Chapter 8

From Extraction to Meliponiculture: A Case Study of the Management of Stingless Bees in the West-Central Region of Mexico

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Additional information is available at the end of the chapter

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Abstract

Currently, stingless bees' populations are declining due to environmental degradation. In this context, the authors have developed a research project in the central-western region of Mexico with the goal to generate strategies for conservation and sustainable management of stingless bees. The chapter aims to present the process of this investigation and its main results in terms of a) local knowledge and management strategies of stingless bees, and b) the social process of technological appropriation of meliponiculture by beekeepers. We recognized specific knowledge on the biology and ecology of stingless bees that result in a system for identifying species and management strategies of wild populations of these bees based on the extraction of nests. The implementation of an innovative productive activity based on the principles of meliponiculture and current techniques has been well received by producers, which has led to the formation of the Meliponicultores Michoacanos del Balsas Association, which grows five species of stingless bees. The research suggests that conservation associated with the use of bees (integral meliponiculture) can be enhanced in the region. Faced with the loss of biodiversity and environmental crisis, it is essential to maintain and enhance local knowledge of stingless bees and management practices. This represents an alternative to develop management schemes that allow the raising and breeding of these bees, while its products are obtained.

Keywords: stingless bees, meliponiculture, Balsas River Basin, Michoacán, México

1. Introduction

Bees represent one of the most important functional pollinator groups for terrestrial ecosystems [1, 2]. It is estimated that nearly 73% of cultivated vegetation species and more than 75% of the world's total vegetation is pollinized by bees [1, 3, 4]. However, in spite of the importance of this group of organisms, there is clear evidence of their population decline, putting at grave risk the pollination services they provide [5] as well as ecosystem and agrecosystem maintenance [6, 7]. This has profound ecological and economic implications. Some of the more relevant causes of this pollination crisis are forest loss and fragmentation, the use of agrochemicals, bee pathogens, invasive species, and climate change, among others [1, 5, 8–18]. In the particular case of stingless bees, the extraction of wild nests and habitat alteration have been cited as primary causes of population deterioration for this group [19].

There are approximately 20,000 species of bees [20] of which *Apis mellifera* has received greater attention due to their ecological and productive qualities having been introduced all over the world [21]. However, in the tropics, one of the Apidae of greatest ecological and sociocultural significance are the stingless bees (*Meliponini*) [2, 16, 20, 22, 23]. The authors of this chapter have developed a research project in the west-central region of Mexico with the purpose of generating strategies for the conservation and sustainable management of stingless bees. The objective of this chapter is to present the investigation process and the results in term of a) diversity, knowledge, and strategies of local managers of stingless bees; and b) the social process of technological appropriation of integrated meliponiculture by the managers in the study area. The chapter is divided into three sections. The first section discusses the diversity of stingless bees in Mexico. The second portion analyzes the management of stingless bees, and in the third and last section, we present a case study of technological appropriation of integrated meliponiculture in the Alto Balsas region of Michoacán, Mexico.

2. Stingless bee diversity in Mexico

Stingless bees form part of the order *Hymenoptera*, family *Apidae*, tribe *Meliponini*. Worldwide there are 24 genus, 18 subgenus, and between 400 and 500 species [20]. The American continent is considered the center of diversity for this group and in the case of Mexico there have been a total of 16 genus and 46 species present (**Table 1**), of which 26.% (12 species) are endemic [24]. After a review of the specialized literature of the total species described for Mexico, 43.5% (20 species) are under some form of human management (**Table 1**).

Species[1]	Local name	Management	Region of managed species	Reference (for useful species)
1 **Cephalotrigona oaxacana* (Schwarz, 1948)				

Species[1]	Local name	Management	Region of managed species	Reference (for useful species)
2 *Cephalotrigona zexmeniae* (Ayala, 1999)				
3 *Cephalotrigona*zexmeniae (Cockerell, 1912)	E'hol, Tajbak	(*e*)	Peninsula de Yucatán	[25]
4 **Frieseomelitta nigra* (Cresson, 1878)	Sak-Xic'/ Abeja zopilota	(*m,e*)	Península de Yucatán, Sierra de Manantlán Jalisco, Cuenca del Balsas Michoacán	[19, 25, 26]
5 **Geotrigona acapulconis* (Strand, 1919)	Colmena de tierra	(*e*)	Cuenca del Balsas Michoacán	[19]
6 **Lestrimelitta chamelensis* (Ayala, 1999)	Abeja limoncilla	(*e*)	Cuenca del Balsas Michoacán	[19]
7 *Lestrimelitta niitkib* (Ayala, 1999)	Niitkib, Limón kab Limoncillo		Península de Yucatán, Soconusco Chiapas	[25, 27]
8 *Melipona beecheii* (Bennett, 1831)	Xunaan-Kab / Abeja real/Ajau-chab	(*m*)	Península de Yucatán, Soconusco Chiapas, Tabasco, Veracruz	[19, 25, 27, 28, 29, 30]
9 *Melipona colimana* (Ayala, 1999)	Colmena real	(*e*)	Volcán Colima	[31]
10 **Melipona fasciata* (Latreille, 1811)	Colmena real	(*m,e*)	Cuenca Balsas Michoacán, Sierra Atoyac Guerrero	[19, 32, 33]
11 **Melipona lupitae* (Ayala, 1999)		(*e*)	Cuenca Balsas Michoacán	[31]
12 *Melipona solani* (Cockerell, 1912)	Abeja real roja	(*m*)	Soconusco Chiapas	[27]
13 *Melipona yucatanica* (Camargo, Moure,	Tsets.	(*m*)	Península de Yucatán	[25]

