Natural Resource Use and Classic Maya Economics: Environmental Archaeology at Motul de San José, Guatemala

KITTY F. EMERY[1]

Curator of Environmental Archaeology
Florida Museum of Natural History

RESUMEN

En el sitio maya clásico Motul de San José, Guatemala, se está utilizando la arqueología medioambiental interdisciplinaria para comprender los patrones de adquisición, uso y distribución de los recursos naturales del medioambiente. Nuestras investigaciones combinan zooarqueología, arqueobotánica y geoarqueología para reconstruir, en primer lugar, la trayectoria de los recursos naturales a través de la antigua comunidad de Motul de San José, en segundo término, el uso de estos recursos por los diferentes miembros de la comunidad y, por último, el movimiento de los productos procedentes de recursos naturales fuera de la comunidad a través del intercambio. El estudio se encuentra en proceso, pero los resultados preliminares sugieren que estos métodos pueden mejorar nuestra comprensión de las diferentes economías y medios ambientes de la civilización maya.

Palabras clave: periodo Clásico maya, arqueología medioambiental, economías, zooarqueología, geoarqueología, Motul de San José.

ABSTRACT

At the Classic Maya site of Motul de San José, Guatemala, interdisciplinary environmental archaeology is used to understand patterns of acquisition, use, and distribution of environmental resources. We are combining zooarchaeology, archaeobotany, and geoarchaeology to reconstruct the flow of natural resources into ancient Motul de San José, the use of these resources by community members, and the movement of natural resource products out of the community through trade. Research is on-going, but preliminary results suggest that these methods can enhance our understanding of Maya economies and environments.

Key words: Classic Maya, environmental archaeology, economics, zooarchaeology, geoarchaeology, Motul de San José.

INTRODUCTION

Among the most important and contentious issues in the world today are the economics and politics of sustainable natural resource use. This is particularly true in the world's most fragile environments, many of which, like the tropical rainforests, are also hot spots of biodiversity particularly vulnerable to abuse. In the southern lowlands of Mesoamerica, archaeologists have debated the sustainability of ancient Maya tropical urbanism for more than 80 years. Unfortunately this debate often ignores the fact that land use strategies are decisions made by individuals within a set of politically defined economic parameters. In addition to understanding the ecological effects of deforestation, therefore, we need to understand the factors that motivated Maya decision-making with regard to the use of natural resources. We need, that is, to understand ancient Maya environmental economics.

The archaeological intersection between cultures and environments is often most clearly expressed in the economic sphere. The environment is a storehouse of resources that must be stocked, maintained, bought, and sold. These resources are essential to daily survival, but are also essential for the maintenance of political and social ties at household, community, and polity levels. If we can track the patterns of acquisition, distribution, use, and discard of environmental resources through an archaeological Maya community, we have the potential to understand the economic rules of ownership and control of natural resources.

[1] kemery@flmn.ufl.edu. Florida Museum of Natural History, 117800. Gainesville, FL 32611-7800 (USA).

MOTUL DE SAN JOSÉ

For the past several years, the Motul de San José Ecology Sub-Project[2] has been developing strategies for approaching questions of natural resource economics in the Classic period Maya community of Motul de San José (MSJ), located approximately three kilometers north of the Lake Peten Itza in lowland Guatemala. My research articulates with the larger Motul de San José Archaeological Project directed by Antonia Foias, who has been investigating political and economic systems at the site since 1998. She and her team have laid the groundwork for my studies, providing archaeological and settlement data, as well as information on the economics of production and trade of other products such as ceramics.

Foias' excavations across the site of Motul de San José and detailed ceramic and radiocarbon analyses have revealed that the site was occupied from the Middle Preclassic (600-300 BC) until the Early Postclassic (950-1200 AD) although the primary phase of occupation was during the Late Classic period (650-830 AD). Neighboring sites, likely subsidiary to Motul de San José during the Classic period, were occupied both earlier (Buenavista likely was first occupied between 900 and 600 BC, and later (at Akte, occupied into the Postclassic.

The Motul monumental core, approximately 0.4 km^2 and the obvious political center of the site, includes five elite residential/ritual groups. The epicenter or urban center of the site, extending for approximately 1.2 km^2 around the monumental core, is continuously settled with structures ranging from low to noble status. The near periphery of the site likely extends to the shore of the Lake Peten Itza and an equal distance in all directions around the site (Figure 1). Transects mapped to the northeast, south, and east have revealed small subsidiary centers such as Buenavista (3 km south), Trinidad (2.6 km south), Chakokot (2 km east), and Kantetul (2 km north). Each site appears to have been strategically located close to specific resources or potential transfer points. Moriarty's regional surveys in the polity have also suggested that more distant sites, such as Akte (7.2 km) and Chachaklum (5 km), may also have been part of the Motul polity and trading system.

