it is hung on thin ropes to resemble the natural growth habit in the forest.

Figure 5. Some traditional uses of *D. rufescens* in San Juan Luvina. A. Arches made with stems of *A. donax*, covered with *D. rufescens*, and decorated with floral arrangements of *D. lucidum* during the San Juan Bautista celebration. B. Floral arrangements of *D. lucidum* with *D. rufescens* in the background. C, D. Elaboration of poultry nest and toys by women using *D. rufescens* from San Juan Luvina community.

For each traditional use category, except for the ceremonial, less than 50 % of the interviewees recognized the traditional use, but the proportions differed by age class (Figure 3). The third age (69-95 years) better recognized the craft, construction, fuel, and ornamental categories as compared to the rest of the age groups. Although individuals of the first and second age categories reported the medicinal uses more than older people, they do not know how to prepare it, nor for which ailment. The second and third ages mentioned the construction category, but there is an evident difference between them. Only the second age did indicate environmental use, but it is represented poorly. The three age categories had similar recognition only for the ornamental category.

After use, *D. rufescens* is most often cast away. However, it is possible to recycle it. An alternative is to use it as fertilizer on farmland or flowerpots or reuse it as an ornamental plant on trees in home gardens. Still, another option is to dry it, store it, and finally rehydrate when needed. The last possibility, that was referenced by fewer interviewees, is to return it to its natural habitat.

Discussion

With seven categories of traditional uses, *D. rufescens* is currently the bryophyte with the highest number of uses and TK in Mexico. Records in the country include one species (e.g., *Braunia secunda* for medicinal purposes) or a species set by use category (*e.g*., *Bryum* sp. and *Thuidium delicatulum* in ceremonial activities) (Cornejo-Tenorio & Ibarra-Manríquez 2019, Delgadillo 2000). The different uses of *D. rufescens* may be due to its durability, size, and long flexible stems, which make it a versatile and malleable multi-purpose material (Pant & Tiwari 1990). Its prolonged use (100 years) may be explained by its abundance in the region of Sierra Juárez.

People of the three age groups recognize the use of all traditional categories. The most representative one is ceremonial, and there is a consensus about how the moss is used in Christian rituals and festivities in the community. All other categories represent infrequent uses that younger generations no longer practice. Although the entire population recognizes the use in all categories, their knowledge of how and when to use the moss varied among age categories. For example, younger generations recognized craft uses as beds for dogs, poultry nests, or toys, while the older generation recognized only traditional rugs or hats. In the medicinal category, young generations participate in the *D. rufescens* harvesting for this use, but only members of the third age group know the type of disease and how it should be used. Because this traditional knowledge is the product of a long-term observation process, if it is not passed on to younger generations, it may be lost (Gomez-Baggethun *et al.* 2013). The most evident differences are in the construction and environmental categories. In the first case, the younger generation ignores the use of moss for roof or tomb construction. In the environmental category, only seven percent in the second group, in charge of silvicultural management, perceived that forestry activities could reduce *D. rufescens* populations. At the same time, this support to that knowledge differs between community members is related to their roles (Boster 1986, Garro 1986). This relation is more evident in the fuel category where there are differences due to the degree of participation of the population in tasks such as burning garbage or protecting the forests; creating fire to burn garbage or to get warm in the forest are activities frequently performed by people in the second and third categories and to a lesser extent by younger people.

Documenting traditional practices with plants provides information on their ecological aspects such as growth habits, size of colonies, or the distribution and abundance in a region (Camou-Guerrero *et al.* 2016). Names assigned to *D. rufescens* in Zapotec and Spanish (*e.g*., yellow moss or yellow curtain) imply an awareness of its hanging growth form in the forest and appearance by color and size the colonies (Figure 2). Also, *D. rufescens* use in the production of hats and temporary beds or the construction of house roofs can provide information about bryophyte properties as insulating material and water absorption capacity. Additionally, the increasing searching distance for *D. rufescens* harvest indicates that its populations have declined over time. One explanation is likely due to the sensitivity of *D. rufescens* to the environmental disturbance driven by forest degradation and climate change (León 2008, Song & Liu 2013). It is also possible that frequent harvest has damaged the natural recovery of these populations (Anastacio Martínez *et al.* 2017) in San Juan Luvina since *D. rufescens* is still present in conserved areas in the Sierra Juárez region.

