Original article

Extinction of *Melipona beecheii* and traditional beekeeping in the Yucatán peninsula

ROGEL VILLANUEVA-G, DAVID W ROUBIK AND WILBERTO COLLI-UCÁN

Rearing of the 'xunan-kab' bee (Melipona beecheii) had been practised widely by the Mayans of the Yucatán peninsula long before arrival of the Spanish in the New World, and had been a culturally and economically important activity in that region. Melipona beecheii is kept almost exclusively in traditional log hives. Beekeepers using this bee, from the Maya zone in Quintana Roo state, Mexico, testify to a 93% decrease in hives during the past one-quarter century. Despite concern that stingless bee beekeeping is going extinct, there were scant data to examine direct impact of competition from feral African Apis mellifera, deforestation, hurricane damage and lack of instruction and incentive for new stingless bee beekeepers. We therefore made a survey of beekeepers constituting 20% of the largest traditional beekeeping group in the Americas. These data combined with our field studies, taken over 24 years, suggest that bees are threatened both by environmental changes and by inappropriate management and conservation efforts. Overharvest and failure to transfer colonies to hives or divide them are serious impediments. The major tactics to confront these problems are presented.

Introduction

A series of papers published during the last quarter century show a downturn in stingless bee beekeeping in at least part of the Yucatán peninsula, and attempt to analyse the causes.[10,19,20,27,46] Long before arrival of the Spanish in the New World and subsequent introduction of a major honey resource from the Old World (honey bees – *Apis mellifera*), the Maya of the Yucatán peninsula were expert practitioners in husbandry of various native honey-making stingless bees, which were kept in log hives. Today and, we suspect, during historical beekeeping times, those bees used most for food and materials are the large-bodied meliponines, *Cephalotrigona*, *Melipona* and *Scaptotrigona*.[3,27,37] Because of its ease of management (the large forager size, flight range and numerous virgin queens for colony propagation are a particular asset of *Melipona*) and excellent honey production, the favourite species has been *Melipona beecheii*, known by its keepers as 'xunan-kab' or 'colel-kab'.[27] It was apparently the only bee propagated using husbandry techniques in the whole of the tropical world. These bees were particularly important to the Maya civilization for medicines (antibiotic honey), sweeteners and mead (balche), and a vital small-scale economy. These bees even provided metaphors for the Maya, whereby they interpreted their place in the universe and relationship to the earth, deities, and later, to the Spanish invaders.[8,39] Xunan-kab were regarded as a gift from the gods to humankind and therefore were handled with utmost care and reverence by trained beekeepers.[9]

Melipona beecheii is one of several hundred bee species – almost all tropical meliponines – that produce abundant honey.[21] This bee's natural range is from Mexico to Costa Rica.[3] Originally a resident of tropical lowland forests, it was dependent on the variety and cycles of the forest resources, for example a major flowering period and honey storage during the dry season, followed by a dearth of nectar and pollen during the wettest part of the year, or in prolonged drought.[29,45]

Over the centuries, the Yucatán peninsula has been deforested, first by the Maya and later particularly in the western and central portion, where agave, sisal and cattle ranching replaced forest, as its people became more involved in plantation schemes or cultural and economic alternatives to traditional slash and burn 'milpas' agriculture. As a result, xunan-kab (literally, the 'royal lady' bee) forages largely among secondary-growth plants.[42,44] At both large- and small-scale, *Apis mellifera*, despite its sting, was economically a better option for many, as it was not commonly associated with relatively low productivity and low income.[27] Hence the Mayan stingless bee lost its place as provider of a sweetener (to sugar cane and to *Apis mellifera*) and to modern pharmaceuticals as a provider of medicine. It now continually competes with *Apis mellifera* for floral resources and nesting sites, and has lost, due to modern cultural changes, central significance in Mayan customs and beliefs. Nonetheless, a potential boost to the local economy may yet come from the re-establishment of a vigorous meliponiculture in Yucatán.[27] Because there were no published long-term data that examine the biology and impact of competition from introduced feral African *Apis mellifera*, deforestation, hurricane damage, natural enemies, lack of instruction for new stingless bee beekeepers, or attendant lack of economic incentives for traditional stingless beekeeping, we therefore made a direct inquiry with a survey of beekeepers and long-term focal studies in the relatively forested area of eastern Yucatán peninsula, in the state of Quintana Roo. We note both similarities and differences, compared with the previous work of a considerable number of authors.