Species[1]	Local name	Management	Region of managed species	Reference (for useful species)
Roubik, 1988)				
14 **Nannotrigona perilampoides* (Cresson, 1878)	Mehenbol / Doncellita prieta / Mumu/ Abeja trompetera	(*m*,*e*)	Península de Yucatán, Soconusco Chiapas, Sonora y Sinaloa, Cuenca Balsas Michoacán	[19, 25, 27, 28]
15 *Oxytrigona mediorufa* (Cockerell, 1913)	Pringadora		Soconusco Chiapas	[27]
16 *Paratrigona guatemalensis* (Schwarz, 1938)				
17 *Paratrigona opaca* (Cockerell, 1917)				
18 **Partamona bilineata* (Say, 1837)	Esculcona/ Mordelona	(*e*)	Cuenca Balsas Michoacán	[19]
19 *Partamona orizabaensis* (Strand, 1919)				
20 *Plebeia cora* (Ayala, 1999)				
21 **Plebeia frontalis* (Friese, 1911)	Us-Kaab/Yaaxich/ mosquito	(*m*,*e*)	Península de Yucatán, Tehuacán Puebla	[25]
22 **Plebeia fulvopilosa* (Ayala, 1999)	Abeja sapito	(*m*,*e*)	Cuenca Balsas Michoacán	[19]
23 *Plebeia jatiformis* (Cockerell, 1912)				
24 *Plebeia llorentei* (Ayala, 1999)				
25 *Plebeia manantlensis* (Ayala, 1999)		(*e*)	Colima, Jalisco	[31]
26 *Plebeia melanica* (Ayala, 1999)				
27 **Plebeia mexica* (Ayala, 1999)				

Species[1]	Local name	Management	Region of managed species	Reference (for useful species)
28 **Plebeia moureana* (Ayala, 1999)				
29 *Plebeia parkeri* (Ayala, 1999)				
30 *Plebeia pulchra* (Ayala, 1999)				
31 *Scaptotrigona mexicana* (Guérin-Méneville, 1844)	Pisil-nekmej/ Abeja congo	(*m*)	Sierra Norte Puebla, HuastecaPotosina-Veracruz, Soconusco	[27, 30, 34]
32 *Scaptotrigona pectoralis* (Dalla Torre, 1896)	Kantsak/Abeja congoalazana	(*m*)	Chiapas. Península Yucatán, Soconusco Chiapas	[25, 27]
33 **Scaptotrigona hellwegeri* (Friese, 1900)	Abeja Bermeja	(*m,e*)	Cuenca Balsas Michoacán y Guerrero	[19, 32, 33]
34 *Scaura argyrea* (Cockerell, 1912)				
35 *Tetragona mayarum* (Cockerell, 1912)				
36 *Tetragonisca angustula* (Latreille, 1811)	Doncellita/sayulita	(*m*)	Soconusco Chiapas	[27]
37 *Trigona corvina* (Cockerell, 1913)	KurisKab		Península Yucatán.	[25]
38 **Trigona fulviventris* (Guérin-Méneville, 1844)	MuulKab, Culo de buey		Península Yucatán, Soconusco Chiapas	[25, 27]
39 *Trigona fuscipennis* (Friese, 1900)	Kuris-kab, Tamagaza, Basurera		Península Yucatán, Soconusco Chiapas	[25, 27]
40 *Trigona nigerrima* (Cresson, 1878)	Tamagaza, Basurera		Soconusco Chiapas	[25]

Species[1]	Local name	Management	Region of managed species	Reference (for useful species)
41 *Trigona silvestriana* (Vachal, 1908)				
42 *Trigonisca azteca* Ayala, 1999				
43 *Trigonisca maya* (Ayala, 1999)	Puup, Chachem			
44 *Trigonisca mixteca* (Ayala, 1999)				
45 **Trigonisca pipioli* (Ayala, 1999)	Puup, Chachem, Cepimilla	(*e*)	Península Yucatán, Cuenca Balsas Michoacán	[19, 25]
46 *Trigonisca schulthessi* (Friese, 1900)				

[1]Based on [58]. *Species reported for Michoacán. (*e*): Extraction. (*m*): Meliponiculture.

Table 1. Diversity of meliponini in Mexico and useful species.

As we mentioned, stingless bees are distributed in tropical and subtropical regions around the world. In Mexico, the distribution is in Neotropical areas [35, 36], intimately associated with dry tropical and evergreen forests, though some species have been found in mountain ecosystems and mesophillic forests as well as temperate mixed pine-oak forests [24]. In the west-central region of Mexico, there is considerable *Meliponini* diversity particularly in two specific regions: 1) the Pacific coast and 2) the Balsas River Basin (an area of relevance in terms of endemism for this group) [19, 24, 31].

