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Notes on Meliponini (Hymenoptera: Apidae: Apinae) of Costa Rica: A Rescue Project of the South Caribe, Limón

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Abstract

Wild populations of stingless bees in Costa Rica present a valuable information gap in terms of wild ecology, due to the great difficulty that national parks and biological reserves represent to carry out population studies due to their great exemption. Due to this, the meliponarium and rescue projects of these bees provide an important opportunity for their study since they bring together local wild populations in the same physical space. In Costa Rica, there are several types of Wildlife Management Centers, which seek sustainable economic development, based on the use of products and by-products of wild flora and fauna. Considering the current legislation, the present study determined that the bee rescue center model represents an important potential in terms of the genetic connection of plant populations, as well as an easy access point for biological studies.

Subject Areas

Environmental Sciences, Zoology

Keywords

Bees, Meliponarium, Plant-Pollinator, Rescue Center, Wildlife

1. Introduction

Stingless bees belong entirely to the Meliponini tribe, which has about 400 species worldwide [1] [2], 59 of which were reported for Costa Rica until 2016, 12 of them highly appreciated for honey production [3]. These bees, unlike *Apis mellifera* L., do not present a domestication so strong that it allows their hives and

queens to be reproduced in masse, but a management that has been transmitted over the years since pre-Columbian times, varying the methods between boxes. and clay pots [3] [4], being the last century of vital importance for their management because of the discoveries about them and due to this they suffer intense pressure in their wild populations due to the high demand for hives by those who extract them directly from nature, to deforestation, to the direct destruction of beehives and to the change in land use from agricultural or forestry to urban.

Added to the above, in Costa Rica the Wildlife Conservation Law and its regulations were created to regulate the development of economic activities linked to the exploitation of wild flora and fauna. However, within this legal framework, it has never been considered to involve wild bees in fauna rescue centers, as these arose from the need to protect vertebrate fauna from hunting and species trafficking, while bees are only considered for honey production, either through an apiary or a meliponarium.

Despite this, an emerging project broke with this pattern of management sites, creating a rescue center dedicated exclusively to the conservation of wild bees, called Api-Agricultura. This project consists of a small rural property, whose owner allocated most of the area to the conservation of stingless beehives that people tried to burn or destroy, either because they were established within the infrastructure of houses or buildings, or because they were on tree trunks that were going to be cut down.

This work, initially empirical, led to the place where the hives are guarded, becoming a genetic reservoir for the species that were rescued, and a site for studying bees' biology. The present study was carried out to characterize the conservation potential that this type of project represents for tropical ecosystems, as well as its legal profile with respect to current legislation.

2. Methodology

2.1. Nomenclature

ACLA-C	La Amistad-Caribe Conservation Area
MAG	Agriculture and Livestock Ministry
MNCR	Costa Rica National Museum
AAP	Api-Agricultura project
SENASA	National Animal Health Service
SINAC	National System of Conservation Areas
Law 7317	Law of Wildlife Conservation
Law 7788	Law of Biodiversity

2.2. Study Area

The inventory was carried out in the district of Cocles, Limón, Costa Rica. The AAP Wild Bee Rescue Center is located at 9˚37'54.23"N and 82˚43'59.18"W, in an area whose vegetation cover corresponds to the Caribbean Tropical Rainfor-

est. The facilities are on private property and consist of three houses, a ranch with a work area for a workshop and environmental education, and large green areas divided into two sectors, one of which is intended to locate the beehives that are rescued.

AAP is directed by Carlos Cortés, who rescues wild hives of stingless bees, in cooperation with the local environmental authorities of SINAC of ACLA-C, as well as residents of the southern Caribbean, including from Cahuita, to Gandoca-Manzanillo.

2.3. Taxonomic Inventory

Between January 2019 and March 2020, quarterly tours were made to the AAP, where a sample of 10 bees was taken from each of the hives that had been rescued.

The specimens of the bees from each hive were collected during the morning hours when the activity of the bees is more intense, then they were preserved in 96% alcohol, identified and deposited frozen in the MNCR, as part of the Collection of tissues (No genetic sequencing of the material was performed).

2.4. Research and Collection Permits

The samplings were carried out using the research and collection permits R-SINAC-PNI-ACLAC-054-2019 and R-SINAC-PNI-ACLAC-002-2020 issued by the La Amistad-Caribbean Conservation Area. Voucher specimens were deposited in the MNCR.