Melipona beecheii is apparently rare in the wild, even in forested areas,[14] although tropical studies on stingless bee or honey bee nest abundance are surprisingly scarce.[16] Its nests occur only in hollows within now relatively rare trees, of ≥ 30 cm girth.[27] At the same time, the traditional practice of propagating domesticated colonies is not being taken up by younger generations of Maya. In short, apart from the sustaining efforts of a handful of enthusiasts, meliponiculture, or stingless bee beekeeping, at least in the areas that long have been deforested, is disappearing.[11,20,27] Several

For the last 14 years the stingless bee beekeepers have been losing, on average, about 22 colonies each year. Continuing that trend, by the year 2008 there will be no domesticated colonies left at all. Only Pedro Cahun-Uh, a meliponiculturist from Tihosuco, increased his colonies from 5 to 12.

institutions, business ventures, and non-government organizations are attempting to develop stingless bee beekeeping. As discussed here, we have observed stingless bee beekeeping efforts commonly fail in the Maya region, and transplanted colonies are lost due to varied reasons. Moreover, the large number of hives lost recently by meliponiculturists and beekeepers in the states of Yucatán and Campeche, after hurricane Isidore, may well be irreplaceable.[11] The objective of this work was to analyse the biological problems related to the maintenance and management of *Melipona beecheii* in the relatively well-forested portion of the Yucatán peninsula, and determine reasons why populations have declined greatly within Mayan communities.

Survey

To compile data which enable us to evaluate the trends in stingless bee beekeeping, we took stock of overall changes at the end of 2004 in Quintana Roo state, Mexico, in an area known as the 'zona Maya' (fig. 1). A standard set of questions was asked in the Maya language of meliponiculturists in the region. The data were assembled after first making a census of all Mayan communities with more than 50 inhabitants, for which population data[15] were available. A total of 150 communities were thus identified, and 120 stingless bee beekeepers were found among them. Previous work by Quezada-Euán and colleagues[27] estimated that there were fewer than 500 stingless bee beekeepers in all of Yucatán. We took a random sample of 24 beekeepers in the zona Maya (20%) and asked the questions in our standard questionnaire in 1981, 1990 and 2004. The meliponiculturists questioned were not strictly beekeepers and none had much formal education or economic means. Some examples of the questions asked were:

- 'How did you obtain your xunan-kab colonies?'
- 'How many did you inherit?'
- 'How many do you have?'
- 'Who taught you to manage the colonies?'
- 'Do you use "rational hives" (wooden box hives)?'
- 'How many log hives and rational hives do you have?'
- Do you divide (propagate) your colonies?'
- 'How much honey do you produce?'
- 'Where or to whom do you sell it?'

In addition, we conducted further interviews on the general state of stingless bee beekeeping, including both local and statewide problems. Periodically (every two or three months) beginning in 1985 we interviewed five stingless bee beekeepers in order to learn of specific bee management problems. These were open-ended interviews in which key questions were asked, such as:

- 'What management problems have been encountered?
- 'Have you divided your colonies?'
- 'Why have your colonies been weak or in poor condition?'
- 'What are the main reasons you are losing your colonies?'

Thus, our study attempted to assess the strengths and weaknesses of meliponiculture under present conditions, threats and opportunities related to honey production.

Decline of meliponiculture activity

Table 1 shows results from the 24 traditional meliponiculturists that were interviewed in the zona Maya of Quintana Roo, indicating the numbers of *Melipona* colonies kept at the end of 1981, 1990 and 2004. The most alarming findings were that, out of the total number of domesticated colonies (755) *known* to be held in 1981, and probably hundreds more for which no precise records were offered by the participants, only 90 have survived or have been replaced. If we consider only the meliponaries ('bee yards', fig. 2) in which the number of hives present in 1981 was stated by the participants, then the decline between 1981 and 2004 has been one of over 93%.

Furthermore, nine out of the 24 questioned no longer had any colonies, a notable phenomenon within the last 14 years. Clearly, the keepers of xunan-kab either cannot maintain their colonies adequately, or they lack sufficient reasons to keep them. Such individuals may not have found a successor to properly care for the colonies, and they have failed to replace colonies lost due to mortality. For the last 14 years the stingless bee beekeepers have been losing, on average, about 22 colonies each year. Continuing that trend, by the year 2008 there will be no domesticated colonies left at all. Only Pedro Cahun-Uh, a meliponiculturist from Tihosuco, increased his colonies from 5 to 12 (table 1). He also divided three to produce three more, using wooden box hives. He was the only beekeeper who was successful in such husbandry efforts. None of the other meliponiculturists used box hives, but rather used traditional hollow log hives, or 'jobones'. Significantly, many beekeepers were reluctant to risk losing their colonies to parasitic phorid flies, *Pseudohypocera* or 'nenem', which often attack and kill colonies that have been moved or disturbed by opening of the nest cavity.[42]

All *Melipona* colonies, except four belonging to Nemesio Pot from Chan Santa Cruz, were inherited either from the fathers or the grandfathers. Mr Pot obtained five of his log hives from wild colonies in the forest.

