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Biocultural Diversity Loss: the Decline of Native Stingless Bees (Apidae: Meliponini) and Local Ecological Knowledge in Michoacán, Western México

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Abstract
Local ecological knowledge (LEK) is of utmost importance for biodiversity conservation; however, a number of studies document the loss of LEK regarding native bees. Stingless bees (Apidae: Meliponini) are important pollinators that have been managed by humans in all tropical areas of the world. Our work documents the decline of Meliponini and associated LEK in the state of Michoacán, western Mexico, as well as local historical management and perceptions of the diversity and abundance of bees. Through ecological sampling, semi-structured interviews, and participant observation, we established the presence of 13 species of Meliponini and recognition of 23 local names. Although stingless bees' pot-honey is harvested directly through extraction of wild nests, local knowledge about bee diversity, behavior, and use can contribute to their conservation. Because of recent access to manufactured products and the scarcity of wild nests, LEK and pot-honey harvest are being abandoned and forgotten in some areas. Maintaining LEK is important in designing sustainable use strategies to prevent the extinction of wild nests and allow conservation of bees as well as the cultural legacy associated with them, essential in the context of a global decline of pollinators.

Keywords Stingless bee (Meliponini) decline · Pot-honey hunters · Erosion of local ecological knowledge · Qualitative data collection · Michoacán · Mexico

Introduction

Local ecological knowledge (LEK) refers to the accumulation of information, beliefs, and practices that a group of people or communities have about the components, interactions, and processes regarding their environment during a specific period (Berkes 1999). This knowledge is transmitted through generations, both orally and through observation. It is fundamental for decision-making regarding the natural environment and the possible implementation of effective sustainable management strategies (Berkes *et al.* 2000; Berkes and Turner 2006). However, LEK that has persisted over many generations is declining in many communities as rapid social and economic changes occur globally (Leff 2004; Ehrlich *et al.* 2012; Aswani *et al.*2018).

Throughout history, human societies have employed management and extractive practices that in some cases led to environmental conservation but in others to environmental damage or even destruction (Johannes 2002). It has been noted that communities may selectively conserve particular areas or resources, and that they may change or even abandon their conservation strategies over time (Berkes and Turner 2006). Thus, LEK is not static or immutable, but continuously changes or can be completely lost as new patterns of knowledge and technologies are adopted (Gómez-Baggethun *et al.* 2013).

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One of the many changes associated with the current anthropogenic crisis associated with the loss of biodiversity worldwide is a dramatic decline in populations of animals that function as pollinators, especially insects and notably bees (Potts *et al.* 2016). Bees have been extensively studied and systematically documented around the worldand are generally recognized to be seriously threatened. However, in some areas, such as the tropics of the Americas, more research is still needed on the conservation status of bees (Biesmeijer 2006; Potts *et al.* 2010, 2016).

Stingless social bees (Apidae: Meliponini) are considered critical pollinators of wild and cultivated vegetation in tropical and subtropical areas of the world (Heard 1999; Slaa *et al.* 2006). Globally, there are more than 400 species of Meliponini, with the largest number of species in the American continent (Michener 2007; Camargo and Pedro 2013). Besides the ecological benefits provided by pollination, bees have been part of the culture and livelihoods of many people who cultivate them under different management schemes, generally called meliponiculture (Crane 1992; Cortopassi-Laurino *et al.* 2006). Traditional management of stingless bees has a strong foundation in LEK (Quezada-Euán *et al.* 2018). There is evidence for meliponiculture in Mesoamerica even before the arrival of Europeans. Many cultures used the products of stingless bees (pot-honey, pollen, wax) for religious purposes, to enrich and complement their medicinal and food resources, and for diverse material uses (Crane 1992; Quezada-Eúan *et al.* 2001; 2018; Cortopassi-Laurino *et al.* 2006). Although pot-honey is used as food and sweetener, it is valued mainly for its medicinal properties to treat eye infections, fractures, sprains, muscular pains, skin wounds, and respiratory and gastrointestinal diseases, among other disorders (Vit *et al.* 2004). Stingless beeswax has been used as a material for the preparation of molds used in the manufacture of ornaments and gold figurines since before the arrival of the Spaniards in Mexico (Schwarz 1945), and also for candlemaking, fashioning ornamental figurines for different community festivities, and as glue and a natural sealant (Schwarz 1945; Bennett 1964; Reyes-González *et al.* 2014; Vargas *et al.* 2014).

In Mexico there are 46 species of stingless bees (26% endemic; Ayala 1999), and up to 20 species are used in the practice of meliponiculture throughout the country (Reyes-González *et al.* 2016), historicalyamong some indigenous and mestizo groups, mainly in the regions of the Gulf of Mexico, and southeastern Mexico, including the Yucatan Peninsula (Porter-Bolland *et al.* 2015; Arnold *et al.* 2018; Quezada-Eúan *et al.* 2018). Recently efforts have been made to support these traditional practices as well as to implement contemporary management strategies to mitigate harm to bee populations.

In the low and warm lands of western and northern Mexico, historical records and recent studies document management of stingless bees under different schemes, ranging from the extraction of pot-honey and wax from wild nests to areas where controlled breeding and reproduction is common (Hendrichs 1941; Kent 1984; Dixon 1987; Reyes-González *et al.* 2014). However, there have been few studies of meliponiculture in these areas. Penninton (1963), Bennett (1964), and Kent (1984) reported the management of stingless bees is a frequent practice in northern states of Sonora, Sinaloa, and Chihuahua. Penninton (1963) reported on pot-honey extraction from stingless bees' wild nests by indigenous Tarahumara groups in Chihuahua, the northernmost location of stingless bee management in the Americas. Other studies report the use and breeding of stingless bees in the western-central state of Nayarit, where hollowed trunks and cylindrical containers with special ornaments were used to house stingless bee nests (Nordenskiöld 1929; Crane 1999). A more recent study also in western-central Mexico, on the coast of Jalisco, documented LEK related to stingless bee management involving nest extraction (Contreras-Escareño *et al.* 2019).

In Guerrero state in southwest of Mexico ssome communities located along the Balsas River contributed pot-honey and wax to the Aztec empire (Borah and Cook 1960; Dixon 1987). During the twentieth century, the indigenous Nahua inhabitants of the Balsas River basin still practiced stingless bees management, moving trunks of trees with nests into their homes (Hendrichs 1941; Dixon 1987). These Nahua communities, experts in the management of stingless bees, were locally called *mieleros* (pot-honey hunters). However, Dixon (1987) reported that stingless bee management was disappearing and only persisted in some sites as a hobby, being replaced by honey beekeeping (*Apis mellifera*).

