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The Origins of Maya Stingless Beekeeping

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Abstract. Beekeeping among the modern Maya of Yucatan, Mexico, reflects an intricate network of symbiotic relationships between bees, flowering plants, humans, and the managed landscape, which includes both settlements (*kaaj, [kah]*) and the cultivated and fallow farmlands surrounding them (*k'ax*). Native stingless bees are valued today both for the honey and wax they produce and the crops they pollinate. This study utilizes the ethnobiology of modern Maya stingless beekeeping to interpret the material correlates of ancient Maya beekeeping through archaeological exploration at Late Formative (200 BC–AD 200) Cerro Maya, Belize. Our contemporary data focus on the species of bees kept, the characteristics of wood species preferred for hive structures (*hobon[ob]*), the functional parameters of limestone disk *hobon* covers (*mak tuun[ob]*), and the plant species identified in symbiotic cultivation with them. The ecological and cultural factors that mediate stingless beekeeping in the present day provide important insights for the interpretation of ancient beekeeping practices at Cerro Maya, evidenced in the worked limestone disks hypothesized to be ancient *mak tuunob*. Beyond Cerro Maya, the documentation of beekeeping activity throughout ancient urban centers has important implications for the interpretation of urban green spaces in early Maya cities. Together with information on the ritual use of hive furniture and effigies, these data suggest ancient elites recognized the importance of pollinator species, and that deliberate management of stingless bees was standard practice during the period of agricultural intensification known as the Late Formative.

Keywords: Maya, beekeeping, archaeology, urbanism, landscape

Introduction

Beekeeping is an ancient form of animal husbandry practiced throughout the world, both for the honey and wax produced, and for the essential role pollinator species play in agricultural production. Today, bee health is national news, and problems, such as colony collapse, can negatively impact the production of food crops at a global scale. The symbiotic relationship between bees and agriculture is as ancient as intentional food production itself. V. Gordon Childe (1950) coined the term "Neolithic revolution" for the population increase and resultant urbanism associated with agricultural intensification. Although Childe focused primarily on the "Old World" experience, that is, the switch to food production in Europe, Asia, and Africa, the domestication of plants and animals in the "New World" followed a significantly different trajectory (cf. Graham 1999:187), yet also supported a variety of early cities.

As recently as the 1980s, some researchers argued that Maya sites, such as Copan, could not be classified as "urban" because their settlement patterns did not fit the pattern Childe utilized to study Old World examples (Fox 1977), and that only large Central Mexican cities with orthogonal layouts, such as Teotihuacan and Tenochtitlan, exemplified New World urbanism (Sanders and Webster 1988). The

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response was swift (cf. Chase et al. 1990), sparking a revolution in theory and method, and redefining Maya urbanism in terms of a "garden city" approach (Dunning et al. 1998; Fedick 1996). Tenets of this model include the integration of food production systems within the urban landscape, such as gardens, orchards, and infields (Isendahl and Smith 2013; McAnany 1995:102), and land modification and management at a massive scale, as recent lidar mapping techniques have confirmed beyond doubt (Brewer et al. 2017; Chase et al. 2014).

Ethnohistoric sources suggest that, by European contact, stingless beekeeping was integrated into the organization of Yucatec Maya garden cities and land-use strategies. As summarized by Patricia McAnany (1995), land tenure was based on a "principle of first occupancy," in which land was passed down through lineages to future generations and ancestral lineage heads were revered in perpetuity. Contact-period records indicate that each Maya settlement (*kaaj, [kah]*) was surrounded by tracts of forest (*k'ax[ob]*) that were controlled through inheritance, with established boundaries that were reaffirmed every 20 years through the calendrical *k'atun* cycle (Hanson 2008:444–445, 557–558). However, McAnany (1995:67) argued that while non-Maya scholars (e.g., Roys 1943) conceptualized the *k'ax* as old-growth, "wild" forest, it also referred to areas with a combination of economic and mature fallow species, which served as a source of medicinal plants, herbs, wild game, and materials for crafting and construction. She also noted (McAnany 1995:67) that fallow fields within communal landholdings (*ejidos*) were used for stingless beekeeping and were described as *u k'axil kab*, which translates into Spanish as *asiento de colmenas, sitio de colmenas* (seat of hives, location of hives) in the Cordomex dictionary (Barrera Vásquez 1980:387) and *monte para colmenas, bueno para colmenas* (woods for bees, good for bees) in the Motul dictionary (Martínez Hernández 1929:241). Thus, employing stingless bees to regenerate fallow fields was an essential component of Maya land-use strategies at Spanish Contact (ca. AD 1557; McAnany 1995:87).

Modern Yucatecan villagers maintain the practices of stingless bee husbandry (meliponiculture) using log hives to produce honey and wax. Although beekeeping is a documented part of the ancient Maya economy, relatively few archaeological studies of pre-Hispanic beekeeping have been done. Increasingly, archaeologists—informed by Maya-identifying community members—are recognizing this ancient tradition in the material record at sites in northern Yucatan and Belize. Though most beekeeping components were made of perishable materials, limestone disks used to plug the ends of log beehives can be used to document the distribution of ancient Maya hives. Today, Maya-identifying community members recognize these ancient artifacts as *hobon* covers, called *mak tuun*(*ob*) (Batun Alpuche 2019).

Here, we use ethnoarchaeological data drawn from modern stingless beekeeping to interpret possible beekeeping furniture from the Late Formative (200 BC–AD 200) period site of Cerro Maya, Belize. We then ask the following questions about these ancient analogues: which bee species were curated; what were the dimensions of beekeeping furniture; what wood species were preferred; and which cultivars were symbiotically intertwined with beekeeping practice? We then discuss insights drawn from the data to describe ancient beekeeping practices in context.

Our study also considers broader cultural implications of the development of stingless beekeeping. Deliberate management of pollinator species is a logical corollary to the significant agricultural intensification documented across the Maya lowlands during the Late Formative period. We consider evidence from Cerro Maya that stingless beekeeping furniture was incorporated into ritual practice at the site (termination and dedication events), highlighting its importance. Comparative evidence suggests that other Late Formative Maya cities also incorporated beekeeping furniture into religious offerings.

The Late Formative Period and the First Maya Cities

An increasing number of studies acknowledge the significant time depth of Maya cities and the sophisticated land management and intensification strategies that supported them (e.g., Freidel et al. 2002; McAnany 1995; Turner and Harrison 1983). Early cities were places of monumental-scale religious and public architecture and the emergence of dynastic kingship (Freidel et al. 2002; Rosenswig and Kennett 2008; Walker, forthcoming). Rapidly expanding and nucleating populations were supported by a range of resource intensification processes within and beyond settlement boundaries, including wet-field agriculture, terracing, intercropping (*milpa* agriculture), and houselot gardening (Batun Alpuche 2009). The scale of beekeeping and its spatial and social distribution in early cities is less well understood. For instance, it is not known how many hives were typically kept by producers; whether beekeeping was common in households; or whether a small number of specialists, possibly elites, practiced at a larger scale.