THE STUDY OF ENVIRONMENTAL ECONOMICS

At the foundation of ecological investigation at Motul de San José is an application of interdisciplinary environmental archaeology to issues of ownership and control of natural resources in Classic Maya households and communities. We are combining zooarchaeology, archaeobotany, and geoarchaeology to reconstruct the flow of natural resources into ancient Motul de San José, the distribution of those resources among community members, and their specific use at the household level. This research requires the cooperative efforts of many experts, and the conclusions reached by the MSJ Ecology Sub-Project are based on collaborative geoarchaeological work with Richard Terry, soil scientist at BYU and his students[3], Henry Schwarcz and Elizabeth Webb[4], geochemists at McMaster University; settlement and ethnoarchaeological research by Matthew Moriarty[5] at Tulane University; preliminary archaeobotanical work[6]; as well as my own zooarchaeological research at the site.

The methods required for such an investigation are complex, in no small part because the very resources we seek to trace are the organic materials most likely to have disappeared from the archaeological record. It is also difficult to bridge the middle range between the archaeological data of discarded bone and plant remains in an ancient Maya city and the complexities of an economic system of acquisition, distribution, and consumption. These issues are approached at two levels:

First, at the level of primary resource acquisition we seek to understand who controlled access to «wild» resources including animals and undomesticated plants, and who controlled the production of

[2] I have directed the Motul de San José Ecology Sub-Project since 1998 as part of the larger Motul de San José Archaeological Project directed by Dra. Antonia E. Foias of Williams College.

[3] Terry and the BYU student soil scientists have worked with the Motul project since 1999 and have been active field participants for several seasons (2001, 2002).

[4] Schwarcz and Webb have been responsible for designing and carrying out all stable isotopic soil research at the McMaster University Stable Isotope Geochemistry laboratories.

[5] Matthew Moriarty is the director of the Motul de San José Settlement Archaeology project and has been a fundamental member of the Motul project since 2000, directing settlement work in 2000 and 2001, and acting as field director while carrying out regional survey and excavation research in 2002 and 2003.

[6] Preliminary archaeobotanical work at Motul de San José was carried out between 2000 and 2001 by Andrew Wyatt of UIC. His research indicated poor macrobotanical preservation in the Motul soils. The project plans for continued macro and microbotanical work in the future.