To explain the use changes of the moss overtime in San Juan Luvina, changes in the community customs should be considered. According to the interviews, making pillows and hats, roof construction, and medicinal therapies with *D. rufescens* ceased with introducing synthetic construction materials and modern medicine in the community. These findings agree that the modernization process is related to the reduction of knowledge of plants' use (Benz *et al.* 2000). Thus, the results obtained here help reconstruct the past life of these communities and the natural history of *D. rufescens* populations in the region (cf. Moller *et al*. 2004).

This study shows that *D. rufescens* is a plant of great cultural importance for a community of the Sierra Juárez since it is part of its traditions and customs. One way to maintain these cultural traditions is their transmission to the younger generations. However, migration and socio-cultural changes as the language loss in the San Juan Luvina population can prevent the generational communication of this knowledge (Pardo de Santayana & Gómez Pellón 2002, Foreman 2006, Saynes-Vásquez *et al*. 2013, Riestenberg & Manzano 2019). Future studies will be necessary to evaluate the traditional knowledge resilience and its permanence in the community.

Research is required to explore how current harvesting practices of *D. rufescens* for traditional uses affect its populations' viability and ecosystem services it provides. For example, due to its high biomass, this moss plays an essential role in the water cycle, which can be affected by its harvesting (Romero *et al*. 2005, Ah-Peng *et al*. 2017). Also, it is convenient to evaluate if it is already at risk or threatened by its harvesting according to the IUCN guidelines for bryophytes (Bergamini *et al.* 2019). To evaluate this, studies on the *D. rufescens* ecology, including knowing the humidity levels in which it develops, host tree species, and growing populations time, will be needed. With this study, we established a working link with the San Juan Luvina community. This represents an opportunity to develop more studies and promote conservation initiatives that include disseminating the traditional ecological knowledge of some of its members (Kimmerer 2002). This knowledge include the effect of forest activity on *D. rufescens* populations, its hydrological importance, and alternatives for their reuse and management. Specifically, some community members have observed the reduction of the moss populations, which could affect their ability to retain and release water, a resource highly valued by the indigenous communities in the Sierra Norte of Oaxaca (Clark-Tapia *et al*. 2016). Likewise, some local people store the moss for reuse, and others reincorporate it into the forest after using it, which represents alternatives to reduce its harvest through rational management (Berkes 2008).

Regarding the last alternatives, residents point out that mosses can re-attach and develop on trees once they returned them to their natural habitat in the rainy season, essential knowledge for ecological restoration of the bryophyte's population (Kimmerer 2000). Finally, an aesthetic appreciation of *D. rufescens* exists among the people in San Juan Luvina that can contribute to its conservation. This valorization could help develop bryophyte conservation strategies covering more species in the region (Rozzi *et al*. 2020).

There is no evidence of the use of *D. rufescens* in other parts of Mexico despite its distribution in other states. This may be due to the lack of studies documenting the use of bryophytes or to a low abundance of the specie that does not allow its use as in the community of San Juan Luvina. In the case of the Sierra Juárez region, its good conservation status and its high levels of humidity (Ponce-Reyes *et al*. 2012) are elements that can favor the high frequency and abundance of *D. rufescens*. Thus, preserving the region is crucial to the conservation of *D. rufescens* and other bryophytes species.

Mexico, in general, and Oaxaca state have high biological and cultural diversity (Anderson *et al*. 2011, Berger 2019). Under this premise, future ethnobotanical studies, including bryophytes, may increase the records of species used and their traditional knowledge. Although mosses can be a part of traditional practices and knowledge in various communities across the state and country, they are generally ignored in ethnobotanical studies. Studies on the relationship between people and bryophytes can provide valuable information for biological sciences, anthropology, and history. We expect that this work will serve as a reference for future ethnobotanical research, thus increasing knowledge of plants of great biological importance. Finally, this study provides a list of use categories with specific information on the utilization of *D. rufescens* offers valuable material to conserve part of the historical and biological-cultural heritage of the San Juan Luvina community (Boege 2008).