The Late Formative period saw an increase in ritual practices, documented in the frequency and elaborateness of dedicatory caches and termination events. Caches served first to ensoul and spiritually charge a building or space, while termination rites served to neutralize or "terminate" an ensouled object (often ritual paraphernalia) or building (often a temple) at the end of its use-life through prescribed forms of destruction (Pagliaro et al. 2003). Object termination involved breaking, burning, and scattering fragments to particular locations, while building termination involved the defacement of stucco facades or architectural veneers, toppling columns, removing lintels, dismantling vaults, and blocking doorways. The inclusion of beekeeping furniture in caches and termination deposits has been documented for Postclassic period deposits at Mayapán (Paris et al. 2018), and the present study also documents this practice at Late Formative Cerro Maya.

Previous Research on Ancient Maya Stingless Beekeeping

By the time of Spanish contact, stingless beekeeping was one of the main productive activities in the northern Yucatan peninsula (Roys 1943). Jars of honey and disks of wax were frequently sold in Yucatecan marketplaces and by traveling merchants (Piña Chan 1978:38) and were used to pay taxes to the Spanish government by 95% of Yucatecan villages and towns in AD 1549 (Roys 1943). The products had a number of important uses; honey was an important sweetener and was used to make the ritual beverage *balché* and medicinal honeys (Chuchiak 2003; Ocampo Rosales 2013). Archaeological evidence indicates that wax was used in lost-wax metalworking (Paris et al. 2018) and as sealant for ceramic jar lids (Blom 1954), while analogies with twentieth century traditional crafting suggests its use in adhesives for weaponry (Nations and Clark 1983) and in artistic media, such as featherwork and mosaics (Berdan et al. 2009).

Archaeological evidence for beekeeping is available for 14 sites in northern Yucatan and Belize (Table 1; recently summarized in Paris et al. 2018). Stingless beekeeping is primarily identified in archaeological contexts through the presence of the limestone disks (*mak tuunob*) used to seal the ends of the *hobones*. However, some early studies classified limestone disks as pot lids (Proskouriakoff 1962:345), pot rests (Garber 1989:32), armatures for modeled stucco (Garber 1989), ballcourt markers (large-diameter specimens), or digging stick weights (perforated disks; Walker, forthcoming), and the exact range of sizes and characteristics that distinguish *mak tuunob* from other discoidal stone objects remains a concern for archaeologists. Below, we use data from modern Maya beekeeping practice to interpret limestone disks and other beekeeping furniture in the archaeological record and apply it to the site of Cerro Maya.

Methods

To better allow us to identify and interpret early instances of beekeeping in the archaeological record, we reviewed extensive contemporary documentation of stingless beekeeping in the region. Our review of the ethnographic and biological literature aimed to identify important material correlates of ancient beekeeping practice at archaeological sites. The main areas of focus for our ethnoarchaeological review included the husbandry of different bee species, the functional parameters of beekeeping furniture, aspects of symbiotic cultivation with specific plant species, and spatial dimensions of beekeeping. Examples of functional parameters included hive dimensions, number of hives kept, disk materials, tree species used in *hobon* construction, and the use of *colmenares*.

Table 1. Metric data for limestone disk sizes, reported for selected archaeological sites. Measurements are in cm.

# Limestone disks	Site	Range diameter	Range thickness	Mean dia.	Mean th.	Time period	Source
109	Cerro Maya	4.8–20.2	1.5–7.8	10.6	4.0	Late Formative	Debra Walker, this study; Garber 1989
12	Cuello	9.5–19.5	4.0–5.0	13.3	4.5	Late Formative	McSwain et al. 1991:190, Fig 8.50
3	Nixtun-Ch'ich'	12.4–11.6	5.9–6.05	12.0	6.0	Late Formative	Timothy Pugh, pers. comm., 2018
13	Chan Chen	~8–10	~3–4	NA	NA	Late Formative	Crane 1992:Fig 6
3	Rio Bec	NA	NA	13.8	6.0	Late Formative, 3 Terminal Classic	Rovner and Lewenstein 1997
2	Becan	NA	NA	NA	NA	Late Formative/ Early Classic	Rovner and Lewenstein 1997
1	Lubaantun	NA	NA	7.0	1.0	Late Classic	Hammond 1975:359
38	Mayapán disks[a]	6.7–16.3	0.86–5.0	11.29	2.83	Late Postclassic	Paris et al. 2018
15	Mayapán thick disks[a]	5.6–13.6	1.3–6.8	9.18	4.25	Late Postclassic	Paris et al. 2018
255	Cozumel	NA	2.0–3.0	12.0	NA	Late Postclassic	Batun Alpuche 2009
8	Santa Rita Corozal	9.2–13.6	2.5–4.3	11.5	3.8	Late Postclassic	D. Chase 1982:518, 613
10	Caye Coco	NA	3.0–4.0	7.0	NA	Late Postclassic	Aguilera 1999:12
8	Tayasal/Cenote	5.6–14.0	2.0–6.0	9.9	3.4	Mixed (Late Formative, Classic, Postclassic)	A. Chase 1983:1318

[a] From Salvamento *Mérida-Chetumal* 2015-2016 only

To investigate ancient Maya beekeeping practice, we analyzed a collection of limestone disks from the site of Cerro Maya (Cerros), located on Corozal Bay in northern Belize (Figure 1), documented by David Freidel and colleagues (Cerros Project 1974–1981; Garber 1981, 1983, 1989), and Debra Walker (Cerros Cooperative Archaeological Development Project [CCADP] 1993–1995; Reese-Taylor 2016; Robertson and Walker 2015; Walker 2016, forthcoming). The site core consists of four temple pyramids and associated plazas covering an area of 5.5 ha, surrounded by a dispersed settlement zone (Garber 1983). Drained fields and irrigation features in the site periphery suggest intensified agriculture (Figure 1). New AMS dates (Vadala 2016; Vadala and Walker 2020) link most monumental construction to the Terminal Formative period (50 BC to AD 200). Cathy Crane's (1986, 1996) paleobotanical studies of Cerro Maya's pollen and macrobotanical plant remains documented a variety of fruit trees and flowering plants. Her samples were taken from deep trenches into temple-lined plazas, Plaza 2A (the site's Main Plaza, to the east of structure 4) and Plaza 5A (in front of Structure 5C), revealing early midden deposits beneath them. Other trenches into *aguadas*, drained fields, and canals (47A and 127A) added to the botanical picture of Late Formative Cerro Maya; 47A was excavated inside a canal within the drained field system in the southwestern corner of the site, while 127A was a trench excavation into various cuts of the main canal.