Kent (1984) listed several sites in the western state of Michoacán where stingless beekeeping was practiced, including an indigenous Purepecha locality where, in 1948, he found native bees nesting in tree trunks. More recently, Ayala et al. (2013) reported ten stingless bee species for Michoacán state. Reyes-González et al. (2016) documented the presence of nine species in only two municipalities of central Michoacán, and reported that local informants recognized eleven species.

Management of native bees in indigenous and mestizo communities is based on LEK, which may be vulnerable to erosion and loss, making research and documention of the socio-ecological system where humans and native bees interact vital, especially in regions like western Mexico, where there is little available data. Preserving the diversity of native bees and the environmental services they provide is important for local ecosystem integrity and inhabitants' wellbeing, but, in light of the current pollinator crisis, is also critical globally. LEK is a fundamental aspect of biocultural processes contributing to the implementation of conservation strategies for this vulnerable group of insects.

We document the current presence of stingless bee species in Michoacán, a region with a significant presence of

Meliponini, as well as the LEK associated with their use, local names, behavior, forms of recognition, traditional management practices, and the implications of this management. In addition, we recorded local perceptions of historical diversity and abundance of native bees, as well as the changes in traditional uses of these bees.

Methods

Study Area

This study was carried out in the tropical environments of Michoacán state in western Mexico (Fig. 1), including the low-altitude regions of the Pacific coast to the base of the mountains of the Trans-Mexican Volcanic System. In the low altitudes (0 to 1300 m), there are two climate types: warm sub-humid to warm arid with an annual average temperature of 22 °C, and semi-warm sub-humid with an annual temperature higher than 18 °C. In the higher elevations (1300 to 2000 m), the climate is temperate sub-humid, with annual average temperatures between 12 and 18 °C. In all areas, the rainy season occurs during the summer (CONABIO 2001). Vegetation of warmer areas are tropical dry forests, xerophytic scrublands, and mangrove along the coast. The higher elevations have mixed oak-pine forests and other temperate conifers forests (INEGI 2015).

We conducted our research in five established zones: 1) *Medium-high Balsas,* which is covered by mixed forest pine-oak vegetation and tropical dry forest inhabited by a mestizo population whose livelihoods are based on forest management, rainfed agriculture, and extensive cattle raising. 2) *High Balsas*, which is covered by highly fragmented mixed pine-oak forest, avocado plantations, and rainfed crops. The majority of the population is mestizo, but there are some indigenous Purepecha communities. The main economic activity is intensive avocado production. 3) *Tierra caliente*, where the dominant vegetation is tropical dry forest and xerophytic scrublands, which are now under extensive agriculture. The mestizo population's economy is based on intensive irrigation agriculture (lemon, cucumber, and melon, among others), and intensive livestock rearing. 4) *Sierra-Costa*, where the predominant vegetation is tropical dry forest, mixed pine-oak forest at the top of the mountains, and mangrove in the southern part of the coast. The population is mostly mestizo, but there are some localities on the coastline inhabited by indigenous Nahua. The main economic activities are extensive cattle ranching, which has transformed vast areas from tropical dry forest to grasslands, and tourism and rainfed agriculture in the coastal zone. 5) *Eastern*, where the mountains are covered by mixed pine-oak forests and tropical dry forests. The population is mestizo with economic activities related to forest management, rainfed agriculture, and extensive cattle ranching.

We conducted research in 43 localities chosen on the basis of two criteria: 1) the existence of a local expert or beekeeper with extensive experience of native bees; and (2) access and security clearances for conducting research necessary in this part of the country.

Qualitative Research and Stingless Bee Ecological Sampling

We adopted a qualitative approach for data collection, using participant observation, workshops, and semi-structured interviews. We conducted three workshops with stingless bee hunters, beekeepers who managed *Apis mellifera,* and others

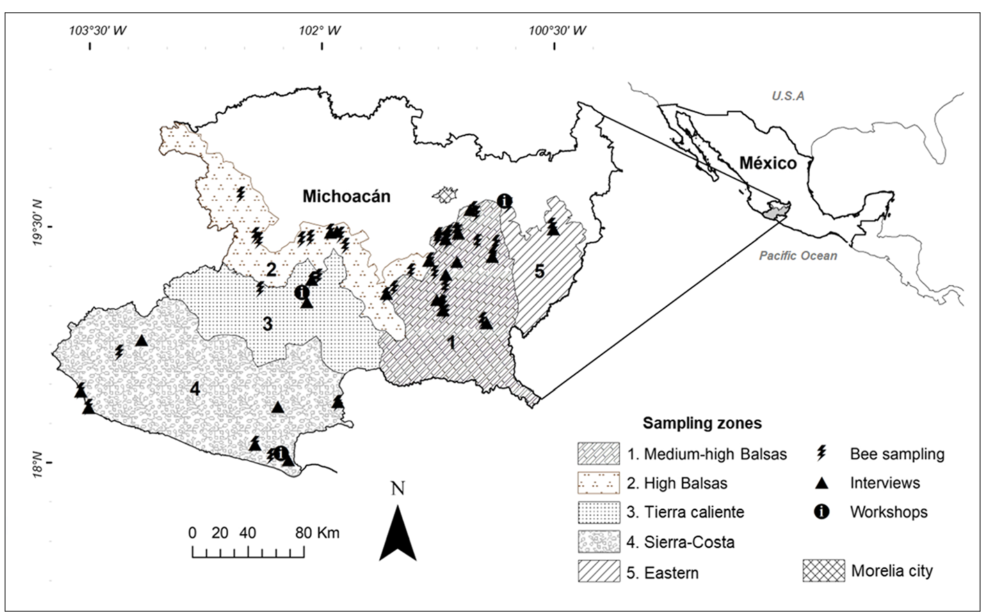

Fig. 1 Study area: geographic zones for stingless bees sampling, and documenting LEK

interested in stingless bees. These workshops served to document LEK, local perceptions regarding bee diversity and abundance, and the history of management of stingless bees. We also conducted participant observation visits with local informants who collect wild stingless bees.

The majority of qualitative data were obtained from 25 semi-structured interviews we conducted with local experts who in the past or currently collect native bee nests, aged between 40 and 85, and (an average of 65 years). The interview consisted of 28 questions organized in three sections: 1) local knowledge about stingless bees (names of recognized species, anecdotal stories or beliefs related to bees, how to recognize bees and their morphological characteristics, habits of bees and characteristics of nests, spatial and temporal distribution of Meliponini); 2) harvesting and use of stingless bees (including stingless bee management techniques, preferred species, abundance, and preparation and use of bee products); and, 3) perceptions of historical management, diversity, and abundance of bees, causes and factors of abundance or current decline, future of the traditional practices, and extent of interest in modern techniques for harvesting. The interviews were not time limited, ranging from 20 min to three hours, with an average of one hour and 20 min. We analyzed the interviews to identidy key words and phrases in each of the three sections (Taylor and Bogdan 1987). We used the mention index (MI) technique to ascertain the relevance of each category of responses to calculate the proportion of mentions of a specified category divided by the total number of interviews (Camou-Guerrero *et al.* 2008).