The bees from the *Meliponini* tribe are anatomically distinct from those with a functioning stinger. Moreover, they present a notable reduction in the venation of the anterior wings, simple, non-bifurcated spurs and a line of thick comb-like hairs along the internal distal margin of the posterior tibia, called *penicillium* [24]. At the same time, this group of bees shows diverse behavior patterns (for example, there are species that show cleptobiosis or thievery) and different nesting habits (species that build their nest in tree cavities, underground or exposed similar to termites) [37].

To demonstrate the ecological importance of stingless bees, it is estimated that they pollinate from 30 to 50% of all plant species in the lowlands in tropical America [22]. In Mexico, it is estimated that more than 80% of cultivates for human consumption depend in various degrees on these pollinators for efficient production [38].

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3. Management strategies of stingless bees

3.1. Traditional management

From a sociocultural perspective, stingless bees are of great significance in the social, economic, and religious aspects of diverse areas in which have been developed various systems of managing and breeding of these insects. In tropical America, from México to Brazil, this activity goes back to the Pre-Hispanic era [30, 33, 39, 40, 41]. The traditional knowledge and management practices associated with the stingless bees still exist in the indigenous communities in Mexico and Latin America that coexist with them.

In Mexico, there are four areas where stingless bees have been traditionally and contiguously managed: 1) the Yucatán peninsula, 2) the Gulf coast of Mexico, 3) the Pacific coast between and Sinaloa y Jalisco, and 4) the Balsas River Basin in Guerrero and Michoacán [28, 33, 42, 43]. In each of these areas exist important management strategies and practices from the extraction of derivative products and breeding to a process called "meliponiculture."

Typically, Mesoamerican meliponiculture has been developed with the goal of harvesting the goods produced by stingless bee, which represent a significant nutritional and medicinal dietary component. The honey is used mainly as a medicinal supplement and treatment for such things as ocular infection, fractures, muscle pain, sprains, cutaneous wounds, as well as gastrointestinal and respiratory illness [19, 44]. Likewise, the pollen (which they call *"pasacuareta"* in the Balsas region [19] is consumed either by itself or mixed with the honey for respiratory infections and "weakness" or fatigue. Another important product is the wax (called "Campeche wax"), which acted as a valuable trade resource during colonial times.

Today, these traditional practices associated with Mesoamerican meliponiculture are only conserved in few specific areas in the Mexican tropics. These practices are particularly significant in the Yucatán peninsula (Mayas) [45, 46], the Sierra Norte of Puebla by the Nahuas and Totonacos [29], in the south of Veracruz by the Popolucas [34], and in the Itzmo de Tehuantepec by the Zapotecos, Mixes, Zoques, Popolucas and Nahuas [47].

Apart from the traditional meliponiculture, extraction of stingless bee products has been documented in other regions in Mexico. Bennett (1964) mentions the presence of stingless bees in areas not considered part of their normal range as in the Sierra Tarahumara and northern Sinaloa, where there is previously documented knowledge of the meliponini, specificaly *Nannotrigona perilampoides* [48].

As previously mentioned, other regions of importance with regard to meliponiculture are the western and southwestern portions of Mexico; From Nayarit, southern Jalisco to the Balsas River Basin, found in the States of Guerrero, Michoacán y Morelos [33, 42, 43]. In these regions, the extraction of honey used to be principally from the species *Scaptotrigona hellwegeri* [49]. Historically, this was an activity of economic and socio-political importance as it was used as an offering to the Valle de México, which was the seat of the Mexica Empire [43]. Hendrichs [42] mentions that the Balsas region was known for its honey production (*"mieleros"),* by groups that would form expeditions to seek out honey and beeswax during the dry season

(November–December). It is notable that, according to the author the extraction methods in the Balsas region was an activity that systematically sought specific nests and was considered a specialized trade but that resulted in the destruction of the nest. More recently Reyes-González and collaborators [19] reported product extraction in the same region but in the State of Michoacán.

3.2. Technical advancements in management

Today, the practice of meliponiculture persists in spite of long periods of inattention and substitution for other production activities, including apiculture. However, there has been resurgence in interest for this particular activity, which has been the impetus for strategies to rescue traditional meliponiculture making it more efficient with the goal of meliponini conservation and alternative productive projects. This resurgence is directly linked with the growing demand for natural, organic, and homeopathic products, which include honey, pollen, propolis, and beeswax. New techniques and production methods have been developed (largely through academic institutions) that has been termed "integrative meliponiculture." This has allowed for more efficient and sustainable management of these insects where they are present. We see examples of this modern management in the States of Chiapas, Yucatán, Campeche, Guerrero, and Veracruz [27, 32, 46].

Integrative meliponiculture is a practice that takes into account not only the production factor but also the conservation and maintenance of viable colonies of stingless bees as well as the integration of the families of those interested in participating in this activity as well as the implication for community benefit. In the production sense, the goal of integrative meliponiculture is to obtain goods like honey, pollen, and propolis from the same nests while encouraging specialized ecosystem benefits like pollination in greenhouses and agricultural fields as well as the landscape in general. Environmental education is also an important aspect of this activity, where possible. Integrative meliponiculture limits the destruction of wild nests and favors their maintenance, rescue, and propagation. This activity also helps to limit the traffic and introduction of non-native species in the areas of the stingless bee's natural distribution. These principles are the main challenge for meliponculture currently developed in various regions of the planet.