Cerro Maya collections housed at the Florida Museum of Natural History, Gainesville, include the largest collection of Late Formative limestone disks excavated to

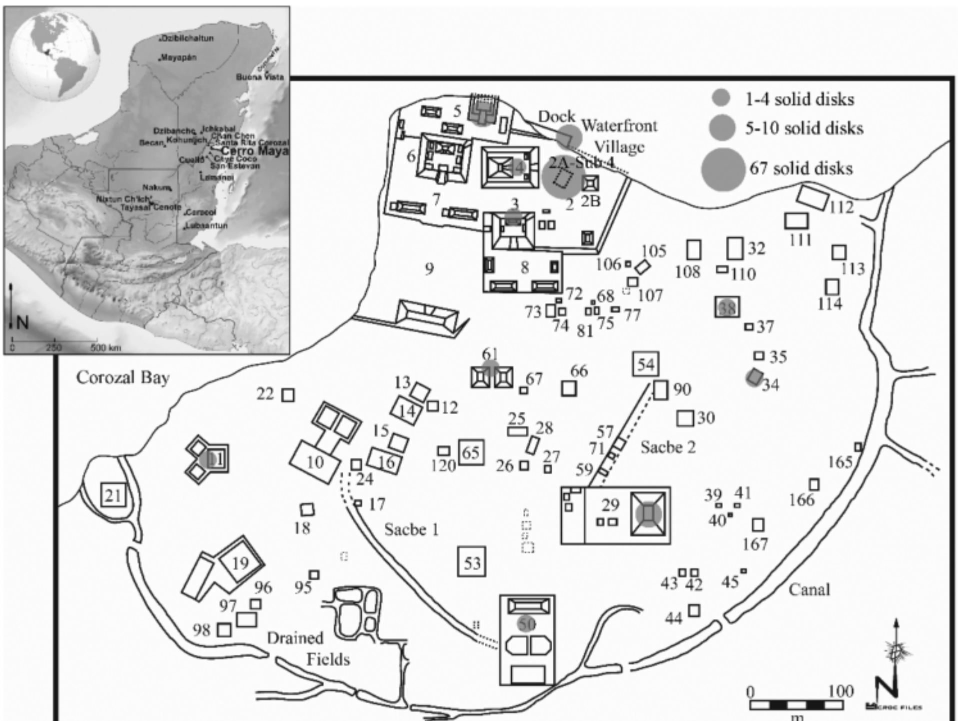

Figure 1. Site map of Cerro Maya, with concentrations of solid limestone disks. Cerro Maya site map by Debra Walker, after Scarborough (1991:8: Fig. 2.1) and Reese (1996:208 Fig. 1.4), with modifications by Elizabeth Paris. Inset map of the Yucatan Peninsula with archaeological sites mentioned in the text, drafted by Elizabeth Paris (base map adapted from Sémhur_Wikimedia Commons, CC-BY-4.0).

date, a uniquely important resource for understanding early stingless beekeeping practices. First analyzed by James Garber (1989), disk attributes include diameter and thickness; the presence of incisions, burning, or perforations; and excavated context. As beeswax rarely preserves archaeologically, and no analytical technique for retrieving honey residue exists, analysis of beekeeping furniture is particularly important in interpreting ancient practices. We excluded 28 perforated limestone disks from the analysis and, following Walker (forthcoming), interpret them as architectural tools, such as plumbobs or digging stick weights. Our Cerro Maya results were compared with those from Mayapán, compiled by Paris and Peraza Lope, and with those published from other Maya sites (Table 1).

We define the archaeological correlates of beekeeping practice based on published studies of modern and historical Maya beekeeping, including the dimensions and attributes of modern *hobones*, utilized tree species, and other materials, and the flowering plants and crops that support different bee species (Supplemental Tables 1–3). Supplemental Table 1 summarizes 47 previous studies of *hobon* architecture, including hive dimensions and tree species preferred by specific stingless bee species. Supplemental Table 2 summarizes plant species preferred by specific stingless bee species for pollen, nectar, and nesting, and compares these results with plant species reported from Late Formative Cerro Maya (Crane 1986, 1996). Supplemental Table 3 includes bibliographic sources cited in the supplementary tables.

Results

Material Correlates for Maya Stingless Beekeeping: A Review of Ethnographic Evidence

Husbandry of Different Bee Species

There are 46 known stingless bee species in Mexico, 17 of which are endemic to northern Yucatan (Ayala et al. 2013:146; González Acereto 2012:34), but not all species are equally suitable for meliponiculture. The ancient Maya could have cultivated meliponas, trigonas, or both. Some species of bees, however, are not suitable for domestication or wild harvesting due to various biological characteristics (Table 2). *Melipona beecheii* (*xunaan kab*) is the preferred species for domestic cultivation in northern Yucatan because it has the highest volume of honey production (1 to 2 L/yr; Roubik 1989). However, although they produce less honey than meliponas, wild colonies of trigonas are occasionally harvested from forested areas and brought back to the houselot; species include *Scaptotrigona pectoralis, Frieseomelitta nigra,* and *Trigona fulviventris* (Redfield and Villa Rojas 1934). Species kept in other areas of Mexico and Central America include *Melipona fasciata* and *Cephalotrigrona capitata* (Crane 1998:Table 1). Reasons for keeping other species vary, but among the Mopan Maya in southern Belize, *Tetragonisca angustula* is considered to produce the sweetest and richest honey (Steinberg 2002), and the honeys of *Melipona yucatanica* and *F. nigra* are considered to have curative properties in traditional Maya medicine (Ocampo Rosales 2013).

Honey volumes of non-melipona species are highly variable, and while average production is below that of *M. beecheii*, Redfield and Villa Rojas (1934) report five species for which "wild hives" were regularly harvested: *kantzak* (*S. pectoralis*), *xic* (*F. nigra*), *ejool* (*Cephalotrigona zexmeniae*), *yaaxich* (*Plebeia frontalis*), and *niitcab* (*Lestrimelitta niitkib*). The first four species were brought back to the house and placed in a *hobon*; however, the "wild hives" were always kept separate from the *M. beecheii* domestic *hobones*. The fifth species, *niitcab*, known as "robber bees," which will attack other hives, are harvested only in the wild. Redfield and Villa Rojas (1934:50) mention that *xic* is a large honey producer,

Table 2. Selected species of stingless bees in the Yucatan Peninsula, including the common name in Yucatec Maya, their length in mm, and hive characteristics (Ayala 1999; Ayala et al. 2013:143; Cauich Muñoz 2018).