Loss of habitat

The peninsula of Yucatán (the states of Yucatán, Quintana Roo and Campeche), once covered with mature tropical forests (although not in some periods before the arrival of Europeans[12]), has been deforested extensively in modern times. In the state of Yucatán, land reform programmes of the 1930s, cattle ranching, logging and large-scale cultivation of agave plants for production of sisal have resulted in nearly complete deforestation of that state.[27] The less populous states of Campeche and Quintana Roo have been less affected.

Although the nectar and pollen plants that now predominate in the zona Maya appear to be quite useful to *Apis mellifera* (171 pollen species used by the exotic honey bee have been recorded recently[40,41,45]), it is reasonable to expect that, for native bees, significant adjustments were needed in response to the changes of flora resulting from human activities, both in historical times and more recently. However, logging, even if it is not clear-cutting, reduces forest habitat by felling large trees that contain *Melipona* nests, and at the same time removes suitable, unoccupied nesting sites. If there are no new natural colonies accessible to the beekeeper, hived colonies lost to natural causes, such as

Figure 2. The stingless bee Xunan-kab, *Melipona beecheii*, and its log hives kept by 120 Maya stingless beekeepers studied among 150 villages occurring in the Maya zone of Quintana Roo, Mexico. ??

predators or hurricanes, cannot be replaced. At the same time, many beekeepers report colonies are dying from a lack of food. They observe their colonies have less and less honey, most notably in the seasons of reduced flowering. We also observed colonies diminishing in size until no longer viable, often succumbing under attacks of ants, phorid flies, toads or *Eira Barbara* ('tayra', a Neotropical weasel); this happened mainly with colonies that were not checked regularly.

Competition between *Melipona beecheii* and Africanized honey bees

The extent to which the colonies of *Melipona beecheii* are in decline is difficult to determine. Many factors are involved, such as reduced or changing floral resources and whether they are unable to forage such resources because of competition from *Apis mellifera*, which also compete for nesting sites.[26,28]. We see the need for further investigations into these and other factors, such as effects of pesticides or changes in annual rainfall patterns,[36] and associated drought and flowering. However, there are marked influences on meliponiculture and bee foraging that coincide with the first arrival of Africanized honey bees in the late 1980s.

An understanding of competition between bees and its result cannot be resolved with short-term field studies, but, rather, requires population and community studies. The question of honey bee impact on native bees in natural habitats has thus been the subject of long-term research programmes, by DWR and collaborators, in French Guiana, Panama and in the present work.[5,31,36] In the Yucatán peninsula, there is a case to be made that domesticated *Melipona beecheii*, often kept in the highly disturbed habitats that surround Maya villages, but also surviving naturally in the relatively intact forests of Quintana Roo, has undergone a population reduction due to competition with honey bees at flowers. The degree of competition for floral resources from *Apis mellifera* (now Africanized) depends on availability of resources and general abundance of honey bees. After their arrival, 18 years ago,[40,43] Africanized honey bees appear now to saturate their habitats.[28,29,36,45]

Xunan-kab foragers most often visit the flowers of shrubs and trees,[42,44] rather than low vegetation such as herbaceous plants, while *Apis* bees visit all of the above.[40,41] At the end of the dry season there are few or no blossoming herbs.[40,41,44] Competition is then potentially more intense for the blossoms of shrubs and trees.[44] Particularly interesting are observations that *Melipona* appear to abandon resources where out-competed by other foraging bees, including exotic Africanized honey bees.[4,5,29] Meliponiculturists in Tepich, Quintana Roo, reported lower honey production by their *Melipona* bees when neighbours begin keeping *Apis mellifera*.[8] At the same time, since the arrival of Africanized honey bees, the surrounding habitat is now for the first time filled with honey bees. This is in stark contrast to the scattered apiaries where European honey bees were once kept in Yucatán and where there was no widespread, naturalized, feral population of *Apis mellifera*, typical for Africanized bees in neotropical lowlands.[32,33] Indigenous hunters of stingless bees in the Amazon basin also observed decreased honey from their bees after colonization by Africanized honey bees, but after 20 years 'production' levels normalized, presumably as population densities of Africanized honey bees decreased or the local bees adapted.[26]

Long-term decline in managed bee populations

The reasons for the rapid decline, especially colony mortality and decline, in the xunan-kab have not been examined in detail by the scientific or conservation communities, or voiced by many scientific authors or students of Maya culture and society. Economic replacement by *Apis mellifera* is not an issue that requires further discussion and is seemingly resolved.[10,20,27] Here we focus on biological and ecological factors and list the insights gleaned from several publications in the list of references cited here, in addition to recommendations that can be made as a result of our ongoing studies in Quintana Roo.