We undertook extensive sampling in areas recommended by informants in the different geographical zones using the direct search technique to compile an inventory and taxonomic determination of stingless bees (Sutherland 1996) (Fig.1). We also collected bee specimens with aerial net and entomological aspirator for identification by informants and subsequent taxonomic determination by a specialist made according to Camargo and Pedro (2013). Part of the specimen collection was deposited in the Biological Collection of Invertebrates of the Estación de Biología Chamela, UNAM.

Results

Local Names and Stingless Bee Recognition

Responses from our informants indicated that LEK was specific to the different geographical zones of the state. We recorded 23 local names for stingless bees, including stick hives, stick honey bees, bush hives, or bees that do not sting *(colmenas de palo*, *abejas de miel de palo*, *colmenas de monte* or *abejas que no pican*). Some species have different names in different zones (Table 1). We were able to corroborate the taxonomic identity of 13 species in the genus *Plebeia*, of which six have nesting characteristics and foraging habits that render them especially suitable for meliponiculture (*Frieseomelitta nigra* Cresson*, Melipona fasciata* Latreille*, Melipona lupitae* Ayala*, Nannotrigona perilampoides* Cresson*, Plebeia fulvopilosa* Ayala, and *Scaptotrigona hellwegeri* Friese).

In some large areas, such as zones 2 (*High Balsas)* and 3 (*Tierra caliente)* that have extensively modified their landscapes due to agricultural activities and urban expansion, local experts reported an average of three bee species that are no longer used, whereas in areas with lower density populations and less intensive land use of shifting cultivation and range-fed cattle (zones 1, 4, and 5), local experts reported an average of six species no longer used. In these latter zones, local knowledge and traditional management practices are deeply rooted and widely used, and informants' responses indicated that local communities still know a range of uses for pot-honey and wax for medicinal purposes even although they currently use native bees only occasionally. Interviewees described bees' morphological characteristics, bees' behavior, and nesting patterns, which allow them to differentiate Meliponini (Table 2).

The most widely reported bee was *S. hellwegeri*, locally referred along the Balsas basin as *abeja bermeja* (76% of local experts), and *abeja alazana* (24% of informants) in the *Sierra-Costa* (zone 4). This bee is easily recognized by its reddish color and defensive behavior. The second most cited bee was *F. nigra*, known as the *abeja zopilota* by 92% of local experts and is recognized by its white tip wings, and in third place was *G. acapulconis,* with 64% of citations. The least cited bee species (4%) were more difficult to collect and the taxonomic identity of only two species was corroborated (*T. fulviventris* and *T. pipioli*). We have not yet determined the taxonomic identity of the remaining four locally named bees (Table 2).

With regard to informants' perceptions of bee abundance, the most mentioned were *S. hellwegeri* (56%) followed by *N. perilampoides* (24%). Local experts' perceptions indicated the rarest and least populous species of bees were *M. fasciata* (44%) followed by *M. lupitae* (20%) (Fig. 2).

Sixty percent of local experts reported that stingless bees are more frequently sighted in the autumn flowering seasons, as they are "looking for food in the flowers," while 32% reported they are easier to see when they look for water and there is less vegetation in the dry season (*secas*) from March to May. Other interviewees indicated that in the past stingless bees were frequently sighted all year round. Their current scarcity makes it more difficult to observe them. Regarding their preferred food sources, all the local experts mentioned that stingless bees visit any plant and tree with flowers, although each has a different perception of the most abundant plant species depending on the specific zone vegetation type and the season.

Table 1 Local names mentioned for stingless bees related to geographic zone and vegetation type

Number	Scientific name	Local name	Zones*	Vegetation type**
1	*Scaptotrigona hellwegeri* Friese	Abeja bermeja	1,2,5	a,c
2		Abeja alazana	3,4	c
3	*Melipona fasciata* Latreille	Colmena real	1,2,3,5	b
4	*Frieseomelitta nigra* Cresson	Abeja zopilota	1,2,3,4,5	a
5	*Geotrigona acapulconis* Strand	Colmena de tierra	1,2,5	a,b,c
6		Abeja prieta de tierra	3,4	a,b,c
7	*Lestrimelitta chamelensis* Ayala	Abeja limoncilla	1,2,3,4,5	a,b,c
8	*Partamona bilineata* Say	Abeja esculcona	1,3,4	b
9		Abeja mordelona	5	b
10		Katzambe	2	b
11	*Trigonisca pipioli* Ayala; *Plebeia moureana* Ayala; *Plebeia frontalis* Friese	Abeja cepimilla	1	a
12		Abeja ojuela	4	c
13	*Nannotrigona perilampoides* Ayala	Abeja trompetera	1,2,	b,c
14		Abeja trompilla	3,4	c
15		Abeja humilde	5	b
16	*Melipona lupitae* Ayala	Abeja pintilla	1,3,4	a,c
17	*Plebeia fulvopilosa* Ayala	Abeja sapita	1,2	b
18	S/D	Abeja prieta esculcona	1	a
19	*Trigona fulviventris* Guérin	Abeja chamacuera	4	c
20	*S/D*	Abeja frijola	4	c
21	*S/D*	Abeja negra culo de caballo	4	c
22	*S/D*	Abeja chaninda	3	a
23	*S/D*	Abeja tindacha	3	a

*Zones: 1. *Medium-high Balsas zone*; 2. *High Balsas zone*; 3. *Tierra caliente zone*; 4. *Sierra-Costa zone*; 5. *Eastern zone*

**Vegetation type: a. Tropical dry forest; b. Mixed pine-oak forest; c. Tropical dry forest and mangroves

In general, interviewees reported stingless bees are found in forests with mature trees, while a few interviewees mentioned that the *colmena real* (*M. fasciata*) is found almost exclusively in *encinos* and *tocuz* trees, both species of the genus *Quercus* (oak). In warmer areas, some interviewees commented that *colmena pintilla* (*M. lupitae*) prefers to nest in *chucumpuz* (*Cyrtocarpa sp.*) trees. Informants did not mention any special nesting preferences regarding tree species for any of the other nest building species. Although they noted that any hollow tree logs are suitable for stingless bees to establish their nest, the most mentioned preferred tree species are *encino* and *tocuz* (*Quercus sp.*), *parota (Enterolobium sp.*), *pinzan (Pithecellobium sp.*), *ceiba* (*Ficus sp.*), *chucumpuz* (*Cyrtocarpa sp.*), *cansangues* (possibly *Apoplanesia sp.*), *tepehuaje* (*Lysiloma sp.*), and *cuerámo* (*Cordia sp.*).