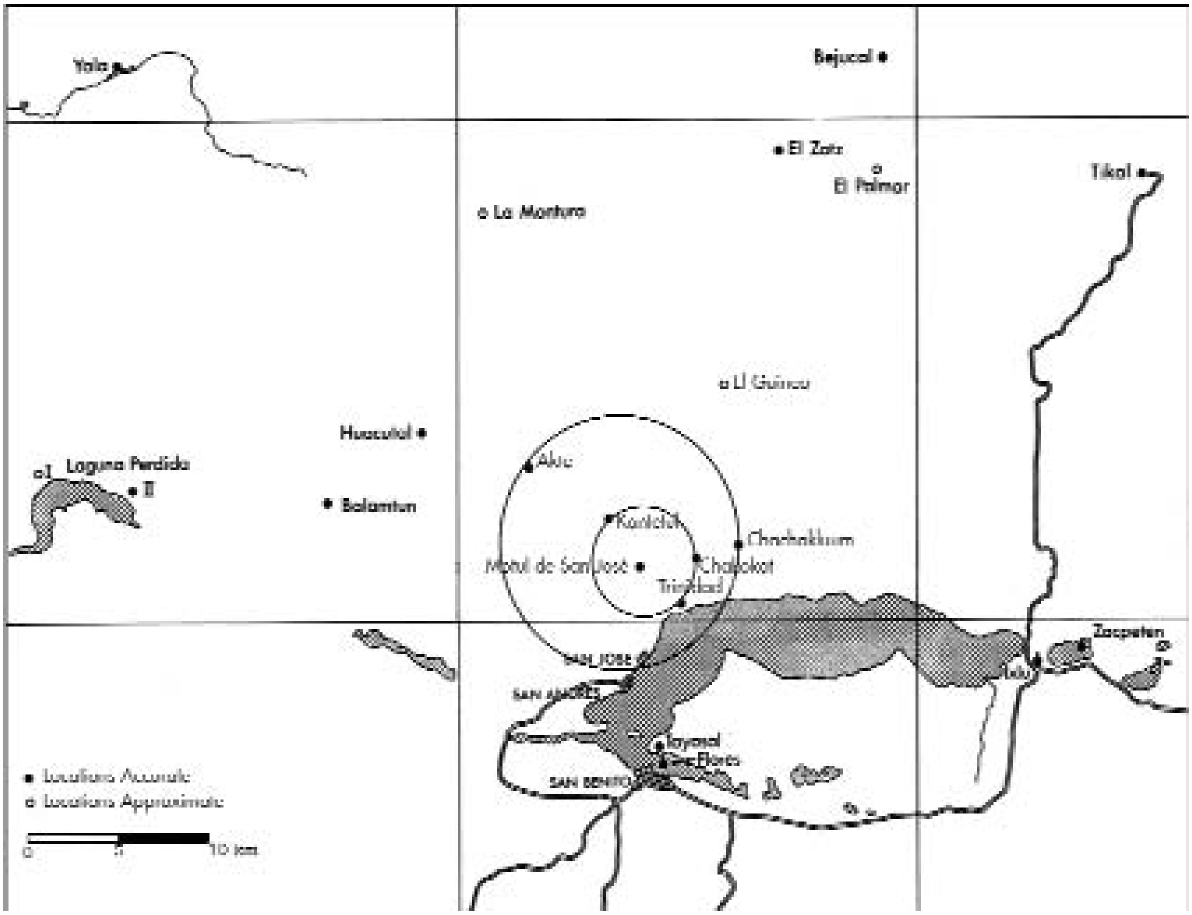

Figure 1. The Motul de San José region and catchment area. Note the site epicenter, near periphery (first circle) and likely resource catchment area (second circle). Subsidiary near periphery and distant periphery sites are noted (map adapted by Moriarty from Ian Graham 1982).

domestic resources such as agricultural products and potentially domestic animals. In essence then, this means we need to understand who «owned» the land in and around the site since in each case the land provides the natural resource products.

Second, at the level of product use (a much more complicated issue) we need to know which members of society controlled the movement of natural resources through the community. Which members of society were involved in the modification of raw materials into final products? Who stored the materials either in their raw state or as secondary products? Who actually used or consumed the products? And in whose garbage did the detritus end up after use?

This discussion considers only biotic resources including wild and domestic animals and plants since these are the resources most susceptible to overuse and mismanagement. The broader investigation of course includes mineral resources, water, and other abiotic products, but that research is still in progress.

PRIMARY ENVIRONMENTAL RESOURCE ACQUISITION

Beginning, then, at the level of primary acquisition of raw resources, we ask how, from where, and by whom natural resources were acquired. I am using a combination of geoarchaeological and zooarchaeological methods to determine source locations for environmental products and to reconstruct land use patterns. From these data we hope to use associative patterning between settlement and source locations to reconstruct ancient land «ownership» or «control». Key to understanding the ownership and control of initial acquisition of natural resources are the locations of agricultural lands vs. «wild» lands, as well as the type of farmed land (i.e. out-field *milpas* or intensively managed orchards or housegardens) in association with settlements which links structure types with land use types.

Needless to say, this link is a difficult one at best. The proximity of structures to resource areas, and particularly to areas of intensified production, has been proposed as archaeological evidence of ownership and maintenance in other areas of the world , and has been used to posit changing patterns of land use and ownership in the Maya realm. The association is considered to have been particularly clear in the Maya lowlands where populations live close to their productive lands. However, preliminary research at Motul indicates that land use by community members was considerably more convoluted than is suggested by this simplistic model.

Agricultural Land Use

The local resource catchment area of the Motul de San José polity can be roughly estimated to include all the territory between this major center and its nearest subsidiary sites (Chakokot, La Trinidad, Buenavista, and Kantetul), an area that includes two major water systems, the lake Peten Itza (3 km south) and the *arroyo* Kantetul (2 km north), as well as a various mineral and other resources. Other resources, including animals and plants available in savanna environs not located within the immediate Motul catchment, were available at a distance of some 5-7 km from the site core, suggesting that a broader catchment estimate might also include the slightly more distant sites of Akte (7 km) and Chachaklum (5 km).

Among the resources available to the ancient MSJ residents within the smaller estimated catchment was land suitable for various types of agriculture. Agricultural soil potential has been determined using the USDA/NRCS soil classification system, and these potentials have been supported using innovative indigenous soil knowledge research. In combination, this work by Moriarty, Jensen, Johnson, and Terry identifies highest potential soils as those located in upland plateaus, including both those on slope edges (Ek Luum soils = *Tierra Negra*), and soils of high fertility but low longevity for agriculture (needing fertilization or fallow periods) located on the flat surfaces of the uplands where coincidentally most ancient settlement is found (*Sacnis*), and clayey lowland low potential soils suitable primarily for maize agriculture (*Barro Negro*) (Figure 2). Two other soil types were identified by Moriarty's indigenous soil classification research and lie outside the immediate Motul core. One of these is the *chachaklum* soil characteristic of savanna lands and found in significant quantities at a distance of some 5 km from the Motul core (at the site of Chachaklum).