The keepers of xunan-kab report that their bees are starving. Honey production and colony size diminish until the bees can no longer defend themselves from natural enemies, or survive the normal or unusual dearth periods. The lack of food stores within the nest is often attributed to scarcity of resources due to deforestation[27] in conjunction with competition at floral resources from Africanized *Apis mellifera*.[5,8,28] However, the loss of colonies may also be attributed to the overharvesting of honey,[30] as we have observed in most of the Mayan communities where meliponiculture is practiced. Beekeepers, in order to meet commercial goals, offset the low honey stores in their hives by increased harvest intensity – clearly a counterproductive practice.

As already stated by other authors, there is little economic incentive to continue keeping xunan-kab and solve the discouraging problems it faces. Xunan-kab colonies now produce an average of two kg of honey each year,[1] compared with 20 or 30 kg produced by *Apis mellifera* colonies in the region (and averages of 130 kg by well-managed Africanized honey bee colonies in heavily forested French Guiana; B Gautier, D W Roubik, personal observation). Our collaborators in San Hermenegildo, Quintana Roo (table 1), indicated that, up until the 1980s, honey could be harvested from *Melipona beecheii* as often as five times a year. The testimony from this Mayan village is telling. In the early 1990s, three years of poor honey harvest were followed by complete harvest in 1993 of all honey stores of all colonies (30 lbs.). One new colony was brought in from the forest in 1994, and then nearly all colonies died or were sold to research groups shortly thereafter. This village had 40 colonies when we began our work, and now it has none.

Although the honey of xunan-kab has been analysed and used for medicinal purposes by

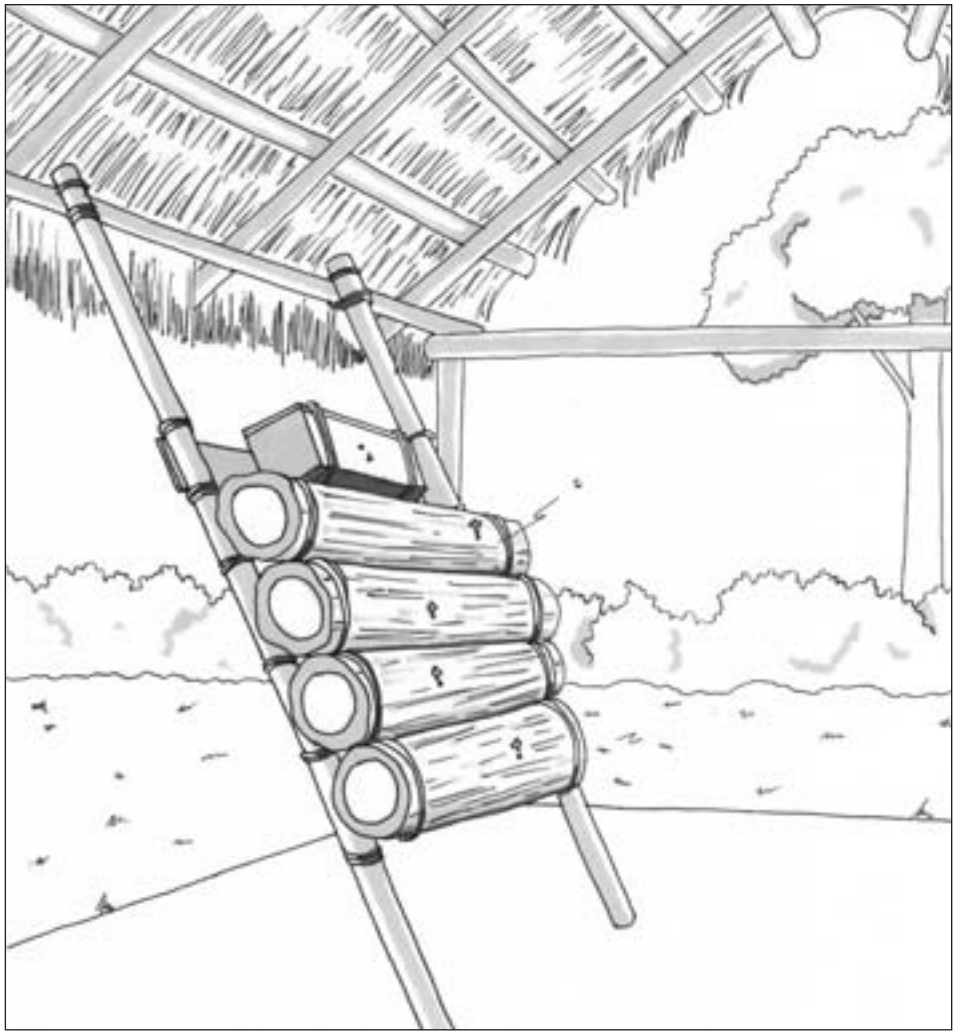

Table 1. Number of *Melipona beecheii* hives that beekeepers from the Mayan zone have kept in the last 54 years.