4. Case study

4.1. Study area

The Balsas River Basin makes up 6% of Mexico's continental mass and covers various economically important regions of the west-central Pacific coast and south-central area between 17°00′-20°00′ N and 97°30′ y 103°15′ E. This traverses eight States in the Mexican Republic: Morelos (100%) and portions of the States of Tlaxcala (75%), Puebla (55%), México (36%), Oaxaca (9%), Guerrero (63%), Michoacán (62%), and Jalisco (4%) (**Figure 1**). For the state of Michoacán, this basin can be divided into three subregions, taking an altitudinal criteria:

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Alto Balsas, Medio Balsas, and Bajo Balsas (Tepalcatepec). The specific area of study falls inside the sub-region of Alto y Medio Balsas, and includes the municipalities of Charo, Madero, Carácuaro, Nocupétaro, Tacámbaro y Tzitzio (**Figure 1**).

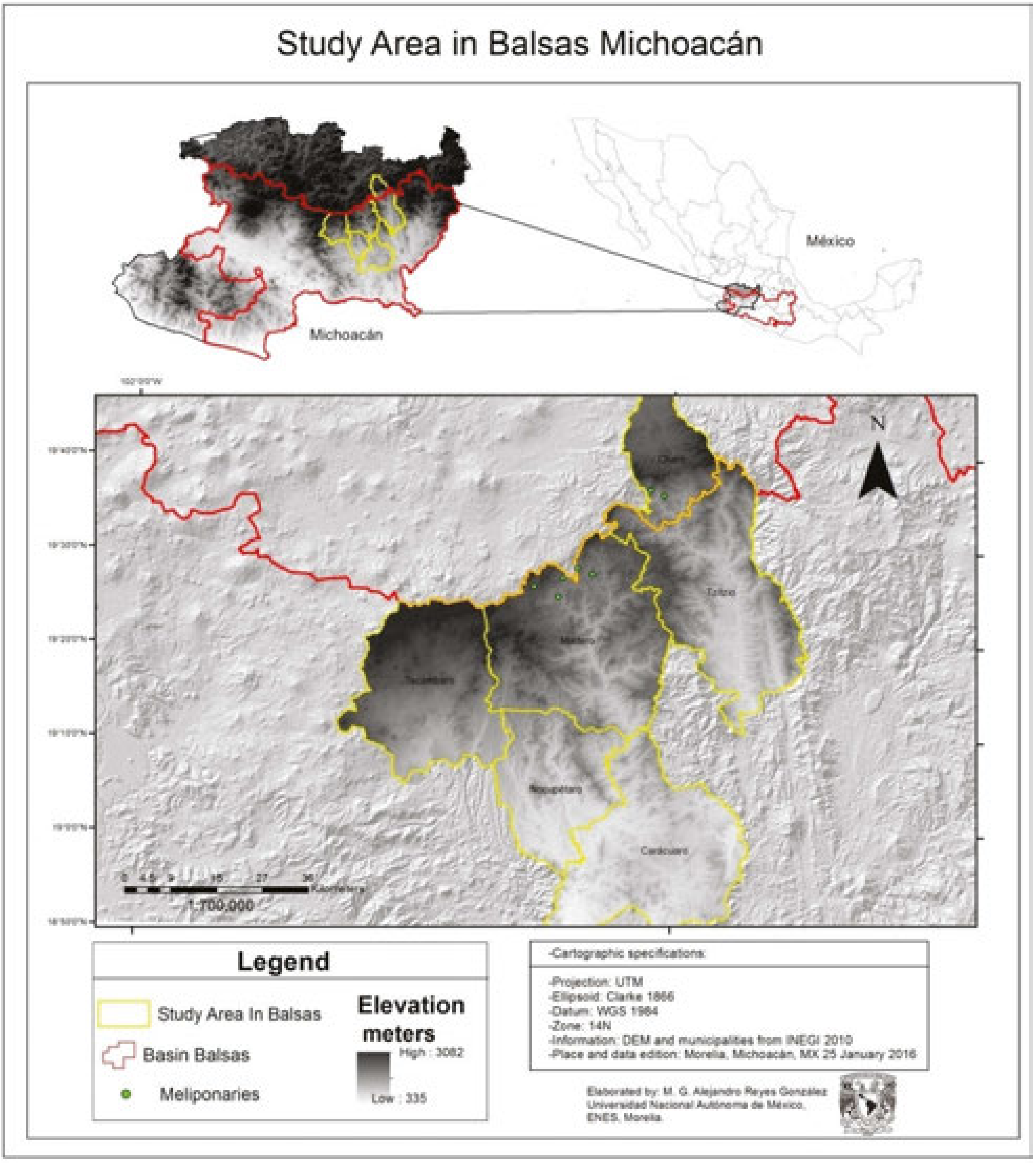

Figure 1. Location map of the study area in the Alto and Medio Balsas, Michoacán, México.