2.5. Review of Current Legislation

Currently, in Costa Rica, the management of natural resources is governed by a series of laws and decrees that regulate any activity that involves wildlife. The two most important in relation to insects are Law 7317 and Law 7788, and their regulations in decrees No. 40548 and No. 34433.

Based on this regulation, we proceeded to analyze the bee rescue center as a model for a wildlife management site, to determine the management route to follow.

On the other hand, the management of stingless bees in this project has been carried out from the perspective of the objective conservation of wild populations, and the development of environmental education activities, which complies with the specifications of the law. The conflict appears when discussing the need for an environmental manager, since, like the sea turtle nurseries; they present management protocols already established by the MAG.

2.6. Ethological Observations

Behavioral observations were also made, both regarding the normal dynamics of bees in the hive entrance area, as well as their defensive behaviors. The latter were recorded during a specific event of attack by invasive bees and making a

physical approach to one of us at different distances from the hive entrance, to determine if the species are defensive or not, and at what distance they react to a possible attack or danger.

3. Results

3.1. Taxonomic Inventory

The project had a total of 108 hives as of March 2020, representing a total of 17 species (Table 1 and Figure 1) of stingless bees that are residents of the project. 10 of these hives were established in natural termite mounds, 35 of them were in artificial boxes and 63 in natural trunks, with respect to the latter, an association with 20 tree species was identified (Table 2).

Table 1. Api-Agricultura Meliponini species list.

Hives	Specie	Local Name
1	*Cephalotrigona zexmeniae* (Cockerell, 1912)[a]	Tamagá
1	*Frieseomelitta nigra* (Cresson, 1878)	Zopilota
6	*Melipona* (*Michmelia*) *costarricensis* Cockerell, 1919	Jicote Barsino
1	*Melipona* (*Michmelia*) *fallax* Camargo & Pedro, 2008	Jicote Congo
4	*Nannotrigona mellaria* (Smith, 1862)	Chicopipe
3	*Nannotrigona perilampoides* (Cresson, 1878)	Chicopipe
1	*Oxytrigona daemonica* Camargo, 1984	Abeja de fuego, Peladora
2	*Partamona orizabaensis* (Strand, 1919)	Enrredapelo
1	*Scaptotrigona luteipennis* (Friese, 1902)	Soncuano
32	*Scaptotrigona pectorialis* (Dalla Torre, 1896)	Soncuano
11	*Scaptotrigona subobscuripennis* (Schwarz, 1951)	Picúsaro
2	*Tetragona ziegleri* (Friese, 1900)	Mariolón
32	*Tetragonisca angustula* (Latreille, 1811)	Mariola
3	*Trigona ferricauda* Cockerell, 1917	Enredapelo
4	*Trigona fulviventris* Guérin, 1844	Culo de buey
3	*Trigona muzoensis* Schwarz, 1948	Boca de sapo
1	*Trigona silvestriana* (Vachal, 1908)	Conga

[a]Non-scientific public: The Zoological Nomenclature uses parentheses when a species was described with a different genus from the current one.

Table 2. Hive-associated tree species.

Hives	Specie	Family	Local Name
1	*Abarema idopoda*	Fabaceae	Cachá
3	*Andira inermis*	Fabaceae	Arenillo
1	*Castilla elastica*	Moraceae	Hule
3	*Cecropia sp.*	Urticaceae	Guarumo

Continued

1	*Cordia alliodora*	Cordiaceae	Laurel
2	*Cordia eriostigma*	Cordiaceae	Laurel blanco, Muñeco
10	*Cordia garascanthus*	Cordiaceae	Laurel negro
5	*Erythrina berteroana*	Fabaceae	Poró criollo
4	*Ficus Insípida*	Moraceae	Chilamate de río
2	*Hieronyma alchorneoides*	Phyllantaceae	Pilón, Zapatero
2	*Hura crepitans*	Euphorbiaceae	Javillo
2	*Lonchocarpus salvadorensis*	Fabaceae	Chaperno negro
1	*Malus domestica*	Rosaceae	Manzano
4	*Ochroma pyramidale*	Malvaceae	Balsa
3	*Pentaclethra macroloba*	Fabaceae	Gavilán
5	*Persea caerulea*	Lauraceae	Aguacatillo
1	*Psidium guajaba*	Myrtaceae	Guayaba
10	*Pterocarpus orbiculatus*	Fabaceae	Sangrillo
1	*Spondias purpurea*	Anacardiaceae	Jocote
2	*Terminalia catappa*	Combretaceae	Almendro de playa