Name of Mayan community	Name of beekeepers or institutions	No. of hives kept between 1950 and end of 1981	No. of hives kept at end of 1990	No. of hives kept at end of 2004
Chan Santa Cruz	Delfino Naal	Unknown	8	2
Chan Santa Cruz	Nemesio Pot	Unknown	12	8
Chancá de Repente	Bernardo Peûa	42	25	8
Chancá de Repente	Anastasio Pérez	Unknown	10	0
Chancá de Repente	Eduardo Yam	Unknown	5	0
Chunyá	Patricio Canul	45	30	8
Felipe Carrillo Puerto	Inst. Nacional Indigenista	0	40	8
Miztequilla	Santiago Pat	Unknown	6	2
Miztequilla	Fernando Yam	40	19	8
Naranjal	Francisco Cimá	25	15	3
Naranjal	Juán Mena	26	12	6
Nueva Lorĺa	Celestino Camal	Unknown	7	2
Nuevo Israel	Ponciano Tun	Unknown	6	0
Palmas	Margarito Tuz	220	5	0
Presidente Juárez	Bernabé Kantún	Unknown	16	4
San Hermenegildo	Humberto Ku Cauichl	60	40	0
Santa Marĺa	Francisco HuiCab	50	37	7
Seûor	Doroteo Pech	22	18	0
Seûor	José Pott	Unknown	6	0
Tihosuco	Pedro Cahun Uh	Unknown	5	12
Tuzic	Isidro Peûa Tuz	200	40	8
X hazil	Modesto Chuc	10	7	0
X hazil	Isaĺas Cahuich	15	10	0
Yo Actún	Rancho San MartÍn	Unknown	10	4
Totals		Likely >1000	389	90

local people, this knowledge has not spread far from scientific circles and local recognition, and more research is required in this field.[22] The specific problems for securing a market for stingless bee honey are many. First, the *Codex Alimentarius* allows only honey from *Apis mellifera* to be marketed for human consumption in Europe.[7] Second, hygienic standards are not always applied to harvesting procedures for stingless bee colonies, which results in lower quality and marketability of the honey. Third, there has been little concerted strategy for the marketing of xunan-kab honey. This honey is sold in small bottles (0.5 litre) in the local markets and within the community where the meliponiculturists live, where it derives no added value. Finally, there remains the question of capacity for fulfilling a steady market demand. There are now few knowledgeable beekeepers to continue the tradition of meliponiculture or to replace the older beekeepers. The younger potential beekeepers are understandably profit-motivated. Many are familiar with management of *Apis mellifera* and no longer appreciate the cultural or ecological value of keeping 'old-fashioned' traditions alive. Mayan villages are becoming depopulated as inhabitants pursue opportunities in cities and tourism areas like Cancún and Playa del Carmen. The techniques and knowledge necessary to maintain and propagate colonies are not being passed on effectively, in either an informal or a formal process of technology transfer, despite excellent published literature on meliponiculture, including extensive illustrations, although only recently has a guide been published in the Mayan language.[6,13,17,23,24,25,38,42] According to Mayan beekeepers that we have interviewed, this break began about 50 years ago. A result is that well-intentioned yet untrained persons or organizations, many familiar with *Apis mellifera* only, obtain colonies of xunan-kab, but then lose them out of carelessness, or out of ignorance of the dangers faced by these bees.

The Yucatán peninsula sits square in the path of trade winds carrying low pressure systems. In June to November those winds may develop into hurricanes. Nearly every year some area of the peninsula suffers hurricane or tropical storm damage. A survey of

RITUAL 'U-HANLI-CAB'

This is a ceremony made by a Mayan priest called "Men" (in Mayan language) twice a year. For this ritual, an altar is prepared, in which there is an offering of drinks and meals, then the "Men" asks permission to the gods to harvest the honey. During the ceremony there are prayers in Mayan language and several musicians called "mayapax" play their instruments while the others are praying, the whole ceremony takes eight hours to do it.

Note: mayapax is a Mayan musician group that plays traditional music.

meliponiculturists in the state of Yucatán at the end of 2002 revealed an almost complete loss of meliponaries affected by floods brought by hurricane Isidore.[11,42] Colonies surviving in other areas faced floral depletion caused by hurricane winds – literally all flowers and buds were blown off of the trees. Hurricane Gilbert in 1988, Roxan and Opal in 1995, and Mitch in 1998, also severely affected both meliponiculture and apiculture of the peninsula. After a hurricane there is generally a drought that places the xunan-kab bees under food (nectar and pollen) stress, and limits their nest building activity (nests are made and modified with soft mud), and their populations decrease.