Acknowledgments

We thank the community of San Juan Luvina for allowing us to carry out this work and the people who kindly allowed us to document their knowledge. Thanks to N. J. Pacheco Cruz for share a photophy of *D. rufescens*. We also thank C. Delgadillo Moya, M.-F. Indorf, M. Feldman, M. Jean, and the Laboratory of Bryology of the Université du Québec en Abitibi-Témiscamingue for their values comments in the development of the document. Finally, we thank the reviewers and associated editor.

Literature cited

Aguilar Santelises, MR. 2007. *Etnobotánica cuantitativa en una región de bosque de niebla de Sierra Norte, Oaxaca. Oaxaca, México*. MSc. Thesis. Instituto Politécnico Nacional.

Ah-Peng C, Williamson Cardoso AW, Flores O, West A, Wilding N, Strasberg D, Hedderson TAJ. 2017. The role of epiphytic bryophytes in interception, storage, and the regulated release of atmospheric moisture in a tropical montane cloud forest. *Journal of Hydrology* **548**: 665-673. DOI: https://doi.org/10.1016/j.jhydrol.2017.03.043

Alcorn JB. 1984. *Huastec Mayan Ethnobotany*. Texas, USA: University Texas Press. ISBN 13: 9780292715431

Álvarez S, Rubio A. 2013. LÍnea base de carbono en bosque mixto de pino-encino de la Sierra Juárez (Oaxaca, México). Aplicación del modelo Co2fix V.3.2. *Revista Chapingo Serie Ciencias Forestales y del Ambiente* **XIX**:125-137. DOI: https://doi.org/10.5154/r.rchscfa.2012.01.005

Anastacio Martínez ND, Franco-Maass S, Valtierra Pacheco E, Nava Bernal G. 2017. El proceso de extracción y comercialización del musgo (*Thuidium delicatulum*) en el Estado de México. *CIENCIA ergo sum* **24**: 44-53. DOI: https://doi.org/10.30878/ces.v24n1a5

Anderson EN, Pearsall D, Hunn E, Turner N. 2011. *Ethnobiology*. New Jersey, USA: Wiley-Blackwell. ISBN: 9781118015872

Ando H, Matsuo A. 1984. Applied bryology. *In*: Schultze-Motel W, ed. *Advances in Bryology 2*. Vaduz: Cramer; pp. 133-224.

Arriaga-Cabrera L, Espinoza-Rodríguez JM, Aguilar-Zúñiga C, Martínez-Romero E, Gómez-Mendoza L, Loza EL. 2000. *Regiones terrestres prioritarias de México*. México Distrito Federal, México: Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. ISBN: 970-9000-16-0

Begossi A. 1996. Use of ecological methods in ethnobotany: Diversity indices. *Economic Botany* **50**: 280-289. DOI: https://doi.org/10.1007/bf02907333

Beike AK, Decker EL, Frank W, Lang D, Vervliet-Scheebaum M, Zimmer AD, Reski R. 2010. Applied bryology-Bryotechnology. *Bryophyte Diversity and Evolution* **31**: 22-32. DOI: https://doi.org/10.11646/bde.31.1.7

Benz BE, Cevallos JE, Sanyana FM, Rosales JA, Graf SM. 2000. Losing knowledge about plant use in the Sierra de Manantlan Biosphere Reserve, Mexico. *Economic Botany* **54**: 183-191. DOI: https://doi.org/10.1007/bf02907821

Bergamini A, Bisang I, Hodgetts N, Lockhart N, Rooy JV, Hallingbäck T. 2019. Recommendations for the use of critical terms when applying IUCN red-listing criteria to bryophytes. *Lindbergia* **42**: 1-6. DOI: https://doi.org/10.25227/linbg.01117