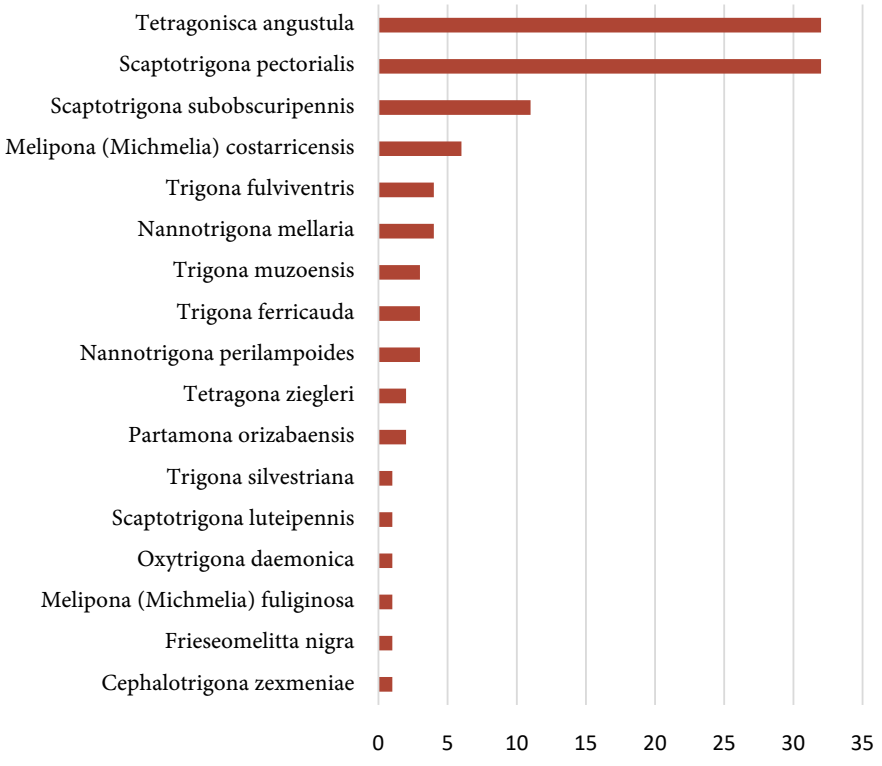

Figure 1. Number of hives by species.

3.2. Voucher Specimens

All the specimens are in the collection of the Natural History Department of the

MNCR, under the following catalog numbers: MNCR-A 5131582, MNCR-A 5131581, MNCR-A 5131791, MNCR-A 5131444, MNCR-A 5131575, MNCR-A 5131448, MNCR-A 5131520, MNCR-A 5131553, MNCR-A 5131434, MNCR-A 5131565, MNCR-A 5131088, MNCR-A 5131805, MNCR-A 5131602, MNCR-A 5131795, MNCR-A 5131588, MNCR-A 5131579, MNCR-A 5131598, MNCR-A 5131577, MNCR-A 5131580, MNCR-A 5131807, MNCR-A 5131455, MNCR-A 5131564, MNCR-A 5131455, MNCR-A 5131560, MNCR-A 5131800, MNCR-A 5131437, MNCR-A 5131436, MNCR-A 5131435, MNCR-A 5131563, MNCR-A 5131801, MNCR-A 5131790, MNCR-A 5131449, MNCR-A 5131596, MNCR-A 5131082, MNCR-A 5131438, MNCR-A 5131462, MNCR-A 5131572, MNCR-A 5131561, MNCR-A 5131450, MNCR-A 5131604, MNCR-A 5131603, MNCR-A 5131562, MNCR-A 5131447, MNCR-A 5131461, MNCR-A 5131605, MNCR-A 5131586, MNCR-A 5131590, MNCR-A 5131601, MNCR-A 5131591, MNCR-A 5131793, MNCR-A 5131463, MNCR-A 5131594, MNCR-A 5131566, MNCR-A 5131599, MNCR-A 5131568, MNCR-A 5131445, MNCR-A 5131441, MNCR-A 5131595, MNCR-A 5131443, MNCR-A 5131585, MNCR-A 5131442, MNCR-A 5131446, MNCR-A 5131806, MNCR-A 5131436, MNCR-A 5131557, MNCR-A 5131593, MNCR-A 5131457, MNCR-A 5131792, MNCR-A 5131798, MNCR-A 5131570, MNCR-A 5131796, MNCR-A 5131453, MNCR-A 5131799, MNCR-A 5131083, MNCR-A 5131573, MNCR-A 5131804, MNCR-A 5131459, MNCR-A 5131460, MNCR-A 5131456, MNCR-A 5131450, MNCR-A 5131576, MNCR-A 5131556, MNCR-A 5131454, MNCR-A 5131559, MNCR-A 5131458, MNCR-A 5131805, MNCR-A 5131794, MNCR-A 5131797, MNCR-A 5131584, MNCR-A 5131453, MNCR-A 5131558, MNCR-A 5131571, MNCR-A 5131569, MNCR-A 5131809, MNCR-A 5131583, MNCR-A 5131440, MNCR-A 5131589, MNCR-A 5131597, MNCR-A 5131439, MNCR-A 5131587, MNCR-A 5131464, MNCR-A 5131592, MNCR-A 5131452, MNCR-A 5131600, MNCR-A 5131555, MNCR-A 5131451.