The study area falls in the foothills of the transmexican volcanic belt, flowing from the perennial streams that descend from an altitude of 3000m from the Turicato, Taretio, and El Perdido hills located approximately 40 km to the southeast of Morelia, Michoacán [50]. These subregions of the Balsas in the state of Michoacán has an altitudinal gradient that extends from 3000m to sea level with various climate regions associated with the altitudinal changes. These climate variations principally include temperate, tropical, warm sub-humid, temperate sub-humid, and semiarid [51]. According to Rzedowszki [52], the Balsas basin is considered one of the most biologically diverse regions in the world with a wide range of vegetation types where the principle ecosystems are the tropical dry forest and mixed pine and oak forest [52]. These climatic and vegetative conditions allow for bee species richness where, according to [24], the Balsas zone between Guerrero and Michoacán demonstrates notably high endemism for stingless bees.

Studies show that temperate zones with mixed pine-oak forest have extensive land use change from forest to agriculture and horticulture where avocado is predominant [53, 54],which has serious implications in the study area. Likewise, in the tropical forest areas, land use change is prevalent for livestock that converts natural cover to induced grasslands [55]. Such perturbations and transformations of the natural or mildly transformed landscapes results in strong repercussions in the stingless bee presence since populations of these important pollinators diminish as important vegetative sources disappear or are degraded eliminating sources of pollen, nectar and resins as well as niches for nests [56, 57].

4.2. The process of technological appropriation

The process that has been designed to orient sustainable management proposals for the stingless bees in the Alto Balsas region of Michoacán, has 4 main stages. The first stage consists of an inventory of the stingless bee species in the proposed area. The second consists of the documentation of local management practices of the species present there. The third is the selection of the working group that determines the selection of species, transference of hives, and outreach and communication of the work. The fourth and final stage is the maintenance and monitoring of the managed hives.

4.3. Local knowledge and management of the stingless bees in the study area

Through exhaustive fieldwork which involved extensive collection in the different climatic zones in the study area, workshops with the local apiculturists and "*colmeneros*" (experts in extracting products from wild nests of stingless bees) and thorough interviews, it was possible to document the stingless bee species of that zone as well as local knowledge and management practices. Of the species listed for Mexico, 15 species (32% of the total) were reported to be present in the State of Michoacán (**Table 1**). It is relevant to reiterate that there is a high species richness of stingless bees in the study area where 9 species (69% of the total species reported for Michoacán) were encountered (**Table 2**). The altitudinal distribution range of stingless bees showed a gradient that extends from 300 to 2000 m, covering the dry tropical forest in the

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warmest section and mixed pine-oak forest in the temperate extreme of the range. The species limited to the warm zone (300–1600 m) are*Scaptotrigona hellwegeri, Trigonisca pipioli, Frieseomelitta nigra.* The species limited to the temperate zone (1700–2000m) are*Partamona bilineata, Plebeia fulvopilosa, Nannotrigona perilampiodes, Melipona fasciata.* Lastly, there are two species of broad distribution (300–2000 m) that are *Geotrigona acapulconis* and *Lestrimelitta chamelensis.*

Local name	**Scientific name**	**Behavior (local knowledge)**	**Morphology (local knowledge)**	**Nesting**	**Distribution**
1) Abeja Bermeja	*Scaptotrigona hellwegeri*	Defensive (gets tangled in the hair and bites).	Intense red dish median bee.	In hollow trunks.	300 –1,600 m Tropical dry forest.
2) Abeja Cepimilla	*Trigonisca pipioli*	Bee type that likes people sweat.	Very small bee.	In hollow trunks, very small nests.	300–1,600 m Tropical dry forest.
3) Abeja Esculcona mordelona	*Partamona bilineata*	Defensive (gets tangled in the hair and bites).	Black middle bee	Aerial and exposed nest as termite mound.	1700–2000 m Oak and pine forest.
4) Abeja Limoncilla	*Lestrimelitta chamelensis*	Docile and attack other bees.	Small dark bee with strong lemon scent.	In hollow trunks.	300–2000 m wide distributions
5) Abeja Sapita	*Plebeia fulvopilosa*	Very docile and timid.	Small dark bee	In hollow trunks and between the trunk and the ground	1700–2000 m Oak and pine forest.
6) Abeja Trompetera	*Nannotrigona perilampiodes*	Very docile and timid.	Small bee.	In hollow trunks. The nest entrance is shaped trumpet (made of beeswax).	1700–2000 m Oak and pine forest.
7) Abeja Zopilota	*Frieseomelitta nigra*	Docile	Median dark bee, very bright with white wing tips.	In hollow trunks.	300–1,600 m Tropical dry forest.
8) Colmena real	*Melipona fasciata*	Defensive (gets tangled in the hair and bites).	Similar to *Apis mellifera* in size, color more reddish abdomen that *Apis*.	In hollow trunks	1700–2000 m Oak and pine forest.
9) Colmena de Tierra or Prieta de tierra	*Geotrigona acapulconis*	Very docile and timid.	Medium bee completely dark.	Buried in the ground.	300–2000 m Wide distribution

Local name	Scientific name	Behavior (local knowledge)	Morphology (local knowledge)	Nesting	Distribution
10) Abeja pintilla	–	–	More small than *Apis mellifera* in size and color similar.	In hollow trunks.	300–1600 m Topical dry forest.
11) Abeja Prieta esculcona	–	–	Black middle bee	Buried in the ground and cavities between the trunk and the ground."	300–1600 m Wide distribution

Table 2. Local knowledge and distribution on stingless bees at the Balsas Region, Michoacan. Based on [19].