Conclusions

Studies of traditional stingless bee beekeeping in Yucatán conducted in the 1950–1970s make no mention of a decline in bee abundance or honey production,[46] but a decline was noted, without a causal analysis, at the end of the 1980s.[19] In the study presented here, approximately 20% of the stingless bee beekeepers in the zona Maya of the south-eastern Yucatán peninsula reported that over 90% of their colonies of xunan-kab had perished in the last 25 years. The losses were probably more drastic for the past half century (table 1). The numbers of natural colonies has also dwindled. We have no data to rank the relative importance of exotic honey bee competition, habitat erosion, natural enemy attack, or waning management and husbandry practices. All are implicated, however. Ironically, with the objective of developing meliponiculture and pollinator 'conservation', non-governmental and governmental organizations and institutions have purchased hives from traditional stingless bee beekeepers. These have been placed with inexperienced individuals, which we believe constitute yet another mortality factor. We therefore suggest that training and management efforts are best directed at established stingless bee beekeepers able to propagate their colonies.

There are many benefits from preserving the xunan-kab tradition. Not only will an important member of the ecological community and pollinator of diverse plant and tree species[2,27] be spared local extinction, but a public awareness of the importance of the forest and its biodiversity can be focused on a native species with a long and distinguished local history.[31] Xunan-kab are among the few native organisms that possess a widely acknowledged status as a cultural, economic, ecological and conservation icon. It is thereby, as are other well-known bees, a de facto indicator of environmental health.[18,35]

To encourage the present efforts to return to sustainable agro-forestry endeavours and cottage industries that directly benefit the villages of the zona Maya, we most emphatically recommend the following measures to forestall extinction of *Melipona* beekeeping:

- Instructing beekeepers in the construction and use of hives as well as techniques such as feeding that will ensure the survival of existing colonies.
- Hive designs permitting easy opening for inspection and to facilitate artificial feeding.
- Conservative rather than aggressive honey harvest from hives.
- Adopting regulations concerning limits on honey bee (*Apis mellifera*) colony establishment, with the aim of reducing honey bee concentrations in areas of meliponiculture activity.
- Legislation to protect forested areas from complete destruction, especially near villages and cultivated areas.
- Encouraging use of existing protected areas and reserves as sites for development of meliponiculture and for re-introduction of colonies to suitable habitats.
- Creation of projects at local level focusing on both reforestation (or forest preservation) and meliponiculture.
- Researching product diversity and potentials, specifically in the areas of medicines and cosmetics derived from stingless bees.
- Researching marketing possibilities, especially in the tourism sector.
- Establishing standards for *Melipona beecheii* honey, conditions for hygiene, and hive types.
- Introduction of high school, vocational school and university courses concerning management of *Melipona beecheii* and other stingless bees.
- Informing beekeepers about precautions to be taken in the event of a hurricane.
- Creation of an institutionally funded central bank of colonies and expertise, where new meliponiculturists will be trained, given colonies, and expected to propagate those colonies so that they can return to the bank the colonies that they have borrowed.
- Communication with loggers requesting that trees containing nests of *Melipona beecheii* be spared or that nests discovered be given to appropriate organizations.

At this juncture, it would not be out of place to incite the Maya ritual of 'u-hanli-cab', for protecting wild bees and the families that have them.[19]

Acknowledgments

We thank El Colegio de la Frontera Sur (College of the Southern Frontier) and the Smithsonian Institution (Scholarly Studies grants to DWR) for financial and logistical support. We thank Dr Francisco Güemez-Ricalde and especially Scott Forsythe for advice and valuable additions to the manuscript, an anonymous reviewer, and Margarito Tuz Novelo and Guillermina Herrera for their help.

References

1. AGUILAR Y CORONADO, A (2001) Mi experiencia en meliponicultura moderna con colmenas racionales: una alternativa para su rescate y aprovechamiento. *Proceedings of the II Mexican Seminar on stingless bees*; UADY, Mérida, Yucatán, Mexico; pp. 44–49.
2. AGUILAR-MONGE, I (1999) *El potencial de las abejas nativas sin aguijón (Apidae: Meliponinae) en los sistemas agroforestales.* http//www.cipav.org.co/redagrofor/memorias99/AguilarI.htm l
3. AYALA, R (1999) Revisión de las abejas sin aguijón de Mexico (Hymenoptera: Apidae: Meliponini). *Folia Entomol. Mex.* 106:1–123.
4. BIESMEIJER, J C (1997) *The organization of foraging in stingless bees of the genus* Melipona*: an individual-oriented approach.* PhD thesis; Department of Comparative Phisiology, Utrecht University, the Netherlands.
5. CAIRNS, C; VILLANUEVA-G, R; KOPTUR, S; BRAY, D B (in press) Bee populations, forest disturbance and Africanization in Mexico. *Biotropica.*
6. CARVALHO, G A; L DE, DE OLIVEIRA ALVES, R M; B DE ALMEIDA SOUZA, B (2003) *Criação de abelhas sem ferrão: aspectos práticos.* Cruz de Almas; Federal University of Bahia, Bahia, Brazil.
7. CODEX ALIMENTARIUS COMMISSION (1969) *Recommended European regional standard for honey*. FAO and WHO.
8. DE JONG, H (1999) *The land of corn and honey: the keeping of stingless bees (meliponiculture) in the ethno-ecological environment of Yucatán, Mexico and El Salvador*. PhD thesis; University of Utrecht, the Netherlands; 423 pp.