Latin taxa	Maya name	Length (mm)	Hive architecture
Melipona beecheii	*Xunan kab*	9.7–10.7	Hollow tree trunks, made of large honeypots.
Melipona yucatanica	*Ts'ets*	8.2–8.5	Hollow tree trunks, made of large honeypots.
Trigona fulviventris	*Muul kab*	~7	Subterranean hives at the base of tree trunks, between tree roots.
Frieseomelitta nigra syn. Trigona nigra nigra	*Sak xik*	~5.7	House walls and roofs, hollow tree trunks and diverse other spaces, made of cerumen in grape-like clusters.
Scaptotrigona pectoralis	*Kantsak*	~5.4	Hollow trunks of live trees and house walls; large, trumpet-shaped entrance. Honeypots grouped in circular formations, with discoidal formations on top.
Nannotrigona perilampoides	*Ya'ax ich; Bool*	~4.2	Cavities of trees or rocks; long, tube-like entrances, usually sealed each night.
Partamona bilineata	*Xnuk*	~5.6	Subterranean hives from clay and mud mixed with cerumen, also takes over other insect nests, or lives in hollows in trees or rocks. Semi-exposed hives; long, tunnel-like entrance.
Plebeia spp.	*Us kaab*	3.5	Hollows in trees; small clusters of circular honeypots.
Lestrimelitta niitkib	*Limon kaab*	5.5	Hollows in trees; entrances have characteristic cerumen protuberances with fairly wide openings; robs and assassinates other bees.
Euglossa spp.	*Euglossa*	8–14	Any type of cavity; small hives with few cells and honeypots.

making up to 3 meters of honey within the hollow trunk; the others are all low-volume producers, with *kantzak* making up to five bottles, *yaaxich* giving one bottle, and *ejool* up to two bottles. Although the bottle volume is not specified, Villanueva Gutiérrez et al. (2005:39) observe that melipona honey is sold in 0.5 L bottles. In sum, *M. beecheii* is preferred for large-volume honey production by modern beekeepers, and this was likely also true in antiquity.

Functional Parameters of Beekeeping Furniture

In northern Yucatan, *M. beecheii* is most frequently kept in a "domestic *hobon*" (Figure 2A), a carved wooden log capped on each end by wooden disks sealed with wax and red clay (Bianco 2014), although in the past, limestone disks were used (Batun Alpuche 2009). Wild colonies of *M. beecheii* and other species may also be kept by harvesting a "natural *hobon*" from a forest tree trunk containing the hive (Figure 2B–E).

In other areas of Mexico, smaller species, such as *Scaptotrigona mexicana* and *Plebeia fulvopilosa*, are kept in clay vessel containers. Vessels may be horizontal cylinders in Nayarit, two lip-to-lip clay jars (*mancuernas*) in Cuetzalan, Puebla, and the Mixteca Alta, or simple clay jars with a wood plank lid (Albores 2015; Arnold and Aldasoro Maya 2018). While *mancuernas* are not commonly used in the Yucatan, we discuss below a vessel from Caracol, Belize, that may represent the first archaeologically documented example.

M. beecheii is physically larger than other stingless bee species and needs

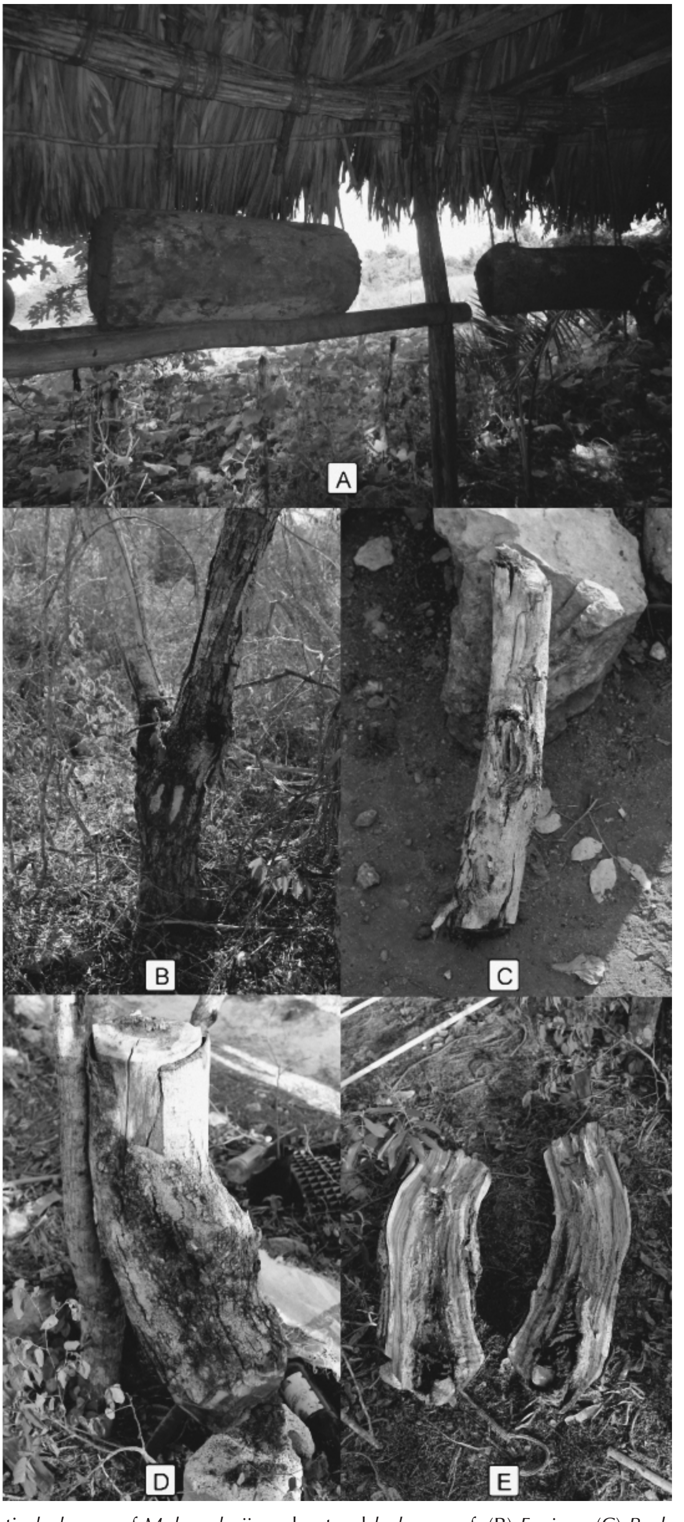

Figure 2. (A) Domestic *hobones* of *M. beecheii,* and natural *hobones* of: (B) *F. nigra*, (C) *P. pleybeya*, and (D–E) *L. niitkib* (exterior and sections). Photographs by Pedro Delgado Kú (A) and Elizabeth Paris (B-E).

larger hives to sustain successful colonies; trigonas are small and tend to prefer smaller hives (Table 2; Supplemental Table 1). Published studies, most notably Van Veen and Arce (1999), suggest that *M. beecheii* generally requires hives with a minimum interior diameter of 8 cm, more commonly between 12 and 15 cm, with a wall thickness of at least 2.5 cm to protect against extreme temperature variation. Smaller species (formerly included within the genus *Trigona* spp.) have hives with an interior diameter of 10 cm or smaller, but natural *hobones* can be up to 15 cm in diameter due to variation in individual tree trunks and limbs (Supplemental Table 1). *Scaptotrigona pectoralis* is a flexible species, well-adapted to urban living and may thrive in *hobones* of most sizes (Roubik 1989). Large-scale melipona husbandry often utilizes hand-carved *hobones*, while small-scale honey producers often harvest wild colonies and bring back the natural *hobones* to their homes. As a result, large-scale melipona husbandry often utilizes a few specific tree species and log sizes, while small-scale harvesting of wild colonies results in a diversity of tree species and log sizes, including asymmetrical logs that require disks of different diameters (Van Veen and Arce 1999).