Regarding LEK of predators or other animals that affect Meliponini populations (Fig. 3), overall badgers (*Nasua narica*) were the most mentioned (68% of the interviewees). In the *Sierra-Costa* zone, the anteater (*Tamandua mexicana*) was cited as a natural predator that consumes both bees and pot-honey. Among insects, ants (*Formicidae*) were the most mentioned (36%) as bee predators. Only one interviewee mentioned that the stingless bee *abeja limoncilla* (*L. chamelensis*) invades and robs other bees' nests.

Management and Use of Stingless Bees

Most interviewees (84%) reported that their parents and grandparents taught them all they know related to native bees, including how to manage them. The remaining 16% reported learning from other relatives, such uncles, or other knowledgable individuals in their communities. The majority of informants argued that currently, the young people of their communities are unfamiliar with these insects, indicating that the generational transmission of local knowledge is being lost. All the local experts considered that bees are beneficial both for the products they provide and because they do not sting.

In the state of Michoacán beekeepers, generally men, either totally or partially extract pot-honey, pollen, or wax from nests in the wild (Fig. 4) and are known locally as *colmeneros* (pot-

Table 2 Local knowledge of stingless bees in Michoacán related to behavior, morphology, nesting and uses

Num	Local name	Scientific name	Behaviour	Morphology	Nesting	Uses*
1 2	Abeja bermeja Abeja alazana	*Scaptotrigona hellwegeri* Friese	Defensive (gets tangled in hair and bites)	Medium, intense reddish bee	Hollow tree trunks	H, W, P
3	Colmena real	*Melipona fasciata* Latreille	Defensive (gets tangled in hair and bites)	Large, Apis-like, hairy bee	Hollow tree trunks	H, W, P
4	Abeja zopilota	*Frieseomelitta nigra* Cresson	Docile	Medium, dark shiny bee with white wingtips	Hollow tree trunks, rocks, ground, wooden posts, house walls	H, W, P
5 6	Colmena de tierra Abeja prieta de tierra	*Geotrigona acapulconis* Strand	Very docile	Medium, completely dark bee	Ground	H, W,
7	Abeja limoncilla	*Lestrimelitta chamelensis* Ayala	Docile, attacks other bees	Small bee, with a lemon scent	Hollow tree trunks	H, W,
8 9 10	Abeja esculcona Abeja mordelona Katzambe	*Partamona bilineata* Say	Defensive (gets tangled in hair and bites)	Medium, completely dark bee	Exposed nests (in abandoned termite and parrot nests), occasionally hollow tree trunks	H, W,
11 12	Abeja cepimilla Abeja ojuela	*Trigonisca pipioli* Ayala; *Plebeia frontalis* Friese; *Plebeia moureana*, Ayala	Docile, likes people's sweat	Very small bee	Hollow tree trunks, very small nest	H
13 14 15	Abeja trompetera/ Abeja trompilla Abeja humilde	*Nannotrigona perilampoides* Cresson	Very docile	Small bee	Hollow tree trunks, entrance to the nest is a wax trumpet	H, W, P
16	Abeja pintilla	*Melipona lupitae* Ayala	Docile	Large, Apis-like, abdomen with stripes	Hollow tree trunks, cavities between trunks and the ground	H, W, P
17	Abeja sapita	*Plebeia fulvopilosa* Ayala	Very docile	Small, completely dark bee	Hollow tree trunks	H, W, P
18	Abeja prieta esculcona	(Not collected)	Defensive (gets tangled in hair and bites)	Medium, completely dark bee	Ground	H, W,
19	Abeja chamacuera	*Trigona fulviventris* Guérin	Occasionally Defensive	Medium bee, orange-colored abdomen	Ground (visible, wide, and shiny trumpet-shaped entrance to nest)	W
20	Abeja frijola	(Not collected)	Docile	Medium bee, grey with white stripes in the abdomen	Stones, sometimes hollow trees trunks	H, W, P
21	Abeja negra culo de caballo	(Not collected)	Defensive (gets tangled in hair and bites)	Large, completely dark bee	Ground (wide trumpet-shaped entrance to nest)	H
22	Abeja chaninda	(Not collected)	Docile	Medium bee, with white wingtips	Hollow tree trunks, stones, ground, wooden posts, house walls	H
23	Abeja tindacha	(Not collected)	Defensive (gets tangled in hair and bites)	Medium, completely dark bee	Ground	H

*Uses: H: Pot-honey; W: Wax; P: Pollen

honey hunters). *Colmeneros* we interviewed mentioned that according to the bee species, they obtain one, two, or all three products (Table 2).

Only two interviewees reported having tried in the past to maintain trunk-nests in their homes to harvest these products regularly. An elderly interviewee from the *Sierra-Costa* zone

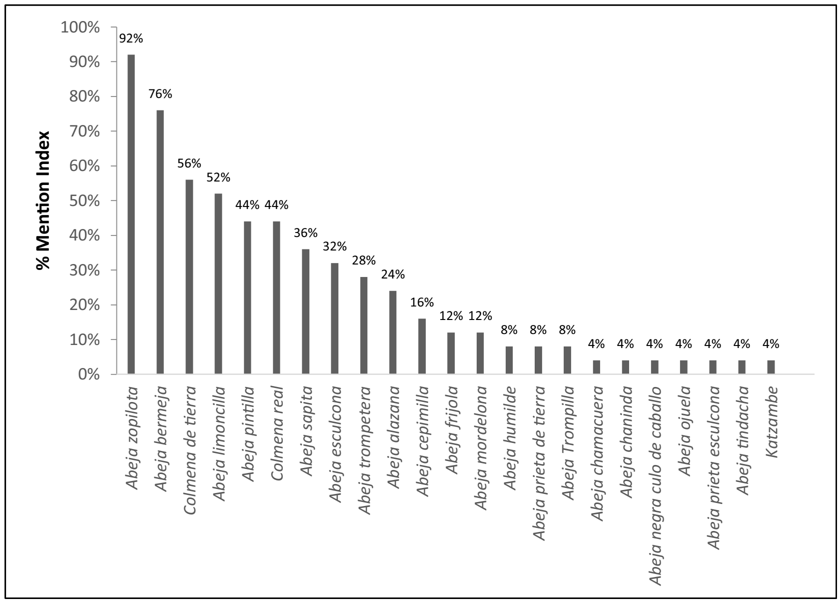

Fig. 2 Mention Index of local names of known stingless bees in Michoacán state

noted that more than 50 years ago, some people hollowed out *bules* (*Lagenaria siceraria*) to maintain *S. hellwegeri* nests. They both observed that after a while the bees would abandon these nests.