Berger DN. 2019. *The Indigenous World 2019*. Copenhagen, Denmark: International Work Group for Indigenous Affairs. ISBN: 978-87-92786-93-7

Berkes F. 2008. *Sacred Ecology*. Second ed. New York, USA: Routledge Taylor and Francis Group. ISBN: 978-0-415-95827-1

Berlin B, Breedlove DE, Raven PH. 1974. *Principles of Tzeltal plant classification: An introduction to the botanical ethnography of a Mayan-speaking people of highland Chiapas*. New York, USA: Academic Press. ISBN: 978-0-12-785047-4

Berlin EA, Berlin B. 2005. Some Field Methods in Medical Ethnobiology. *Field Methods* **17**: 235-268. DOI: https://doi.org/10.1177/1525822X05277532

Bernal-Ramírez LA, Bravo-Avilez D, Fonseca-Juárez RM, Yáñez-Espinosa L, Gernandt DS, Rendón-Aguilar B. 2019. Usos y conocimiento tradicional de las gimnospermas en el noreste de Oaxaca, México. *Acta Botanica Mexicana* **126**: 1-24. DOI: https://doi.org/10.21829/abm126.2019.1471

Boege E. 2008. *El patrimonio biocultural de los pueblos indígenas de México: Hacia la conservación in situ de la biodiversidad y agrodiversidad en los territorios indígenas*. México Distrito Federal, México: Instituto Nacional de Antropología e Historia, Comisión Nacional para el Desarrollo de los Pueblos Indígenas. ISBN: 978-968-0385-4

Boster JS. 1986. Requiem for the omniscient informant: there's life in the old girl yet. *In*: Dougherty JW, ed. *Directions in Cognitive Anthropology*. Urbana, Illinois, USA: University of Illinois Press, pp. 177-197. ISBN: 9780252011948

Bray DB. 1991. The Struggle for the Forest: Conservation and Development in the Sierra Juarez. *Grassroots Development* **15**: 13-25.

Bray DB. 2020. *Mexico's community forest enterprises: success on the commons and the seeds of a good Anthropocene*. Tucson, Arizona, USA: The University of Arizona Press, pp. 312. ISBN: 9780816541126

Briones-Salas M, Lavariega-Nolasco MC, Cortés-Marcial M, Monroy-Gamboa AG, Masés-García CA. 2016. Iniciativas de conservación para los mamíferos de Oaxaca, México. *In*: Briones-Salas M, Hortelano-Moncada Y, Magaña-Cota G, Sánchez-Rojas G, Sosa-Escalante JE, eds. *Riqueza y conservación de los mamíferos en México a nivel estatal, Vol. I*. Ciudad de México, México: Instituto de Biología, Universidad Nacional Autónoma de México, Asociación Mexicana de Mastozoología A.C., Universidad de Guanajuato. pp. 329-366. ISBN: 978-607-02-8431-1

Camou-Guerrero A, Casas A, Moreno-Calles AI, Aguilera-Lara J, Garrido-Rojas D, Rangel-Landa S, Torres I, Pérez-Negrón E, Solís L, Blancas J, Guillén S, Parra F, Rivera-Lozoya E. 2016. Ethnobotany in Mexico: History, Development, and Perspectives. *In*: Lira R, Casas A, Blancas J, editors. *Ethnobotany of Mexico: Interactions of people and plants in Mesoamerica*. New York, USA: Springer, pp. 21-39. DOI: https://doi.org/10.1007/978-1-4614-6669-7_2

Casas A, Camou A, Otero-Arnaiz A, Rangel-Landa S, Cruse-Sanders J, Solís L, Torres I, Delgado A, Moreno-Calles AI, Vallejo M, S Guillén, Blancas J, Parra F, Farfán-Heredia B, Aguirre-Dugua X, Arellanes Y. 2014. Manejo tradicional de biodiversidad y ecosistemas en Mesoamérica: el Valle de Tehuacán. *Investigación Ambiental, Ciencia y Política Pública* **6**: 23-44.