The diameter of a limestone disk is proportional to the internal diameter of its original *hobon,* because disks need to fit *hobones* snuggly to prevent the invasion of ants and phorid flies (Roubik 1989; Van Veen and Arce 1999). Therefore, in archaeological contexts, where limestone disks have a well-documented history as *hobon* covers, the size of bees kept may have a loose positive correlation with diameters of limestone disks recovered archaeologically (meliponas vs. trigonas). The presence of both large and small disks may indicate the husbandry of multiple species, while a majority of large disks over 8 cm may indicate an emphasis on meliponas.

Most modern beekeepers use wood disks (e.g., Bianco 2014), a practice also noted in the 1930s by Redfield and Villa Rojas (1934) and Wauchope (1938); however, some modern beekeepers continue to use shaped stone disks (Crane 1992:35) or limestone cobbles (Luxton 1981:136–139). The switch from limestone to wood may be related to the decline of flintknapping skills and the proliferation of metal cutting tools. Supporting this hypothesis, modern stingless beekeepers in Nicoya use other expedient materials to plug their hobones, including carved pieces of *jícaro* gourd, tin cans, crude wooden plugs, or pieces of lumber (Kent 1984:21).

Because Yucatecan bees are stingless, *hobones* do not need to be kept away from residences, as is necessary for European honeybees (*Apis mellifera*). Instead, bees can be kept in a variety of locations, as long as sufficient sources of water, pollen, and nectar are located within their flight radius, provided by the beekeeper if necessary (Batun Alpuche 2009). Meliponas have a flight radius of 800 m, but most foraging takes place within a 500 m radius (Araújo et al. 2004). Hives also need shade; homeowners who harvest a wild colony often suspend it from the overhanging eaves of their traditional thatched roof houses, while larger volumes of hives are kept under a free-standing thatched roof structure (*colmenar* or *nahil kab*) stacked on angled supports (*horcones*) (Bianco 2014:68; Weaver and Weaver 1981:8). Many beekeepers keep bees in their houselots, including smaller *colmenares* (Wauchope 1938), but archaeological evidence suggests that on Cozumel Island, larger *colmenares* were sometimes located in special-purpose enclosures or near monumental structures (Batun Alpuche 2009).

The number of *hobones* kept by an individual or family can vary significantly in Maya communities. Modern meliponiculture is often a low-intensity household undertaking, in conjunction with traditional *milpa* agriculture (Villanueva Gutiérrez et al. 2005). Wauchope (1938:128) reports that a *colmenar* was typically present in most rural houselots in Yucatan and Campeche in the 1930s. Villanueva Gutiérrez et al. (2005) report that most Maya beekeepers kept between 20 and 60 *hobones* from 1950–1981; however, a few beekeepers practiced high-intensity husbandry, with as many as 220 *hobones* (Palmas, Quintana Roo, in 1980; Villanueva Gutiérrez et al. 2005), 400 *hobones* (Yaxcabá, Yucatán in 1973, Weaver and Weaver 1981:8), and 500 *hobones* (Yucatán, Francisco Javier Clavijero [1824]; Villanueva Gutiérrez et al. 2013). While some limestone disks may have been recycled or reused for new *hobones*, disk quantities can estimate the minimum number of *hobones* that were discarded in particular contexts.

Beekeeping and Symbiotic Cultivation

Modern beekeepers engage in symbiotic cultivation, in which bee species, tree species, food crops, and medicinal plants are managed—an important cornerstone of ecological farming practice. Maya beekeepers often plant flowering species in their home gardens that are important food sources for bees during the height of the dry season (March to May) when other sources are unavailable (Ucan Yam 2018); a lack of food sources, often due to deforestation, can cause colony death (Villanueva Gutiérrez et al. 2005). Common tree species that are planted in home gardens include *chakah* (*Bursera simaruba*), *tsi'tsi'lche* (*Gymnopodium floribundum*), *ja'abin*, (*Piscidia piscipula*), and *tsalam* (*Lysiloma latisiliquum*), which provide nectar and pollen for bees (Villanueva Gutiérrez et al. 2005). The most famous example is the strategic placement of *hobones* under *xtabentun* vines (*Turbina corymbosa*) to create honeys with hallucinogenic properties. The honey was mixed with *balche'* (*Lonchocarpus longistylus, Lonchocarpus violaceus*) bark to make a fermented drink of the same name that remains important in traditional ritual practice, despite centuries-long attempts by the Catholic church to ban it (Chuchiak 2003; Ott 1998:262).

Hobones and *colmenares* are generally constructed from preferred wood species that are grown on the edges of houselots, harvested from *k'ax* zones along the edges of cultivated fields, or from more mature trees in forested areas. To craft domestic *hobones*, beekeepers deliberately select woods with specific characteristics, such as durability, properties of thermal insulation, and a lack of odors; the *ya'ax niik* tree (*Vitex gaumeri*) is particularly favored (Ucan Yam 2018:24). Some tree species are typically avoided by wild bees. For example, some tree species emit odors that attract pests such as the *neném* fly (*Pseudohypocera kertezi*), while others, such as cedar (*Cedrela odorata*), can be toxic to bees; however, cedar can be dried in direct sunlight to remove odors and toxic properties (Ucan Yam 2018:24). Species preferred for *horcones* have wood that can sustain the weight of the *hobones*, and resist degradation by heat, humidity, and insect pests (e.g., *ja'abin* [*Piscidia piscipula*], *kitinche'* [*Caesalpinia gaumeri*], *sak ya'ab* [*Gliricidia sepium*], *ts'uts'uk* [*Diphysa carthagenensis*], and *chakte' viga* [*Caesalpinia platyloba*]). Species with light yet firm wood grain are preferred for *colmenares* roof supports, such as *p'eres kuch* (*Crotan arboreus*), *bo'ob* (*Coccoloba barbadensis*), and *sak loob* (*Eugenia buxifilia*).