This information can be publicly accessed through the following portal: https://biodiversidad.museocostarica.go.cr/.

3.3. Wildlife Management Site Model

Under current national legislation, this site partially fits into two main categories: Zoological Farm and Wildlife Rescue Center.

Although the site does not intend to reproduce the hives in large numbers, it uses a management in which the swarming of the hives is encouraged in a passive way instead of the division of nuclei. Likewise, honey, wax and propolis are used to prepare cosmetic and natural medicine products that are sold on the site.

However, the site's purpose is not to sell hives as such, but to keep them as much as possible in their original trunks and only transfer them when they are already in a state of decomposition, to disturb the colony as little as possible. Also, calls are answered from residences, restaurants, and tourist projects in the area, to safely extract the colonies or swarms that are installed within the infrastructure.

3.4. Important Ethological Observations

1) Some important behavior patterns for management were detected, which must be considered for the management of this type of site. Initially, a synchronization was detected between bees belonging to the species *Tetragonisca angustula* and *Scaptotrigona pectoralis* at the time of the attacks by stingless bees of the genus *Letrimelitta* Friese, 1903 (kleptoparasite bees that steal resources from other hives), during which the bees from those hives swarmed and remained suspended in the air, minutes later we were able to perceive the characteristic lemon smell of the *Lestrimelitta* swarms, which once they arrived at the site were attacked by the swarming bees. The *Tetragonisca* attacked in pairs, each biting into a pair of wings, resulting in either the *Lestrimelitta* losing its wings entirely and falling to the ground, or all 3 ending up dead; on the other hand, the *Scaptotrigona* managed to cut off the head of the *Lestrimelitta* without problems, so that a single individual could eliminate two or more invaders.

This behavior was taken advantage of by the project administrator, who used a *Scaptotrigona* pectoralis hive to repel the attack of the *Lestrimelitta* in more vulnerable hives such as the *Nannotrigona* and *Tetragona*, placing the entrances of the affected colony with that of the *Scaptotrigona* face to face, less than 3cm (about 1.18 in) from each other. What happened was that the *Scaptotrigona* began to attack only the invaders, and not the residents of the hive, so that even the individuals entered the affected hive eliminating the invaders and ignoring the residents, which may be due to the smell of each species.

2) Regarding the defensive behavior of the project species, it was determined that only five species need to be away from the main trail used by visitors, because they are defensive and react at distances between 2 m and 5 m away (**Table 3**).

3) Due to an accident during the daily operation of the site, the entrance of the *Melipona* (*Michmelia*) *fallax* broke, which caused a dynamic in the bees of the hive in which the entry of individuals with pollen was stopped, and a large quantity of pollen came out. A number of individuals inside the hive, they were divided into two groups, one of them was observed on the street collecting small stones between 2 mm (about 0.08 in) and 5 mm (about 0.2 in) in diameter, and the other dispersed in the trees near the project. Meanwhile, individuals arrived at the entrance with loads of viscous resins that they layered on the remains of the previous entrance, to later receive the stones that the other group collected from the street and place them on top of the resin. In this way, they were placing simultaneous layers to rebuild the entrance.

4) Due to the fact that the management of the hives in the project did not contemplate the division of the nuclei manually to reproduce the hives, these often swarmed abandoned the boxes or old trunks, within these, two hives were recorded inside termite mounds that were abandoned by a previous colony of *Trigona fulviventris*, and during the last field tour two new colonies of *Trigona muzoensis* were found at the sites, but preserving the architecture of the entrance

Table 3. Defensive behavior detected.