The extraction of stingless bee products from the wild occurs either fortuitously, when nests are located while *colmeneros* are engaged in other activities but are able to extract them; or when they organize trips with the sole purpose of searching for nests, which is called *colmenear* (pot-honey hunting). The practice of deliberately searching for bee nests was more frequent in some localities 40 to 50 years ago. Simple hand tools such as axes and machetes were used to open the bark of trees to extract the bee products. More recently, chainsaws are also used. Nests in the ground are dug up with tools such as shovels, picks, and a mini-spade for digging *chuzos* (Fig. 4).

Eighty percent of informants reported that extraction of bee products usually takes place after autumn flowering, from October to December, when the beehives have more pot-honey. Other local experts (12%) declared that the best time to obtain pot-honey is in the dry season, from March to April, when it is ripe. Another group of interviewees stated that they did not have a preferred season to extract pot-honey or wax.

The work of harvesting bees' nests is usually undertaken by two people without protective equipment as the bees do not sting. Some interviewees reported that it is common to fell an entire tree to obtain both the bee products and wood. Four interviewees noted that in the past when they harvested products they recovered nest with woody remains so that the bees could continue using it. Nevertheless, they observed that after products were harvested from nests, the bees abandoned the nest or became easy prey to other animals, such as badgers, opossums, and ants.

Interviewees reported thatthey get an average of 2 l of pot-honey and up to 3 kg of wax from an *S. hellwegeri* nest and 2–3 l of pot-honey and up to 4 kg of wax from *M. fasciata* nests.

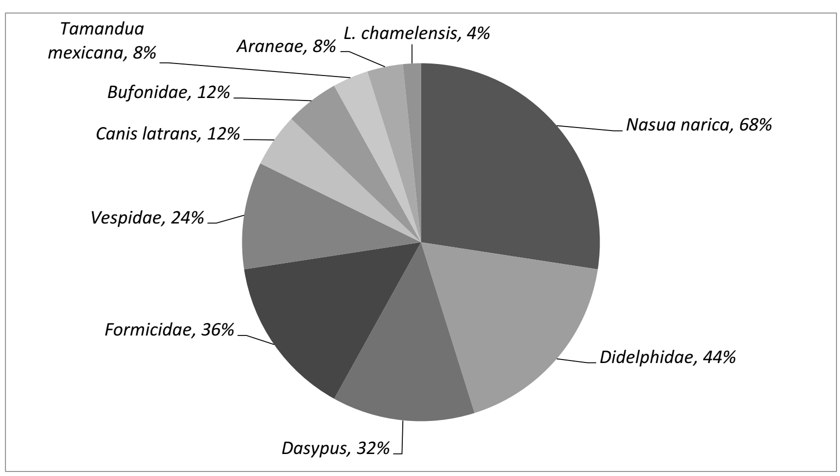

Fig. 3 LEK about animals that predate or harm stingless bees in Michoacán state

Fig. 4 Traditional management of stingless bees in Michoacán, Mexico. a) Extraction of a wild nest of *Melipona fasciatan*; b) Extraction of a wild nest of *Melipona lupitae* Ayala, in a *Cyrtocarpa sp.* tree; c) Extraction of *Scaptotrigona hellwegeri* Friese, in the base of a dead tree; d) Extraction of *Nannotrigona perilampoides* Cresson, nest located in a cavity between a rock and the ground

F. nigra and *N. perilampoides* produce approximately 1 l of pot-honey and up to 1.5 kg of wax per nest. Generally only wax is extracted from ground nesting species, with 12% of interviewees noting that eating pot-honey from ground-nesting hives causes vomiting.

There are diverse local names for nests. Brood nests are *mazorca de huevera*, *hijos*, *agrios* o *enjambre*; pot-honey storage pots are *mazorca de miel*, *tarritos* o *guajitos*; stingless beeswax is known as *cera* or *cera de Campeche*; pot-honey is *miel virgen* (virgin honey) or simply *miel* (honey); and, pollen is *pasacuareta* or *tamalillo*. For the Nahuas of the *Sierra-Costa* zone the word *pasacuareta* means "something scrambled or mixed."

Stingless bee products are harvested mainly for self-consumption, and occasionally to sell the beeswax. As noted earlier, pot-honey is used for food and medicinal purposes. Only 12% of interviewees described ways of mixing pot-honey with other ingredients for medicinal uses, all from zones 1 and 4.

Four informants reported that pollen is only consumed when it tastes sweet; when it is sour or consumed in excess it causes vomiting. Wax is used to make traditional candles and to seal or glue other local home utensils, such as pots (*guajes* and *bules* made of *Lagenaria siceraria* gourds) to store water.

About 40 to 50 years ago when synthetic commercial materials were not available, wax was traded for grafting fruit trees and for candle production. Most local experts explained that the production of candles was the domain of women.

Pot-honey of *S. hellwegerii* was the most mentioned for medicinal uses (68% of interviewees), perhaps because it is the best-known bee, including for eye diseases, such as cataracts and pterygium (surfer's eye) (60%), for which *F. nigra* and *N. perilampoides* are also very effective, although pot-honey from any species can be used for these treatments. Pot-honey is also used to treat disorders related to the respiratory tract, such as cough, asthma, and sore throat (44%), usually through direct consumption or combined with citrus, mainly lemon. Six people mentioned that pot-honey combined with alcohol or mezcal is an excellent remedy for cough and chest pain, and 32% noted that direct application can also treat abdominal cramps, sprains, fractures, body bumps, burns, and skin wounds. Two interviewees remarked that, for burns, sprains, and fractures, Meliponini wax could be mixed with pot-honey and placed over the affected area.

Perceptions of Diversity and Abundance of Stingless Bees

Only two interviewees mentioned that, as far as they remembered, stingless bees' abundance has remained the same as in the past. The remaining interviewees reported perceiving a notable decrease in the quantity and diversity of Meliponini citing several causes driving the decline (Fig. 5).