There is a high level of local knowledge in the study area with regard to the bative stingless bees which are called *colmenas* or *colmenas de palo*. It is important to mention that apart from the 9 species encountered, the apiculturists and *colmeneros* mention 2 other types of stingless bees that have not yet been collected: *abeja pintilla* and the *abeja prieta esculcona* (**Table 2**). This implies that the species richness could be higher than recorded in the study area. As shown in **Table 2**, the local apiculturists and *colmeneros* are aware of the morphological characteristics, nesting habits, foraging habits, and defense tactics.

As previously described [19], the regional management in Balsas in the State of Michoacán relies on the direct extraction from wild hives with simple tools (axes and machetes). This was an important activity until the 1980s when the *colmeneros* relied on seasonal periods to extract wax and honey. The beeswax was used in candle making and for sale in other regions as material for fruit tree grafting. Honey is still a popular product for medicinal purposes associated with ocular infections, wounds, bruising, as well as an effective sweetener. However, in spite of the importance of these bee products there is much knowledge that has been forgotten with regard to management practices due to cultural changes and the diminished bee populations as a result of anthropomorphic land change [19]. Apiculture has been increasing in popularity as a common and generalized activity in rural families in the Alto Balsas, Michoacán region. For decades, in almost all households in the area the inhabitants had rustic hives using the *abeja de castilla* (*Apis mellifera*). These rustic hives were installed near the keepers' houses or sites very close to their homes for easier access and individual household consumption or local sale. However, this activity has been largely compromised with the introduction of the Africanized bee in Balsas during the period 1988 to 1989, in which the families not only stopped having rustic hives but also stopped using the European bee. In spite of the complications that came as a result of the introduction of the Africanized bee, the value placed on the natural bee products and in the face of the need to diversify livelihood activities and subsistence in rural areas is providing impulse to apply alternative projects in which integrative meliponiculture have been developed in the Alto Balsas in Michoacán.

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4.4. Forming the working groups

As previously discussed, the Balsas region in Michoacán has significant diversity of stingless bees and their actual diversity and distribution is not fully known. However, with the investigation efforts made in this study resulted in a useful pilot project with regards to integrative meliponiculture in the municipalities of Nocupétaro and Madero. Due to the influence and direction of the researchers in this study, the group "Meliponicultores Michoacanos del Balsas" has become an organization dedicated to the management and conservation of stingless bees. Most importantly, it must be noted that the initiative came out of a genuine interest by the apiculturists whose objective is the wider recognition of the importance of these bees along with the conservation and proliferation of these species as well as alternative livelihood potential that the bees offer.

4.5. Species selection and hive relocation

We started with collecting and documenting the bees and the location of wild hives in the study area (**Figure 1**). As a result, we observed that in the transitional ecotones between temperate forest and dry tropical forest, the most frequently encountered species were those of *Nannotrigona perilampoides* and *Plebeia fulvopilosa*. In the warmer zones, *Frieseomelitta nigra and Scaptotrigona hellwegeri* was more common. The relocation of hives was initiated with these three species, where we placed the entire hive into the customized bee boxes. Later, we sought out *Melipona fasciata* and *Scaptotrigona hellwegeri*, which are considered the most apt for production according to past experience [32] and by preference of the local managers.

Initially, we adopted techniques and management processes that had been employed in other regions of the country for the same genus found in this area [27, 32], but with undesired results since the percentage of adaptation and retention of nests (*Scaptotrigona hellwegeri* and *Melipona fasciata*) was 30%. Also other species as *Nannotrigona perilampoides* and *Plebeia fulvopilosa* did not develop their nests. The exercise did serve as a means to better understand biological particulars in the development of each genus that we worked with.

Through this process, we learned that it was of fundamental importance to use hives at risk of destruction or disappearance either by extraction or habitat destruction, which was causing significant impact on the bee populations. To ensure this means of selection, we developed a series of communication strategies to find out the location of hives and in particular those hives that were at risk.

Through direct dialogue with the inhabitants of the study area and formal presentations in municipal meetings pertaining to rural development organized by the local governing agencies (which were attended by all heads and representatives of the local ejidos, landholders, and communities), we presented the project and activities of the Meliponicultores Michoacanos del Balsas. This allowed us to establish rescue strategies for the nests that were at greatest risk (**Figures 2** and **3**).

Figure 2. Transfer of wild nest of *Plebeia fulvopilosa* who was in a oak tree (*Quercus* sp) at El Herrero, Madero, Michoacán.

Figure 3. Rescue of pillaged nest. One portion of the nest is removed, and recapped for maintenance. *Melipona fasciata* nest in a pine tree at Pie de la Mesa, Tzitzio, Michoacán.