9. DE JONG, H (2001) La meliponicultura en la cosmovisión Maya. *Proceedings of the II Mexican Seminar on stingless bees*. Universidad Autónoma de Yucatán; Mérida, Yucatán, Mexico; pp. 10–18.
10. ECHAZARRETA-GONZÁLEZ, C M; QUEZADA-EUAN, J J G; MEDINA, M L; PASTEUR, K L (1997) Beekeeping in the Yucatán peninsula: development and current status. *Bee World* 78: 115–127.
11. ECHAZARRETA-GONZÁLEZ, C; VILLANUEVA-G, R; MARTÍNEZ, L R; GÜEMES-RICALDE, F R (2004) *Impacto del huracán Isidoro en la apicultura yucateca.* SISIERRA-CONACYT; Mérida, Yucatán; 48 pp.
12. GÓMEZ-PAMPA, A; KAUS, A (1992) Taming the wilderness myth. *BioScience* 42:271–279.
13. GUZMÁN-DÍAZ, M A; RINCÓN-RABANALES, M; VANDAME, R (2004) *Manejo y conservación de abejas nativas sin aguijón (Apidae: Meliponini)*. ECOSUR; 40 pp.
14. HUBBELL, S P; JOHNSON, L K (1977) Competition and nest spacing in a tropical stingless bee community. *Ecology* 58: 949–963.
15. INEGI (2000) *Cuaderno EstadÍstico Municipal, Felipe Carrillo Puerto, state of Quintana Roo.* INEGI, Gobierno del estado de Quintana Roo and Ayuntamiento Constitucional de Felipe Carrillo Puerto; Quintana Roo, Mexico.
16. KAJOBE, R; ROUBIK, D W (in press) Honey-making bee colony abundance and predation by apes and humans in a Uganda forest reserve. *Biotropica*
17. KERR, W E; CARVALHO, G A; NASCIMENTO, V A (1996) *Abelha Uruçu: biologia, manejo e conservação.* Fundação Acangaú; Belo Horizonte, Minas Gerais, Brazil; 144 pp.
18. KEVAN, P G (1999) Pollinators as bio-indicators of the state of the environment: species, activity and diversity. *Agriculture, Ecosystems and Environment* 74: 373–393.
19. KINTZ, E R (1990). *Life under the tropical canopy. Tradition and change among the Yucatec Maya*. Holt, Reinhart & Winston; Fort Worth, FL, USA; 170 pp.
20. MEDELLIN, S; CAMPOS-LÓPEZ, E; GONZÁLEZ-ACERETO, J; CÁMARA-GONZÁLEZ, V (1991) *Meliponicultura Maya: perspectivas para su sostenibilidad.* Reporte de sostenibilidad Maya no. 2; 67 pp.
21. MICHENER, C D (2000) *Bees of the world.* Johns Hopkins University Press; Baltimore, MD, USA; 913 pp.
22. MOLAN, P (2001) Why honey is effective as a medicine. 2. The scientific explanation of its effects. *Bee World* 82: 22–40.
23. NATES PARRA, G (2001) *Guia para la crÍa y manejo de la abeja Angelita o Virginita* Tetragonisca angustula *Illiger.* Convenio Andres Bello; Bogota, Columbia.
24. NOGUEIRA-NETO, P (1997) *Vida e criação de abelhas indÍgenas sem ferrão.* Editora Nogueirapis; São Paulo, Brazil; 446 pp.
25. NOGUEIRA-NETO, P (2002) Inbreeding and building up small populations of stingless bees (Hymenoptera, Apidae). *Revista Brasileira de Zoologia* 19: 1881–1214.
26. POSEY, D A; CAMARGO, J M F (1985) Additional notes on the classification and knowledge of stingless bees by the Kayapó indians of Gorotire, Pará, Brazil. *Annals of the Carnegie Museum* 54: 247–274.
27. QUEZADA-EUAN, J J; MAY-ITZÁ, W; GONZÁLES-ACERETO, J A (2001) Stingless beekeeping in Mexico: problems and perspectives for development. *Bee World* 82: 160–167.
28. ROUBIK, D W (1988) An overview of Africanized honey bee populations: reproduction, diet and competition. *Proceedings of the International Conference on Africanized honey bees and bee mites.* E Horwood Ltd.; Chichester, UK; pp. 45–54.
29. ROUBIK, D W (1989) *Ecology and natural history of tropical bees.* Cambridge University Press; New York, USA; 514 pp.
30. ROUBIK, D W (1991) Repercusiones de la Africanización en poblaciones de Xunan-kab de la zona maya. *Yik 'El Kab A C* 4: 12.