Trees used to craft *hobones* and *colmenares* also provide nectar and pollen for meliponas, and have other important cultural uses, which provide a broader context for their deliberate cultivation in urban gardens, and for their recovery in paleobotanical samples (Supplemental Tables 1 and 2). For example, *ramón* (*Brosimum alicastrum*) and *ciruela* (plum; *Spondias* spp.) are important nut and fruit crops. Achiote (*Bixa orellana*) is a cooking condiment as well as a red-colored dye; *pixoy* (*Guazuma ulmifolia*) produces fruit, oil used in *hobon* manufacture, and its bark is used in traditional medicine to treat skin diseases. *Chakah* and *chulul* (*Apoplanesia paniculata*) have a wide range of uses, including as natural dyes and tints in the production of stucco floors, and a variety of uses in traditional medicine; additionally, *chulul* was a historically-preferred wood for crafting bows and the wood shafts of other stone-tipped weapons (Rice et al. 2009). *Chakah* leaves are used in beekeeping itself, rubbed on *hobones* and disks to repel insects (Bianco 2014).

Stingless bee species have mutualistic relationships with tropical plants, including the pollination of culturally valued plants, such as food crops (Supplemental Table 2). Specifically, *M. beecheii*, *S. mexicana*, and *Nannotrigona perilampoides* have been observed to play an important role in the pollination of traditional crops, including the Solanacea family (tomatoes and peppers, including chiles), the Curcubitacea family (squashes, melons, cucumbers, and watermelon), and fruit trees, such as avocado (*Persea americana*), and they may be deliberately introduced into greenhouses for pollination (Ayala et al. 2013; Can-Alonzo et al. 2005; Cauich et al. 2004; Supplemental Table 2). Although many food species were domesticated prior to the Late Formative, widespread agricultural intensification demanded consistent access to pollinators to sustain the high crop yields that supported early cities. Thus, ancient beekeepers may have intentionally cultivated important crops, tree species, and medicinal plants in tandem with beekeeping practice, as we argue below for Cerro Maya.

Stingless Beekeeping Practice in the Archaeological Record of Cerro Maya

Excavators recovered 109 chipped or ground solid limestone disks at Cerro Maya, 79 of which were burned (Figure 3; cf. Garber 1989:26–29, 31–32, Fig. 11b). Most limestone disks were recovered from clear Late Formative contexts; several others found in mixed or surface contexts were undated, yet the lack of evidence for later worked limestone industries suggests that virtually all were produced in the Late Formative period. The disks were made through a combination of flintknapping techniques, principally using percussion flaking; in some cases, edges were abraded. Overall, there is considerable variation in symmetry and modification from raw limestone to finished product (Figure 3).

Solid Limestone Disks

The average disk diameter (10.6 cm) is slightly smaller than at Mayapán, and

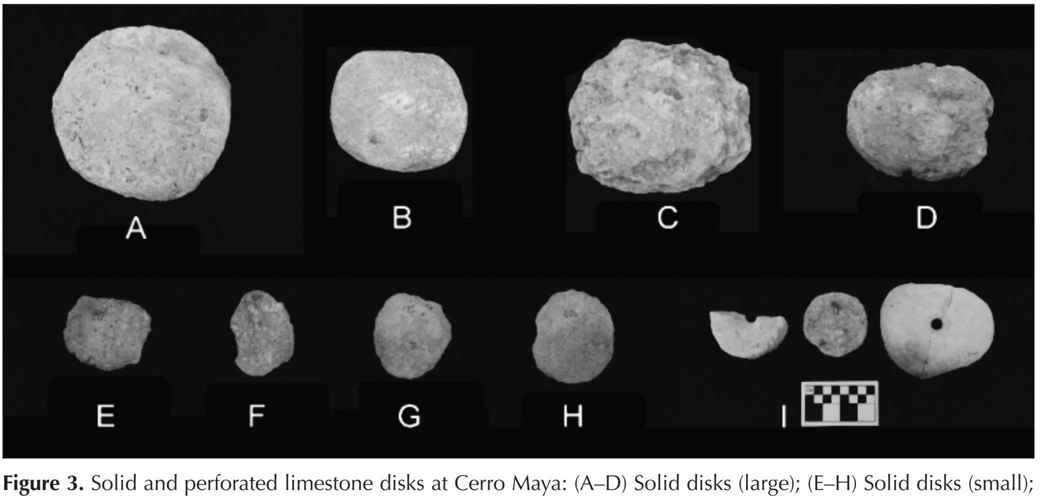

Figure 3. Solid and perforated limestone disks at Cerro Maya: (A–D) Solid disks (large); (E–H) Solid disks (small); (I) Perforated disks and solid incised disk. Photographs by Nezahualcoyotl Xiuhtecutli, courtesy of Debra Walker and the Anthropology Division of the Florida Museum, FLMNH Cat. Nos. SF-1726, SF-1812, SF-1213, SF-1357, SF-1876-A, SF-1876-B, SF-1876-C, SF-1876-D, SF-1132, SF-1211, SF-1203.

average thickness (4.0 cm) is generally comparable to Mayapán's "thick disks" (Table 1; Figure 4). Given the dimensions and characteristics of modern log hives (Quezada-Euán 2005; Van Veen and Arce 1999; Supplemental Table 1), we propose that disks from 10–17 cm are more likely to be associated with *M. beecheii*, while disks with smaller diameters (< 10 cm) are more likely to represent *Trigona* spp. hives. However, we acknowledge that there is a degree of overlap; melipona hives may be as small as 8 cm in interior diameter, while trigona hives may be as large as 15 cm. Within the Cerro Maya sample, 54 disks have diameters below 10 cm, while 33 disks fall between 10 and 17 cm, and four disks are above 17 cm. Measurements were unavailable for 16 disks in the database.

At Cerro Maya, 67 limestone disks were recovered from a termination deposit associated with Structure 2A-Sub 4, a small two-tiered pyramid that was interred beneath a two-meter-high plaza around AD 1–50 (Robertson and Walker 2015; Walker, forthcoming). Sixty-four of 67 disks were burned, and 13 of 67 disks were broken. The disks were associated with a lens of white marl and other smashed and burned objects, including ceramic vessels, incense burners, charcoal, and other chipped limestone spheroids and subspheroids. Limestone disks from this context ranged from 8.1 to 15.9 cm in diameter (9.9 cm average), consistent with the use of melipona hives for high-intensity honey production. With two disks per *hobon*, the deposit included between 34 and 67 *hobones*. While the *hobones* could have been brought from neighboring structures to be burned in a termination rite, we suggest they represent a concentration of meliponiculture activities by ritual practitioners. Significantly, the deposit included a substantial number of smashed drinking mugs and three-handled jugs that Robertson (2016; Robertson-Freidel 1980) interpreted as *balche′* drinking vessels. We concur that the pyramid was a locus of *balche′* production and consumption.