In zone 1 (*Medium-high Balsas*), informants reported a notable decrease of bees after the 1990s and that some species, such as *M. lupitae, L. chamelensis*, are no longer seen. In zone 4 (*Sierra-Costa*), informants reported that the decrease of

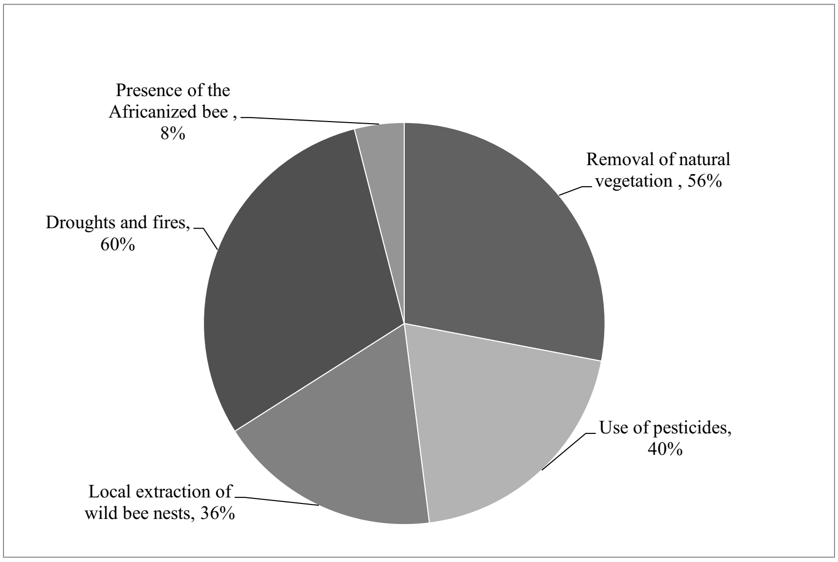

Fig. 5 Causes of stingless bees decline mentioned by local experts

native bees has occurred since 1980–1990 and that *abeja frijola* (species not collected), known only in this zone, is "almost extinct." We were unable to corroborate the taxonomic identity of this bee because we did not find a single specimen. For zone 2 (*High Balsas*), informants attributed the decreased abundance and presence of stingless bee species, but especially of the *colmena real* (*M. fasciata*), to the expansion of avocado cultivation. According to interviewees, they began to observe fewer stingless bee species up to 40 years ago. All interviewees reported that stingless bee species are more abundant in the highest parts of the mountains and hills, locally called *cerros*, as well as in ravines (*barrancos*), where less anthropogenic disturbance has occurred.

Most of the local experts interviewed (72%) expressed the opinion that these bees will disappear because they are becoming scarcer every day. They also stated that it is "sad and serious," because they will no longer be able to harvest their products, nor will the younger generations recognize these bees or be familiar with their products. Some mentioned the importance of stingless bees for pollination.

The remaining 28% were more optimistic, and they said that they considered an increase in stingless bees' abundance is likely. They stated that many deforested areas are recovering, and local inhabitants are no longer extracting wild nests because young people do not recognize these bees and are not interested in bee management. They did not know or have an opinion about what the consequences of their disappearance might be.

Discussion

The 13 species of Meliponini we identified through this research represent 35% of the total number of stingless bee species reported for Mexico, highlighting the importance of Michoacán state in maintaining Meliponini diversity. This number is higher than the nine and ten stingless bee species previously reported for Michoacán by Reyes-González *et al.* (2016) and Ayala *et al.* (2013), respectively. However, Meliponini diversity of this region may be greater, requiring a more extended and intensive sampling effort. For example, besides the use of entomological aspirator and aerial nets we used, there are other techniques such as pan-traps or Malaise traps that could provide complementary data to improve understanding of the richness and diversity of these insects.

Of the 23 species of stingless bees locally named, we were unable to scientifically identify five since not a single nest or specimen was found. The remaining 18 common local names, some of them synonyms, correspond to 13 identified species. This number is much higher than the 11 local names reported for only two municipalities of the *Medium-high Balsas* zone (Reyes-González *et al.* 2014, 2016), and the nine local names registered for two mestizo localities on the Jalisco coast in western México (Contreras-Escareño *et al.* 2019). However, it is lower than the approximately 150 local names in nine indigenous languages and 35 species of Meliponini recently found in the state of Oaxaca (Arnol *et al.* 2018).

Two of the Meliponini species in Michoacán, *P. bilineata* and *N. perilampoides,* are notable because each has three different local names. In the *Sierra-Costa* zone*,* most stingless bees have local names that differ from those in other Michoacán geographic zones. In the *High Balsas* zone*,* three local names for stingless bees in the Purepecha language are registered for the first time: *katzambe*, *chaninda,* and *tindacha*. *Katzambe,* identified as *P. bilineata,* means "the one that bites," reflecting its defensive biting behavior allowed by its strong mandibles.

The most frequently mentioned and best-known bees are *S. hellwegeri* and *F. nigra* and they inhabit only the dry tropical forest (Reyes-González, in preparation), which is the most extensive vegetation type in the state of Michoacán. The next most mentioned bee species are *G. acapulconis*, *L. chamelensis,* and *N. perilampoides*, which are widely distributed in all geographic zones.

The two bee species local informants perceived as rare are of the *Melipona* genus. This genus is particularly important as it includes the largest number of bees with potential for meliponiculture management (Quezada-Euán 2018).

LEK on stingless bees is, unfortunately, at high risk of being lost because it is held primarily by the older generation. The local experts (*colmeneros*) who assisted us in this research were always the most older individuals. When questioning younger informants about stingless bee populations and management, their responses frequently indicated disinterest if not almost total ignorance, particularly in the areas of major landscape transformations. This crisis in generational transmission of knowledge related to native bees in rural communities of Michoacán is recognized by the villagers but not considered to be of major concern. Further research using other techniques for obtaining qualitative information, such as focus groups, group interviews, and life stories, could complement and deepen our understanding of LEK about stingless bees' management.

LEK loss related to native bees is also occurring in other regions of tropical America (Stearman *et al.* 2008; Quezada-Euán *et al.* 2018) as a consequence of cultural and economic changes driven by globalization (Gómez-Baggethun *et al.* 2013; Lyver *et al.* 2014; Aswani *et al.* 2018), which our results indicate also contribute to loss of local knowledge of bees in the rural communities of Michoacán. This is notably the case in some municipalities in the *High Balsas* and *Tierra Caliente* zones, which have suffered extensive transformations of their natural landscapes (Mas *et al.* 2017). In these zones, stingless bee products are no longer managed and extracted, and our data from this research indicate that LEK is on the verge of disappearing, as are bee populations of some species (Reyes-González in preparation). This loss of LEK and bee populations has already occurred in the Yucatan peninsula (Quezada-Euán *et al.* 2001; Villanueva-Gutiérrez *et al.* 2005; Villanueva-Gutiérrez *et al.* 2013) and in some other regions of the Americas (Quezada-Eúan *et al.* 2018).