Species	Defense
Cephalotrigona zexmeniae (Cockerell, 1912)	Not defensive, it hides
Frieseomelitta nigra (Cresson, 1878)	Not defensive
Melipona (*Michmelia*) *costarricensis* Cockerell, 1919	Little defensive, only less than 10 cm (about 3.94 in) from the entrance
Melipona (*Michmelia*) *fallax* Camargo & Pedro, 2008	Little defensive, only less than 10 cm (about 3.94 in) from the entrance
Nannotrigona mellaria (Smith, 1862)	Not defensive, it hides
Nannotrigona perilampoides (Cresson, 1878)	Not defensive, it hides
Oxytrigona daemonica Camargo, 1984	Defensive, attacks on physical contact
Partamona orizabaensis (Strand, 1919)	Defensive, attack from 3 m from the entrance
Scaptotrigona luteipennis (Friese, 1902)	Defensive, attack from 3 m from the entrance
Scaptotrigona pectorialis (Dalla Torre, 1896)	Defensive, attack from 2 m from the entrance
Scaptotrigona subobscuripennis (Schwarz, 1951)	Defensive, attack from 1 m from the entrance
Tetragona ziegleri (Friese, 1900)	Little defensive, only less than 10 cm (about 3.94 in) from the entrance
Tetragonisca angustula (Latreille, 1811)	Little defensive, only less than 10 cm (about 3.94 in) from the entrance
Trigona ferricauda Cockerell, 1917	Defensive, attack from 1m from the entrance
Trigona fulviventris Guérin, 1844	Little defensive, only less than 10 cm (about 3.94 in) from the entrance
Trigona muzoensis Schwarz, 1948	Defensive, attack from 2 m from the entrance
Trigona silvestriana (Vachal, 1908)	Aggressive, attack from 5 m from the entrance

previously built by *T. fulviventris*. It is important to mention that no successful settlements of *T. muzoensis* were recorded on any substrate other than a termite mound; the project's attempts to transfer them to wooden boxes ended in swarming.

4. Discussion

4.1. Wildlife Rescue Centers in Costa Rica

The rescue center model in Costa Rica is typified by the regulations of the wildlife conservation law with an exclusive focus on vertebrates. However, its definition of Wildlife Rescue is attention to the needs of wild animals that have seen their well-being and survival compromised, requiring immediate human intervention to survive.

Likewise, it is defined in its article 5 that wildlife is constituted by all species of organisms of all biological kingdoms found in the wild in terrestrial, aquatic, and marine environments throughout the national territory, and mentions insects, arachnids, and crustaceans.

If we consider the provisions, the wild hives of social bees that are in danger of being destroyed, or whose substrates have been damaged, endangering the hive population, or even that their settlement is linked to human infrastructure where the hive as well as the well-being of the people affected, we can affirm that they are wildlife that needs to be rescued or relocated.

However, this group of wild animals is not considered within the law within the rescue center category, despite the fact that only 12 of the species reported for Costa Rica are suitable for honey production [3], the rest being completely ignored by the producers in cases of requiring rescue.

4.2. Zoological Farms and Meliponini Species

Zoological farms have as their primary objective the production of individuals of the species of interest in order to trade them directly or generate products derived from their bodies, an example of this are butterfly gardens, which sell the pupae, dried adults, jewelry with wings, or pictures with dried individuals, an industry with more than 60 species that are exported all over the world [5]. Another example is the production of meat from wild animals such as the Tepezcuintle (*Cuniculus paca* Miller & Gidley, 1918) which is carried out to avoid illegal hunting [6].

In the case of bees such as those of the genus Bombus Latreille, 1802 (Apinae: Bombini), they have been widely produced on farms around the world in order to sell large numbers of hives in order to pollinate crops [7]; the same occurs with the bees *Apis mellifera* Linnaeus, 1758, which are the global base of honey production, and whose management has made its European variety the only completely domesticated one and the wild Africanized one the least used due to its aggressiveness [8] [9]. But, unlike these species, those of the Meliponini group cannot be reproduced in masse, because the nuclei cannot be divided more than two sections once a year, taking into account that the presence of another queen or cell is essential real [10] [11] [12], and unlike in the genera *Bombus* and *Apis*, it is not yet possible to generate several queens of meliponini bees to be changing or adding when required, due to how fragile they are.