Beekeeping can be practiced along a continuum of production intensity; based on ethnographic observations on historic numbers of hives per beekeeper, Villanueva Gutiérrez et al. (2005), and archaeological findings from Mayapán (Paris et al. 2018:Figure 10), we define less than 5 hives (< 10 disks) per structure as low-intensity beekeeping, 5–10 hives (10–20 disks) as intermediate-intensity,

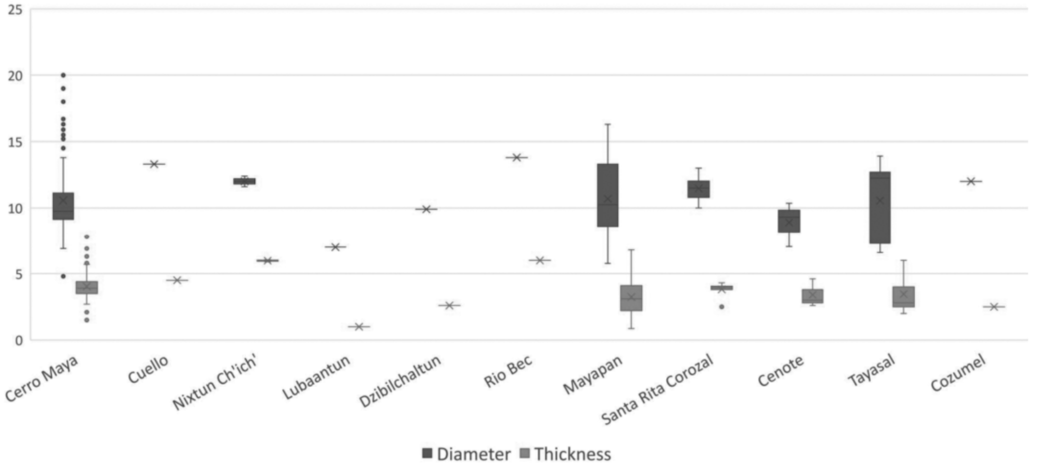

Figure 4. Limestone disk sizes from sites in the Maya lowlands (northern Yucatan, Northern Belize, and Central Peten; see Table 2). Measurements are in cm. Cuello, Rio Bec, and Cozumel plots represent published averages, as individual disk measurements were not available. Drafted by Elizabeth Paris.

and 10 or more hives (> 20 disks) per structure as high-intensity. Based on these figures, low-intensity beekeeping may be inferred for 16 Cerro Maya structures with fewer than 10 disks; these included both residential structures and temples located throughout the site (Figures 1 and 5). The 67 disks in the termination deposit at Cerro Maya's Structure 2A-Sub 4 represent the site's only high-intensity production locus.

Excavated context is also important in interpreting disk function, and particularly large, thick disks may have had other uses. For example, Ballcourt 50D and and Mound 38A contained disks that were over 20.2 cm in diameter and over 6.9 cm thick, which could have been ballcourt markers or cache lids (Figure 5). Excavations in the canal (127A) identified a pair of large disks (18–19 cm) together with three smaller (9.7–15.5 cm) disks; these could represent one large and two small *hobones*, but given their thickness (4 and 7 cm), it is also possible that the large disks are not *mak tuunob*. Four disks from surface and domestic debris in the waterfront village (1A) are small, thin disks between 4.8 and 8.2 cm in diameter, consistent with natural trigona *hobones* associated with residences (Quezada-Euán 2005).

The Paleobotanical Record of Cerro Maya

Crane's paleobotanical study (Crane 1986, 1996; Supplemental Table 2) identified many flowering tree and shrub species preferred by meliponas as pollen, nectar, and nesting sources. Nance (*Byrsonima crassifolia*), a fruit tree, was ubiquitous throughout sampled contexts at Cerro Maya; other tree crops included coyol palm (*Acrocomia mexicana* syn. *Acrocomia aculeata*), mamey (*Calocarpum mammosum* syn. *Pouteria sapota*) and *xcapoch* (*Mastichodendron* spp. syn. *Sideroxylon* spp.), guava (*Psidium guajava*), passionflower (*Passiflora* spp.), persimmon (*Diospyros* spp.), avocado (*Persea americana*), papaya (*Carica* spp.), *jícara* (*Crescentia* spp.), *siricote* (*Cordia* spp.), and *caimito* (*Chrysophyllum* spp.), all favored as sources of pollen for stingless bees, together with vegetables, such as chiles (*Capsicum* spp.) and squash (*Cucurbita* spp.) (Crane 1996:266; Supplemental Table 2). Staple crops, such as maize (*Zea mays* spp.) and beans (*Phaseolus vulgaris*), and special-purpose crops, such as cotton (*Gossypium hirsutum*) and copal (incense; *Protium copal*), were also present (Crane 1996:266), but have not been documented in association with melipona use. Most of the samples were taken from sub-plaza

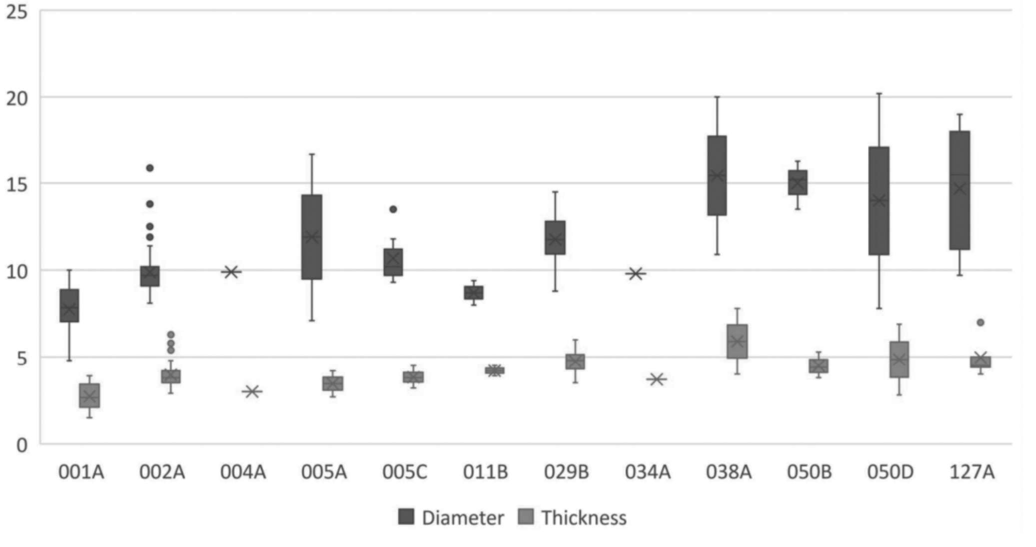

Figure 5. Solid limestone disks from Cerro Maya by structure. Measurements are in cm. Drafted by Elizabeth Paris.

midden deposits (2A, 5A), where concentrations of limestone disks were associated with slightly later construction phases.