However, our study establishes that, in some areas of the state of Michoacán, traditional uses of stingless bee products continue, albeit infrequently. However, the lack of interest and knowledge of the younger generation, low demand for Meliponini products, and greatly reduced bee populations were cited by most of our informants as causes leading to abandonment of meliponiculture. Only two interviewees reported have tried in the past to raise native bees in hollow tree trunks. However, this practice has been reported for some Nahua communities of the Balsas basin in the neighboring state of Guerrero (Hendrichs 1941; Dixon 1987). Currently, in all geographic zones, some keepers of honey bees (*Apis mellifera*) also keep some species of stingless bees with modern meliponiculture techniques (Reyes-González *et al.* 2016).

Despite the uncertain future of LEK related to bees in Michoacán, the extensive understanding and expertise that older generations retain regarding the morphological characteristics, habits, behavior, and nesting patterns of the bees' species present in their territory remain of great relevance. This is very important although traditional management techniques do not necessarily lead to the maintenance or growth of stingless bee populations, and the extraction of nests could adversely affect Meliponini populations severely (Kerr *et al.* 1999; Brosi 2009; Reyes-González *et al.* 2016). It is necessary to undertake awareness-raising actions about traditional management and disruptive practices that are harmful to stingless bees. Therefore, while efforts to retain LEK should be pursued, the adoption of modern techniques for extraction that do not imply the destruction of wild nests should be encouraged.

There is a widespread perception among our informants of a decrease in stingless bee populations in the state of Michoacán starting up to 40 years ago, caused mainly by climate-related changes and human activities. We argue that further research into the processes of local and regional loss of species and the associated LEK should be undertaken systematically, particularly in the tropical areas of the Americas (Brosi *et al.* 2008; Potts *et al.* 2016), as critical decline of bee populations is a phenomenon of global concern.

Conclusions

Our study contributes to knowledge about stingless bees' diversity in the tropical areas of western Mexico, and the associated LEK of rural mestizo and indigenous inhabitants of this region. This information is relevant in the context of the current global pollinator crisis. Knowledge is a key element to prevent further decline of both native bee populations and their biocultural legacy in the form of LEK and associated practices.

LEK will only persist if rural communities, particularly the younger generation, recognize the importance of these insects, particularly the ecosystem services they provide as pollinators to the economic, nutritional, and health outcomes of their communities.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Informed Consent Following the respective institutional ethics protocols, full informed consent was obtained from all participants in the study.

References

Arnold, N., Zepeda, R., Vásquez-Dávila, M. and Aldasoro-Maya, M. (2018). Las abejas sin aguijón y su cultivo en Oaxaca, México: con catálogo de especies. El Colegio de la Frontera Sur, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Rémy Benoit Marie Vandame, San Cristóbal de Las Casas.

Aswani, S., Lemahieu, A., and Sauer, W. H. (2018). Global trends of local ecological knowledge and future implications. PLoS ONE 13(4): e0195440. https://doi.org/10.1371/journal.pone.0195440

Ayala, R. (1999). Revisión de las abejas sin aguijón de México (Hymenoptera: Apidae: Meliponini). Folia Entomológica Mexicana 106: 1–123.

Ayala R., González V., and Engel, M. (2013). Mexican stingless bees (Hymenoptera: Apidae): divesity, distribution, and indigenous knowledge. Vit P, Pedro-Silvia RM, Roubik D. (ed). Pot-Honey: A Legacy of Stingless Bees. Springer, New York, pp. 135–152.

Bennett, C. F. (1964). Stingless beekeeping in western Mexico. The Geographical Review 54: 85-92.

Berkes, F. (1999). Sacred Ecology. Traditional Ecological Knowledge and Resource Management, Taylor & Francis, Philadelphia and London.

Berkes, F., Colding, J., and Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. Ecological Applications 10: 1251–1262.

Berkes, F., and Turner, N. J. (2006). Knowledge, learning and the evolution of conservation practice for social-ecological system resilience. Human Ecology 34(4): 474–494.

Biesmeijer, J.C., Roberts, S.P.M., Reemer, M., Ohlemüller, R., Edwards, M., Peeters, T., Schaffers, A.P., Potts, S.G., Kleukers, R., Thomas, C.D., Settele, J., and Kunin, W.E. (2006). Parallel declines in pollinators and insect pollinated plants in Britain and the Netherlands. Science 313(5785): 351–354.

Borah, W., and Cook, S. F. (1960). The population of central Mexico in 1548. An analysis of the Suma de Visitas de Pueblos. University of California Press, Los Angeles.

Camargo, J. M. F., and Pedro, S. R. M. (2013). Meliponini Lepeletier, 1836. In Moure, J. S., Urban, D. and Melo, G. A. R. Catalogue of Bees (Hymenoptera, Apoidea) in the Neotropical Region - online version. Available at http://www.moure.cria.org.br/catalogue. Accessed Feb/20/2019

CONABIO, (2001). Climas (clasificación de Köppen, modificado por García). Escala 1:1000000. México.

Brosi, B. J., Daily, G. C., Shih, T. M., Oviedo, F., and Durán, G. (2008). The effects of forest fragmentation on bee communities in tropical countryside. Journal of Applied Ecology 45(3): 773-783.

Brosi, B. J. (2009). The complex responses of social stingless bees (Apidae: Meliponini) to tropical deforestation. Forest ecology and management 258(9): 1830-1837.

Camou-Guerrero, A., Reyes-García, V., Martínez-Ramos, M., and Casas, A. (2008). Knowledge and use value of plant species in a Rarámuri community: a gender perspective for conservation. Human Ecology 36(2): 259-272.

Contreras-Escareño, F., Echazarreta, C. M., Guzmán-Nóvoa, E., and Macías-Macías, J. O. (2019). Traditional Knowledge and Potential Use of Stingless Bees (Hymenoptera: Meliponinae) in the Manantlan Sierra, Jalisco, Mexico. Sociobiology 66(1): 120-125.

Cortopassi-Laurino, M., Imperatriz-Fonseca, V. L., Roubik, D. W., Dollin, A., Heard, T., Aguilar, I., and Nogueira-Neto, P. (2006). Global meliponiculture: challenges and opportunities. Apidologie 37(2): 275-292.

Crane, E. (1992). The past and the present status of beekeeping with stingless bees. Bee World 73(1): 29–42.

Crane, E. (1999). The world history of beekeeping and honey hunting. Routledge, New York.

Dixon, C.V. (1987). Beekeeping in Southern Mexico. Conference of Latin Americanist Geographers. Year Book 13: 68-77.