We also employed a collection technique in which only part of the hive was extracted with only a fragment of the hive resources (honey combs and pollen) that were transported immediately to the new locations where the bee keeping boxes were already prepared for their arrival. This meant very careful extraction from the wild hives to avoid damaging the preexisting internal structure and covering the nest after extraction was completed. If the nest was located in a tree trunk or crevice, the cutting was made with power saw, which allowed for lower disturbance so that the remainder nest was not moved or altered from the original spot and could continue developing in its original location as we have seen in about 80% of nests worked.

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We worked with the following five species of meliponini in the study area: *Frieseomelitta nigra,Melipona fasciata*, *Nannotrigona perilampoides*, *Plebeia fulvopilosa* and *Scaptotrigona hellwegeri* (**Figure 4**). For each species, we have made every effort to adapt the management strategies and box design to their particular development needs. The smaller boxes have been used with *Frieseomelitta*, *Nannotrigona*, and *Plebeia* genera. By contrast, *Melipona fasciata* requires much larger boxes because the size of their brood combs, pots of storage and bee population (**Figure 4**).

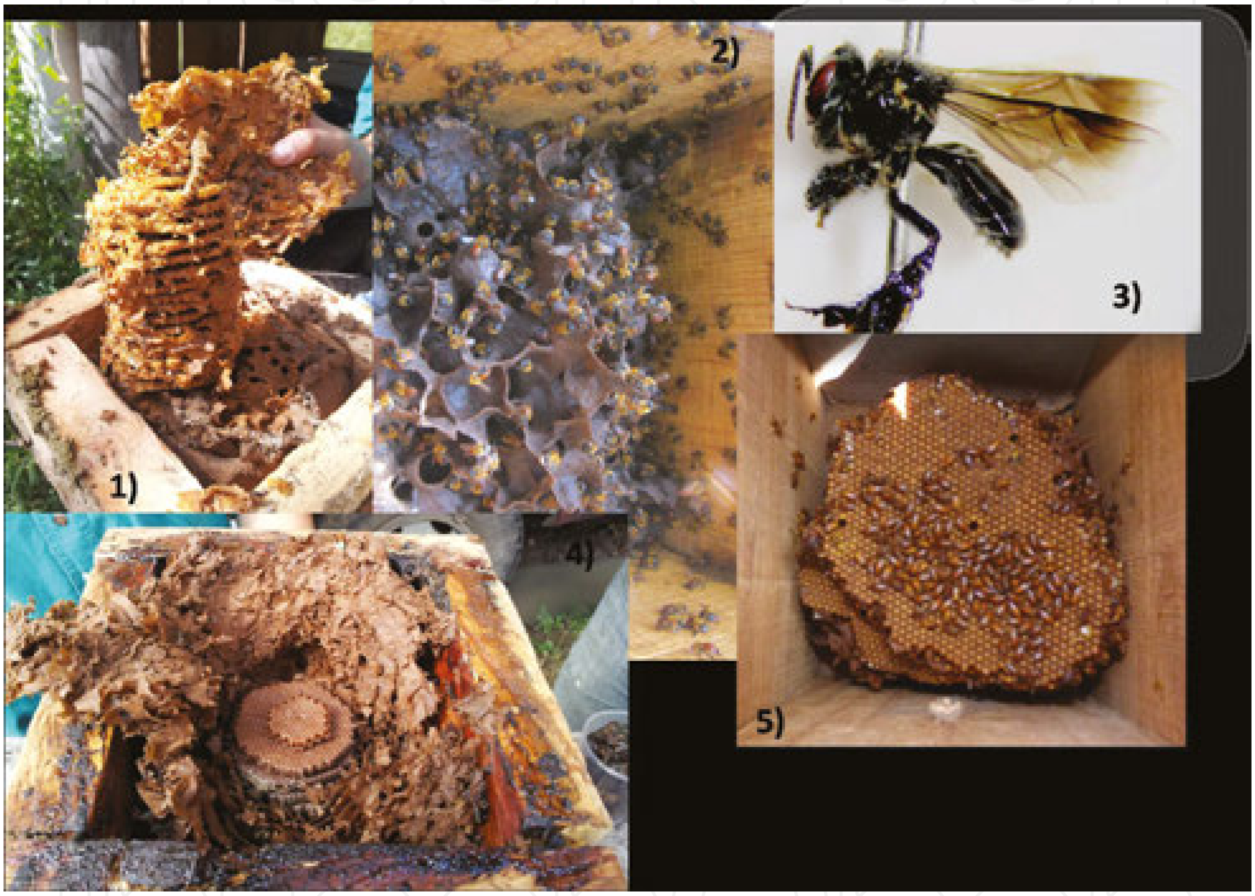

Figure 4. Managed species by the meliponicultores Michoacanos del Balsas: 1) *Nannotrigona perilampoides,* 2) *Melipona fasciata,* 3) *Frieseomelitta nigra*, 4) *Plebeia fulvopilosa*, 5) *Scaptotrigona hellwegeri*.