Chao A, Gotelli NJ, Hsieh TC, Sander EL, Ma KH, Colwell RK, Ellison AM. 2014. Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies. *Ecological Monographs* **84**: 45-67. DOI: https://doi.org/10.1890/13-0133.1

Chapela F. 2007. El manejo forestal comunitario indígena en la Sierra de Juárez, Oaxaca. *In*: Bray DB, Merino-Pérez L, Barry D, eds. *Los bosques comunitarios de México: manejo sustentable de paisajes forestales*. México Distrito Federal, México: Secretaría de Medio Ambiente y Recursos Naturales, Instituto Nacional de Ecología, Consejo Civil Mexicano para la Silvicultura Sostenible, Instituto de Geografía-Universidad Nacional Autónoma de México, Florida International Institute, pp. 123-145. ISBN: 978-968-817-841-6

Clark-Tapia R, Ramos Morales MF, Alfonso Corrado C, Mendoza Díaz MM, Fuente Carrasco M. 2016. *Recursos hídricos de la Sierra Norte de Oaxaca caracterización, diagnóstico y gestión*. México Distrito Federal, México: Universidad de la Sierra Juárez. ISBN: 978-607-95991-2-6

Cornejo-Tenorio G, Ibarra-Manríquez G. 2019. Los tapetes florales de Patamban, Michoacán, México: elaboración y especies utilizadas. *Revista Mexicana de Biodiversidad* **90**: 1-19. DOI: https://doi.org/10.22201/ib.20078706e.2019.90.2700

De la Cruz M. 1552. *Libellus de medicinalibus indorum herbis*, Latin translation by Juan Badiano. México Distrito Federal, México: Instituto Mexicano del Seguro Social 1964.

Delgadillo CM. 2000. Native moss names in Mexico. *Evansia* **17**: 84-86.

Delgadillo CM. 2014. Biodiversidad de Bryophyta (musgos) en México. *Revista Mexicana de Biodiversidad* **85**: 100-105. DOI: https://doi.org/10.7550/rmb.30953

Flowers S. 1957. Ethnobryology of the Gosuite Indians of Utah. *The Bryologist* **60**: 11-14. DOI: https://doi.org/10.2307/3240044

Foreman JO. 2006. *The morphosyntax of subjects in Macuiltianguis Zapotec*. PhD Thesis. University of California.

Frahm J-P. 2004. Recent Developments of Commercial Products from Bryophytes. *The Bryologist* **107**: 277-283. DOI: https://doi.org/10.1639/0007-2745(2004)107[0277:rdocpf]2.0.co;2

Gadgil M, Berkes F, Folke C. 1993. Indigenous knowledge for biodiversity conservation. *Biodiversity: Ecology, Economics, Policy* **22**: 151-156.

García-Mendoza AJ, Ordoñez MJ, Briones-Salas M. 2004. *Biodiversidad de Oaxaca*. México DF, México: Instituto de Biología, Universidad Nacional Autónoma de México, Fondo Oaxaqueño para la Conservación de la Naturaleza, World Wildlife Fund. ISBN: 970-32-2045-2

Garro LC. 1986. Intracultural variation in folk medical knowledge: a comparison between curers and noncurers. *American Anthropologist* **88**: 351-370. DOI: https://doi.org/10.1525/aa.1986.88.2.02a00040

Gomez-Baggethun E, Corbera E, Reyes-Garcia V. 2013. Traditional Ecological Knowledge and Global Environmental Change: Research findings and policy implications. *Ecology and Society* **18**: 72. DOI: https://doi.org/10.5751/es-06288-180472

Gradstein SR, Churchill SP, Salazar-Allen N. 2001. *Guide to the Bryophytes of Tropical America*. New York, USA: The New York Botanical Garden Press. ISBN: 9780893274351

Harris ESJ. 2008. Ethnobryology: traditional uses and folk classification of bryophytes. *The Bryologist* **111**: 169-217. DOI: https://doi.org/10.1639/0007-2745(2008)111[169:etuafc]2.0.co;2