31. ROUBIK, D W (1996) Measuring the meaning of honey bees. *In* Matheson, A; Buchmann, S L; O'Toole, C; Westrich, P; Williams, I H (eds.) *The conservation of bees*. Academic Press; London, UK; pp. 163–172.
32. ROUBIK, D W (2002) The value of bees to the coffee harvest. *Nature* 417: 708.
33. ROUBIK, D W (2002) Feral African honey bees augment Neotropical coffee yield. *In* Kevan, P G; Imperatriz-Fonseca, V L (eds.) *Pollinating bees: the conservation link between agriculture and environment.* Ministry of Environment; Brasilia, Brazil; pp. 255–264.
34. ROUBIK, D W (2003) Honey biodiversity. *Proceedings of the II Seminario Mesoamericano sobre abejas sin aguijón.* ECOSUR; Tapachula, Chiapas, Mexico; pp. 45–47.
35. ROUBIK, D W; HANSON, P E (2004) *Orchid bees of tropical America. Biology and Field Guide..* Editorial INBIO; Heredia, Costa Rica; 370 pp. (Spanish/English edition).
36. ROUBIK, D W; WOLDA, H (2001) Do competing honey bees matter? Dynamics and abundance of native bees before and after honey bee invasion. *Population Ecology* 43: 53–62.
37. ROUBIK, D W; VILLANUEVA-G, R; CABRERA CANO, E; COLLI-UCÁN, W (1990) Abejas nativas de la reserva de la Biosfera de Sian Ka'An, Quintana Roo, Mexico. *In* Navarro, D; Robinson, J G (eds) *Diversidad biologica en la reserva de la biosfera de Sian Ka'an, Quintana Roo, Mexico.* Centro de Investigaciones de Quintana Roo and Program of Studies of Tropical Conservation, University of Florida, USA; pp. 317–320.
38. STIERLIN, E; SZABO, H (2004) *Manual de manejo de abejas nativas: Suro y ObobosÍ* Scaptotrigona *spp.* Aguaragie; Santa Cruz de la Sierra, Bolivia; 146 pp
39. TEC-POOT, J; BOCARA, M (1980) Abejas y hombres de la tierra Maya. *Boletín ECUADY* 7: 1–24.
40. VILLANUEVA-G, R (1994) Nectar sources of European and Africanized honey bees (*Apis mellifera*) in the Yucatan peninsula, Mexico. *Journal of Apicultural Research* 33: 44–58.
41. VILLANUEVA-G, R (2002) Polleniferous plants and foraging strategies of *Apis mellifera* (Hymenoptera: Apidae) in the Yucatán peninsula, Mexico. *Revista de Biología Tropical* 50: 1035–1044.
42. VILLANUEVA-G, R; BUCHMANN, S; DONOVAN, A J; ROUBIK, D W (2005) *Crianza y manejo de la abeja Xunan cab en la Península de Yucatán.* ECOSUR-University of Arizona, USA; 35 pp.
43. VILLANUEVA-G, R; COLLI-UCÁN, W (1994) Apicultura en la zona fronteriza México-Belice. *In* Suárez-Morales, E (ed.) *Estudio integrado de la frontera México-Belice (Recursos Naturales).* Centro de Investigaciones de Quintana Roo; Chetumal, Quintana Roo, Mexico; pp 93–105.
44. VILLANUEVA-G, R; COLLI-UCÁN, W (2003) Estudio melisopalinológco de mieles de *Melipona beecheii* en el JardÍn Botánico de Puerto Morelos, Quintana Roo. *Proceedings of the XVII American Seminar in Apiculture.* SAGARPA and UNA; Aguascalientes, Mexico; pp. 144–146.
45. VILLANUEVA-G, R; ROUBIK, D W (2004) Why are African honey bees and not European bees invasive? Pollen diet diversity in community experiments. *Apidologie* 35: 481–491.
46. WEAVER, N; WEAVER, E C (1981) Beekeeping with the stingless bee *Melipona beecheii* by the Yucatecan Maya. *Bee World* 62: 7–19.

ROGEL VILLANUEVA-G,[1], DAVID W. ROUBIK[2] AND WILBERTO COLLI-UCÁN[1]

[1]El Colegio de la Frontera Sur, Av. Centenario km 5.5, Apdo. Postal 424, Chetumal, Quintana Roo, C P 77900, Mexico

e.mail: rogel@ecosur-qroo.mx

[2]Smithsonian Tropical Research Institute, Unit 0948, APO AA 34002-0948, USA

e.mail: roubikd@tivoli.si.edu