4.6. Hive maintenance and product commercialization

Once the hives have become established in the modern nesting boxes, it was important to monitor them for parasitic fly infestations by *Pseudohyphocera kerteszi*. In the cases where infestations were detected, apple-cider vinegar traps were used along with directed elimination of the flies. We also ensured that the nests had a stable resource stock for the population (pollen and honey) and if reserves were low we supplemented with honey from *Apis mellifera* nests having abundant resources.

In the hives where development was unhampered by external influences or resource limitations, we were able to obtain (in the fall—Oct-Nov) the following quantities of honey (per hive): *Melipona fasciata* 1500–2000 ml; *Scaptotrigona hellwegeri* 800-1,000 ml; *Nannotrigona perilampoides* 100–250 ml; *Frieseomelitta nigra* 100–250 ml and *Plebeia fulvopilosa* 40–80 ml (**Figure 5**).

Figure 5. Honey harvest of Melipona fasciata by decanting method. Piumo, Michoacán.

Figure 6. Selling products at fairs and festivals.

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In the experience of the working group, though there is a period of flowering in the spring and honey production as a result, products were not extracted from the hives. Instead that was the time when hives were divided to augment the bee and product inventory. As a result of this strategy to allow the hives to take advantage of natural production and leave their nutritional reserves, the monitoring of the nests was not as frequent over the rest of the year when harvesting or dividing were not occurring.

The division of the nests was carried out by taking half of the relocated nests (after they were well established) and dividing the storage vessels. In this regard, *Nannotrigona perilampoides* showed the greatest productivity and growth followed by *Plebeia fulvopilosa*. The species that responded less favorably in terms of growth and production after division was *Melipona fasciata* with an estimated 40% success rate after each division.

At the moment, Meliponiculture en el Balsas is being developed on a small scale, it is an innovative activity and has been well received by a group of apiculturists concerned about the rescue and conservation of stingless bees. The products obtained from these bees have a niche in the local and regional market and are sold directly from the producer to the consumer (**Figure 5**). The honey made into a suspension and is sold as a treatment for ocular infections at a price of around de $50 MN for 25 ml ($3 US dollars). This provides an earning of approximately $120 US dollars per liter of honey made into suspension. The pure honey is sold locally with a cost per liter of approximately $1000 MN ($65 US dollars). In the regional market, the working group has participated in various commercial events like the State fair and gastronomic events, among others (Image 6). The pollen is also sold, mixed with the honey at a proportion of 100 g of bee pollen per 1000 ml de honey of the species *Apis mellifera*. This product is marketed as a nutritional supplement with high protein and energy potential at a price of $150 MN ($9 US dollars) per 250 ml of the mix.

4.7. Challenges and prospects for meliponiculture in Alto Balsas, Michoacán

During this experience, it was necessary to adapt to various ecological and biological contexts, in particular the specific needs of each of the species we worked with. Environmental conditions like flowering periods, seasonality (resulting in limited resources during part of the year), temperature fluctuations, presence and abundance of wild nests, among others, influenced the management decisions and resulting interventions. All of this speaks to adaptive management.

Without a doubt, the most influential factor was the distribution and abundance of wild nests for the species we worked with. For example, *Melipona fasciata* is found exclusively in mountainous zones in areas where mixed pine-oak forest is well conserved. This has been a significant complication for the meliponiculture in the region due to the limited presence of species with the highest production potential. In particular, Melipona fasciata, "la colmena real" is quite scarce and has low resilience to disturbance in the area around nesting sites as it is only found in areas where the vegetation is well conserved and in the hollowed trunks of oaks (Quercus sp).

This was the only species that required special management attention. Initially, we tried to apply the same relocation strategies as for the other species of *Meliponini*; however, we realized that they were not adapting to the relocation sites where they would either abandon them or showed high susceptibility to predation by *Pseudohyphocera kerteszi*. As a result, the managers experimented with extraction by moving them to larger rustic nest boxes located in the same sites where the wild nest was located. As such, it was observed that these bees were able to adapt and continue developing and producing leading to the conclusion that this species is "hermit" and prefers to be far from human settlements. This resulted in the experimentation with the continued use of rustic nests versus the modernized ones (creating hollows in oak trunks) for use as relocation sites for complete or divided wild nests already being managed. This is comparable to the Mayan technique of "jobones" which is the hollowing of oak trunks as described [46].

5. Conclusions

The interaction of the human populations with bees has been of great importance among diverse cultures in America. The relationship between the Mesoamericans and stingless bees was always been of great significance and continues to persist in some tropical areas in Mexico. Various management schemes exist to take advantage of the products of these insects. Today stingless bee populations are in decline as a result of environmental degradation primarily in the form of land use change, deforestation, and degradation [19]. Likewise, the traditional knowledge and related management practices are also at risk of disappearance as a consequence of cultural changes, economic pressures and environmental change.

In the face of these risks, it is of fundamental importance to maximize local knowledge about stingless bees and management strategies in accordance with the realities of the local context. This research program presents a development alternative to develop alternate strategies in the breeding and reproduction of these bees to aid in their conservation, while at the same time taking advantage of the products they provide. This is a viable means to promote the conservation of stingless bees and the environmental services they provide, strengthen local knowledge and encourage production activities that offer sustainable alternative to the rural communities that manage these insects.

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