Hernández-Rodríguez E, Delgadillo CM. 2021. The ethnobotany of bryophytes in Mexico. *Botanical Sciences* **99**: 13-27. DOI: https://doi.org/10.17129/botsci.2685

Hernández-Rodríguez E, Escalera-Vázquez L, Calderón-Patrón JM, Mendoza E. 2019. Mamíferos medianos y grandes en sitios de tala de impacto reducido y de conservación en la sierra Juárez, Oaxaca. *Revista Mexicana de Biodiversidad* **90**: 1-10. DOI: https://doi.org/10.22201/ib.20078706e.2019.90.2776

Hsieh TC, Ma KH, Chao A. 2016. iNEXT: an R package for rarefaction and extrapolation of species diversity (Hill numbers). *Methods in Ecology and Evolution* **7**: 1451-1456. DOI: https://doi.org/10.1111/2041-210x.12613

Kimmerer RW. 2000. Native knowledge for native ecosystems. *Journal of Forestry* **98**: 4-9.

Kimmerer RW. 2002. Weaving traditional ecological knowledge into biological education: A call to action. *BioScience* **52**: 432-438. DOI: https://doi.org/10.1641/0006-3568(2002)052[0432:wtekib]2.0.co;2

León YV. 2008. Propuesta de algunas especies de la familia Cryphaceae (Musci) para la lista roja de briofitas de Sudamérica. *Cryptogamie, Bryologie* **29**: 211-214.

López-Santiago J. 2015. *Plantas útiles del municipio de San Pablo Macuiltianguis, Oaxaca*. BSc Thesis. Universidad de la Sierra Juárez.

Manuel MG. 1994. Cryphaceae. *In*: Sharp AJ, Crum H, Eckel PM, eds. *Moss Flora of Mexico*. New York, USA: New York Botanical Garden, pp. 689-696. ISBN: 978-0893273798

Mittermeier RA, Gil PR, Hoffmann M, Pilgrim J, Brooks T, Mittermeier CG, Lamoreux J, Fonseca GABD. 2004. *Hotspots Revisited*. Mexico DF, Mexico: CEMEX, Conservation International and Agrupacion Sierra Madre. ISBN: 978-9686397772

Moller H, Berkes F, Lyver POB, Kislalioglu M. 2004. Combining Science and Traditional Ecological Knowledge: Monitoring Populations for Co-Management. *Ecology and Society* **9**: 2. DOI: https://doi.org/10.5751/es-00675-090302

Ortiz CD. 1970. *Contribución al conocimiento de la flora de la Sierra de Juárez*. BSc Thesis. Universidad Nacional Autónoma de México.

Pant G, Tiwari SD. 1990. Bryophytes and mankind. *Ethnobotany* **2**: 97-103.

Pardo de Santayana M, Gómez Pellón E. 2002. Ethnobotany: traditional management of plants and cultural heritage. *Anales del Jardín Botánico de Madrid* **60**: 171-182. DOI: https://doi.org/10.3989/ajbm.2002.v60.i1.86

Ponce-Reyes R, Reynoso-Rosales VH, Watson JEM, VanDerWal J, Fuller RA, Pressey RL, Possingham HP. 2012. Vulnerability of cloud forest reserves in Mexico to climate change. *Nature Climate Change* **2**: 448-452. DOI: https://doi.org/10.1038/nclimate1453

R Core Team. 2021. R: A language end environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria. http://www.R-project.org/

Rees JD. 1976. The Oaxaca Christmas plan market. *Journal of the Bromeliad Society* **26**: 223-232.