Therefore, stingless bees fit with a biology corresponding to vulnerable wild populations, both the species that are already used in meliponarium, and those that are not, therefore, the bee populations from which new centers are created of meliponiculture. The Meliponini are of wild origin in Costa Rica, and therefore, they must adhere to Law 7317, this does not mean that their extraction should be prohibited, but as long as the collection permits are requested, and even the population studies that are carried out, required for a zoological farm or a rescue project, the activity could be well regulated, and thus reduce the pressure that wild populations are suffering.

This is why the rescue center model is more consistent with the conservation discourse of stingless bees than the conventional meliponarium, since the former is fully aimed at rescuing and protecting all the species of the group while the latter only those which allow the production of honey and other derivatives, that is, only species that can be exploited.

4.3. Research and Education

Environmental education aims to teach people to find a balance between con-

servation and economic needs, in order not to affect wildlife [13], that is, it is not about depriving human beings of Natural resources that they need for development, but to do so in which nature can recover properly. However, the educator requires training that allows them not only to acquire the technical and theoretical knowledge that they are going to impart, but also to develop the skills to transmit that information assertively.

On the other hand, Costa Rica has been a country that has earned the reputation of "Green Republic" due to its great progress in conservation and environmental education [14], but we have a serious backlog in terms of generating updated scientific information on the conservation status of wild populations of groups of invertebrates, one of them bees.

Added to this, the current dynamics of meliponariums at the national level lacks control of the origin of the hives, resulting in a lack of knowledge of the impact that the free capture of wild swarms for honey production has had, or the supposed rescues that are not documented, nor are they monitored by the environmental authorities, and this issue continues to be not included in environmental education.

4.4. Management Protocols and Legislation

Although it is true that there are already manuals aimed at raising and managing stingless bee hives [4] [10], there is no material aimed at the non-scientific public that condenses the correct procedures for the acquisition of wild hives, regarding the current legislation, and this is where we put on the table the most controversial topic of debate: Is it necessary for a meliponarian to have a regent?

If we base ourselves on Law 7317, we can see that in its articles 18, 21, 22, 23 it clearly determines the need for prior scientific research to determine the feasibility of estrating from wildlife, as well as the cost-benefit of extraction, this has been continually required of butterfly gardens to extract their broodstock, as well as other stringent requirements.

To this is added that in the regulation of this law (Decree No. 40548-MINAE) in its article 5 it includes insects within the groups of wildlife, without making any type of exclusion in article 1 of the same document. This means that the current management of wild bee populations should include meliponaria in the category of Wildlife Management Site.

Therefore, returning to the question posed previously, the answer is that a wildlife regent is needed, since it is essential not only to generate the wildlife management plan, but also the entry control and certificate of origin of each one. of the hives that enter the project, since as established in article 18 of the regulation, since wildlife is a public domain good, its use must be adhered only to current legislation, which only excludes nurseries of turtles to have an environmental regent, all the others must have one, and not only is there no exclusion for bees from being wildlife, but there is no other legislation that protects them from illegal extraction and the destruction of their hives.

4.5. Botanical Associations

While we have made it clear that stingless bees in addition to being wildlife, we also have to be clear that they represent an important source of income for those who are dedicated to extracting honey and other derivatives such as wax and propoling [15] [16]. This is why, considering the content of article 88 of the Regulation to Law 7317, it is important that as part of the Wildlife Management Plan the plants and trees that provide the necessary resources are included, so that the present species can produce Propoleo, food and wax without problems. This of course implies a constant observation and research plan, in order to duly know the flora to which each species is associated present in the immediate environment of the project.

5. Conclusions

Based on the observations and reviews carried out during the work in the Api-Agricultura rescue project, we conclude:

1) Rescue centers should not be exclusively focused on vertebrates, but consider all groups of wildlife whose biology is compatible with the term.

2) The meliponarium are genetic reservoirs of wild populations and allow the observation of behaviors that are impossible to appreciate *in-situ*. Therefore, they represent a valuable resource for conservation and research.

3) In accordance with current law, meliponaria and wild bee rescue centers must have a regent biologist, who certifies the origin of each hive.

4) The rescuer must properly document each rescue, and keep an inventory of the hives of his project and a log of the actions carried out with each one.

5) This type of project can apply a quality environmental education to visitors, since it immerses people in the reality of wild bees, making them part of the conservation dynamics.

6) It is essential that future research contemplate developing identification guides and cultivation manuals associated with bees, as well as other important resources.

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Conflicts of Interest

The authors declare no conflicts of interest.

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