Ehrlich, P. R., Kareiva, P. M., and Daily, G. C. (2012). Securing natural capital and expanding equity to rescale civilization. Nature 486: 68–73.

Gómez-Baggethun, E., Corbera, E., and Reyes-García, V. (2013). Traditional ecological knowledge and global environmental change: research findings and policy implications. Ecology and Society: a journal of integrative science for resilience and sustainability 18(4): doi:https://doi.org/10.5751/ES-06288-180472.

Heard, T. (1999). The role of stingless bees in crop pollination. Annual Review of Entomology 44(1): 183-206.

Hendrichs, P.R. (1941). EI cultivo de abejas indígenas en el Estado de Guerrero. México Antiguo 5: 365-73.

INEGI. (2015). Carta de Uso del Suelo y Vegetaci´on, 1:250 000. INEGI, Aguascalientes.

Johannes, R. E. (2002). Did indigenous conservation ethics exist. Traditional Marine Resource Management and Knowledge Information Bulletin 14(3): 3-7.

Kent, R. (1984). Mesoamerican stingless beeekeeping. Journal of Cultural Geography 4(2): 14-28.

Kerr, W., Carvalho, G.A., and Nascimento, V.A. (1999). The probable consequences of the destruction of Brazilian stingless bees. Advances in Economic Botany 13: 395-403.

Leff, E. (2004). Racionalidad ambiental. La reapropiación social de la naturaleza. México: Siglo XXI Editores, México D.F.

Lyver, P., Perez, E., Carneiro da Cunha, M., and Roué, M. (2014). Indigenous and local knowledge about pollination and pollinators associated with food production: outcomes from the global dialogue workshop. UNESCO, Paris.

Mas, J. F., Lemoine-Rodríguez, R., González, R., López-Sánchez, J., Piña-Garduño, A., and Herrera-Flores, E. (2017). Evaluación de las tasas de deforestación en Michoacán a escala detallada mediante un método híbrido de clasificación de imágenes SPOT. Madera y Bosques 23(2): 119-131.

Michener, C.D. (2007). The bees of the world. Second edition. The Johns Hopkins University Press, Baltimore.

Nordenskiöld, E. (1929). L'apiculture indienne. Journal de la Société des Américanistes 21:169–182.

Pennington, C. (1963). The Tarahumar of Mexico: Their Environment and Material Culture. University of Utah Press, Salt Lake City.

Porter-Bolland, L., Gallardo, C., Ruiz de la Merced F., and Quiroz, R. (2015). La meliponicultura en el municipio de Atzalan, Ver.: un diagnóstico sobre la situación actual de la actividad y sus necesidades In Guzmán, M., and Vandame, R. (Coords.), Manejo de las abejas sin aguijón en Mesoamerica, El Colegio de la Frontera Sur, San Cristobal de las Casas.

Potts, S. G., Biesmeijer, J. C., Kremen, C., Neumann, P., Schweiger, O., and Kunin, W. E. (2010). Global pollinator declines: trends, impacts and drivers. Trends in Ecology & Evolution 25(6): 345-353.

Potts, S. G., Imperatriz-Fonseca, V., Ngo, H. T., Aizen, M. A., Biesmeijer, J. C., Breeze, T. D., and Vanbergen, A. J. (2016). Safeguarding pollinators and their values to human wellbeing. Nature 540(7632): 220-229.

Quezada-Euán, J. J. G. (2018). Stingless bees of Mexico. Springer, Cham, Switzerland.

Quezada-Euán, J.J.G., May-Itzá W. de J and González-Acereto J.A. (2001). Meliponiculture in México: problems and perspective for development. Bee World 82: 160-167.

Quezada-Euán, J. J. G., Nates-Parra, G., Maués, M. M., Roubik, D. W., and Imperatriz-Fonseca, V. L. (2018). The economic and cultural values of stingless bees (Hymenoptera: Meliponini) among ethnic groups of tropical America. Sociobiology 65(4): 534-557.

Reyes-González, A., Camou-Guerrero, A., Reyes-Salas, O., Argueta, A., and Casas, A. (2014). Diversity, local knowledge and use of stingless bees (Apidae: Meliponini) in the municipality of Nocupétaro, Michoacán, Mexico. Journal of Ethnobiology and Ethnomedicine 10(1): 47.

Reyes-González, A., Camou-Guerrero, A., and Gómez-Arreola, S. (2016). From extraction to meliponiculture: a case study of the management of stingless bees in the West-central region of Mexico. In Chambo E. (ed.), Beekeeping and Bee Conservation-Advances in Research. InTech, Rijeka.

Schwarz, H. F. (1945). The wax of stingless bees (Meliponidae) and the uses to which it has been put. Journal of the New York Entomological Society 53(2): 137-144.

Slaa, E. J., Chaves, L. A. S., Malagodi-Braga, K. S., and Hofstede, F. E. (2006). Stingless bees in applied pollination: practice and perspectives. Apidologie 37(2): 293-315.

Sutherland, W.J. (1996). Ecological Census Techniques: A Handbook. Cambridge University Press, United Kingdom.

Stearman, A.M., Stierlin, E., Sigman, M.E., Roubik, D.W., and Dorrien, D. (2008). Stradivarius in the jungle: traditional knowledge and the use of "Black Beeswax" among the Yuquí of the Bolivian Amazon. Human Ecology 36(2): 149-159.

Taylor, S. J., and Bogdan, R. (1987). Introducción a los métodos cualitativos de investigación (Vol1). Paidós, Barcelona.

Vargas, P. J. P., Vásquez-Dávila, M. A., María, T. G. G. G., and González l. A (2014). Pisilnekmej: Una mirada a la cosmovisión, conocimientos y prácticas nahuas sobre *Scaptotrigona mexicana* en Cuetzalan, Puebla, México. Revista Etnoecologica 10: 37- 40.

Villanueva-Gutiérrez, R., Roubik, D.W., and Colli-Ucán, W. (2005). Extinction of *Melipona beecheii* and traditional beekeeping in the Yucatán Peninsula. Bee World 86(2): 35–41.

Villanueva-Gutiérrez, R., Roubik, D.W., Collí-Ucán, W., Güemes-Ricalde, J., and Buchmann, S.L. (2013). A critical view of colony losses in managed Mayan honey-making bees (Apidae: Meliponini) in the heart of Zona Maya. Journal of the Kansas Entomological Society 86(4): 352-363.

Vit, P., Medina, M., and Eunice-Enríquez, M. (2004). Quality standards for medicinal uses of Meliponinae honey in Guatemala, Mexico and Venezuela. Bee World 85(1): 2-5.