Riestenberg KJ, Manzano REC. 2019. Teaching Task-Based Writing in Zapotec in Oaxaca, Mexico. *In*: Sherris A, Peyton JK, eds. *Teaching Writing to Children in Indigenous Languages*. New York, USA: Routledge-Taylor & Francis Group, pp. 126-142. ISBN: 978-0367661755

Romero C, Putz FE, Kitajima K. 2005. Ecophysiology in Relation to Exposure of Pendant Epiphytic Bryophytes in the Canopy of a Tropical Montane Oak Forest. *Biotropica* **38**: 35-41. DOI: https://doi.org/10.1111/j.1744-7429.2006.00099.x

Rozzi R, Valle MTL, Russell S, Goffinet B, Massardo F. 2020. Ecoturism with a hand-lens: A field environmental

philosophy experience from the south of the world. *In*: Brister E, Frodeman R, eds. *A Guide to Field Philosophy: Case Studies and Practical Strategies*. New York, USA: Routledge, pp. 222-239. ISBN: 78-0815347576

Saynes-Vásquez A, Caballero J, Meave JA, Chiang F. 2013. Cultural change and loss of ethnoecological knowledge among the Isthmus Zapotecs of Mexico. *Journal of Ethnobiology and Ethnomedicine* **9**: 1-10. DOI: https://doi.org/10.1186/1746-4269-9-40

Song L, Liu W-Y. 2013. Potential Impacts of Global Changes on Epiphytic Bryophytes in Subtropical Montane Moist Evergreen Broad-Leaved Forests, SW China. *In*: Lowman M, Devy S, Ganesh T, eds. *Treetops at Risk: Challenges of Global Canopy Ecology and Conservation*. New York, USA: Springer, pp. 155-167. ISBN: 978-1-4614-7160-8

Trejo I. 2004. Clima. *In*: García-Mendoza AJ, Ordoñez MJ, Briones-Salas M, eds. *Biodiversidad de Oaxaca*. México DF, México: Instituto de Biología, Universidad Nacional Autónoma de México, Fondo Oaxaqueño para la Conservación de la Naturaleza, World Wildlife Fund, pp. 67-85. ISBN: 970-32-2045-2

Young KJ. 2007. *Ethnobotany*. New York, USA: Chelser House Publishers. ISBN: 9780791089637

Associate editor: José Blancas

Author contributions: EHR, study conceptualization, methodology, data curation, interpretation results, investigation, resources, writing - original draft, writing - review and editing; JLS, fieldwork, methodology, data curation, Zapotec - Spanish traslations, writing - original draft, writing - review and editing.

Appendix 1. Interview structure in Zapotec. English translation is in italics.

Kuestionariua'

Questionnaire

Ladaa' (*Date*): ___/____/____

Bi-lalu' (*Name*): _____ Generua' (*Gender*): _____ Yeda'(*Age*): ___

Sii'na (*Occupation*): _____ Gradua' (*Schooling*): _____

Yuu'-dina (*Community*):_____

Rua'nana' (*Mother language*): _____ Segundua'rua'/Chuu'pa rua' (*Second language*): _____

1. ¿Yavelasiluu' ni iyya? _____ O'o' ____ Lavii' _____

Do you know this plant? (Show the stems of *D. rufescens* and photographs) *Yes___ No___*

2. ¿Bi-lalu' yavelasiluu'?

What name (s) do you know?

3. ¿Yavelasiluu' si denlu' tu' usua'? O'o' ____ Lavii' _____

Do you know if it has any use? Yes__ No___

4. ¿Bi usua' denlu' luu' lani iyya lani formaa'?

Do you use this plant? And in what way?

5. ¿Yavelasiluu' otru' usua' ki iyya nii luu-bina'? O'o' ____ Lavii' _____ ¿Bii'?

Do you know any other use of the plant in the community? Yes___ No___ which one?

6. ¿Bi runlu' lani iyya después-ki usua'?

What do you do with the plant once it is used?

7. ¿Xhiveriulassii' lani yeda ki deta' usua' ki iyya nii'?

Remember since when (year) has this plant been used?

8. ¿Bi formaa' denlu' iyya nii'?

How is the plant collected?

9. ¿Tito' informacionaa' respetua' ki-begachi yaa' xia?

Do you know anything else about this plant?

10. ¿Larkalasiluu' ki-ni informacionaa' ki-loo iyya para' publicacionaa' nii' siempre' ki bi-lalu' lavii' te' loo iyya'?

Do you authorize the inclusion of this information in a publication of the results of this study? Do you want your name to remain anonymous?