Beekeeping Practice and Ritual at other Late Formative Period Sites

Rare direct evidence for beekeeping comes from ceramic effigy *hobones* from two Late Formative sites. One example was discovered at Late Formative Nakum, Peten, Guatemala, consisting of an unslipped ceramic tube with two ceramic disks as end plugs (Źrałka et al. 2014:Fig. 9). The effigy was recovered from a small masonry cist within Structure 99 Sub-1, a single-room building on a low platform, later covered by a Terminal Formative (AD 80–260) temple (Źrałka et al. 2014:107). Tube dimensions are similar to modern domestic *hobones* (Supplemental Table 1), 30.7 cm long, with a 3-cm hole in the tube center; the ceramic plugs measure 16.7 and 17 cm respectively. A second effigy *hobon* was documented at the site of Chan Chen, Corozal, Belize, consisting of two stone disks and a barrel-shaped stone with similar dimensions: 31 cm long and 18 to 21 cm in external diameter. The effigy was recovered at a small, rectangular platform. A low platform nearby supported two small rectangular structures, which contained 33 limestone disks, suggesting that these platforms supported *colmenares* (Crane 1992; Sidrys 1983:91, 298–299). Both effigies are idealized representations of domestic *hobones* for meliponas, although both are 20 cm shorter than typical modern *M. beecheii* hives, with interior diameters at the large end of the size range (Van Veen and Arce 1999).

Late Formative caches sometimes contain limestone disks, such as the recently discovered cache at Nixtun-Ch'ich' (Peten, Guatemala), which contained two limestone disks (Rice et al. 2019; Timothy Pugh, pers. comm., 2018; Table 1). Based on dimension, they likely represent *mak tuunob* for melipona hives, and plausibly could have plugged a wooden *hobon*, now decayed in situ. The cache also contained two highly polished hard limestone cylinders, similar to *manos* for grinding maize. Ovoid in shape, they were most likely produced for votive rather than food production purposes, suggesting a food or feasting theme. Limestone disks were uncommon at Nixtun-Ch'ich', thus far only known from this singular deposit.

A cache vessel deposited within Structure A6, the Late Formative ritual center at Caracol, Belize, may represent the earliest known example of a *mancuerna*. The lidded cylindrical vessel held an entire wax and cerumen honeypot structure of a hive. Carbon samples from the cache dated to 1980 ± 50 cal BP (190 BC–AD 210, 2σ; Chase 1988:Fig. 2a; Chase and Chase 1995:96). We observe that in Chase's (1988) Figure 2a, the lid and vessel body have aligning small apertures consistent with a *mancuerna*, and that the vessel itself approximates the shape of a *hobon* turned vertically. There were no wood fragments or disks in the cache, but the cache contained bees that were in the hive at the time of its interment. Below the honeypot itself, the vessel contained other ritual offerings, including marine shells, malachite pebbles, jadeite ornaments, pumpkin seeds, and pine needles (Chase and Chase 1998), suggesting the cache was a constructed deposit, rather than a *mancuerna* interred without modification.

Discussion: Maya Stingless Beekeeping in the Late Formative Period

The identification of meliponiculture at Cerro Maya has broader implications for the development of stingless beekeeping in the context of a garden city. The complex cityscape would have sustained multiple levels of beekeeping, associated with diverse productive zones, including household gardens, urban terrace plots, wet-fields, drained fields near reservoirs, orchards, more distant milpas, fallow fields, and managed forests. These would have been mitigated by the average distance a bee could travel in a day, embedded in a vast urban landscape. *Hobones* situated near drained fields and irrigation features on the site's periphery would have facilitated the pollination of milpa crops, such as legumes and vegetables, as well as *k'ax*-zone plants, while hives associated with large temples and small residences in the urban core would have thrived in tandem with cultivated fruit trees and other garden species. Disk concentrations at multiple residential structures suggest hives were suspended from roofs, as documented in modern practice, and the distribution of disk diameters suggests that both meliponas and trigonas were kept. Elite religious practitioners at Structure 2A-Sub 4 likely practiced high-intensity melipona husbandry for honey or *balche'* production.

Most Cerro Maya residents probably benefited from meliponiculture, especially emerging elites who, it appears, actively promoted its practice for several reasons. First, the strategic positioning of *hobones* within cities and near agricultural fields would have regularized the pollenization of tree crops and vegetables, leading to higher crop yields. While evidence of plant domestication and agriculture predate evidence of meliponiculture in the Maya area by many centuries (Pohl et al. 1996; Pope et al. 2001), the Late Formative period is associated with the proliferation of large-scale agricultural intensification, including drained fields, terracing, and reservoir systems (Brewer et al. 2017), that ultimately supported a significant population expansion. We think it is more than coincidence that the earliest archaeological evidence for meliponiculture is associated with this period in Maya history. Second, stingless bee management would have ensured regular access to, and increased production of, honey and wax. These products undoubtedly benefited community residents, but also provided a mechanism for elites, such as early dynastic rulers, to build wealth and prestige through commercial exchange and conspicuous consumption of bee products (Freidel et al. 2002). Third, elite religious practioners may have intensified beekeeping for honey production used in *balche'* production, medicinal use, or as an additive in elite chocolate beverage consumption (Powis et al. 2002).

The association of beekeeping furniture with ritual deposits suggests that beekeeping was considered important and worthy of reverence. As discussed above, the Cerro Maya termination deposit is part of a broader ritual landscape in which beekeeping furniture (effigy *hobones*, limestone disks, and a possible *mancuerna*) was incorporated into elaborate caches in important temples at several early Maya cities. While there are no depictions of the Bee God (Ah Mucen Kab or Hobnil) dating to the Late Formative period, later generations of elite ritual practitioners created codices, architectural friezes, and effigy incense burners depicting the Bee God (Paris et al. 2018). At Cerro Maya, a Late Postclassic period cache at the summit of Structure 6A contained an effigy incense burner depicting a winged Bee God (Milbrath and Walker 2016:206, Figure 10.11; Walker 1990:437).

Our findings suggest that the earliest evidence of meliponiculture in early Maya cities occurred in tandem with the emergence of "garden cities" (Chase and Chase 1998; Dahlin et al. 2005; Dunning et al. 1998) that explicitly incorporated green spaces and flowering plants into cityscapes. As an increasing number of archaeological projects focus on residential and rural spaces, we will gain a better understanding of the degree to which limestone disks, as material indicators of stingless beekeeping, are associated with houselot gardens and agricultural plots. Here, we have demonstrated that an ethnobiological approach to beekeeping informs our view of the complex web of symbiotic relationships and land management systems comprising ancient garden cities. As deforestation and land use changes in Yucatan continue to create long-lasting impacts on humans, bees, and plant species, we hope that ancient cities, such as Cerro Maya, provide insights for modern communities seeking to incorporate bees, honey production, green spaces, and flowering plants into urban landscapes.

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