From these analyses and a review of the information provided by Moriarty's settlement survey along the east transect , we can estimate the proportion of high-potential agricultural land in the site periphery (Ek Luum = *Tierra Negra* soils = 20%), high fertility/high maintenance land (suitable for in-field gardening) (*Sacnis* soils = 52%), and low fertility/low maintenance land (suitable for corn agriculture or as unfarmed land) (*Barro Negro* soils = 14%)[7].

However, potential resource availability provides only one part of the resource use equation. In order to understand resource control, we must describe actual resource acquisition patterns. Two geoarchaeological measures —phosphate levels and stable carbon isotope ratios— have been combined with settlement analyses to investigate likely patterns of land use for agriculture in the Motul polity. Phosphates[8] were mapped at a broad scale (25 meter intervals) across the monumental core of the site and along the periphery transects and at a finer scale around various groups both in the monumental core and the periphery. These geochemical analyses revealed significant phosphate

[7] Percentage land classified by soil type is estimated from data provided in Jensen *et al.* n.d. transect and soil maps. I calculated these percent estimates as count of 50 meter units per soil type across the east transect. These are rough estimates only as they are based on a single transect and therefore a limited evaluation of the total environs surrounding the Motul site.

[8] Quantitative phosphate measures test for phosphate depletions that may be the result of agricultural activity without amendments, and phosphate enrichments that may indicate the addition of agricultural fertilizers or the deposition of organic garbage or burials (Ball and Kelsay 1992; Craddock *et al.*1986; Eidt 1986; Sánchez *et al.* 1996; Terry *et al.* 2000, Wells *et al.* 2000).

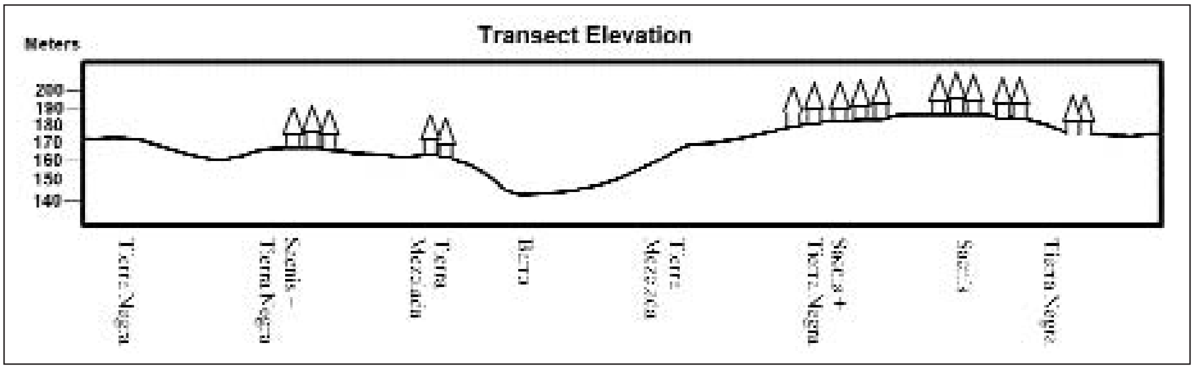

Figure 2. Transect soil profile indicating topography, soil type, and settlement location (adapted from Jensen *et al.* 2003 and Moriarty 2002a, data and figures).

enrichment in two flat, non-architectural areas in the core[9], as well as in association with several residential groups in the core and in the site periphery. However, test excavations in the epicenter non-architectural areas (Foias, personal communication 2003) and as part of test pitting midden prospection revealed no midden or burials in some of the areas with the highest phosphates. In the residential test-pitting program, phosphate testing showed correlation between elevated phosphates and midden deposits in only 6 of the 25 test pits with high phosphate levels although the highest phosphate signature was correlated with a high density midden. Similar results were found during test pitting in a residential group (E2E) in the site periphery. Moriarty (personal communication 2003), suggesting that these areas of elevated phosphates unassociated with archaeological materials might be the result of either now invisible waste products, or organic amendments for in-field gardening[10].

Further evidence that appears to support an interpretation of in-field agriculture comes from a new and innovative geoarchaeological technique designed by Schwarcz; the method is described in. The techniques were implemented on Motul samples in the University of McMaster Stable Isotope Geochemistry laboratories. This technique allows geochemists to use carbon isotope ratios to distinguish soils on which corn has been grown[11]. Webb and Schwarcz have shown an ancient increase in $\delta^{13}C$ (or corn growing signature) for almost all areas of the site (including both high and low potential soils), but particularly on elevated hilltops near peripheral residential settlement, and more surprisingly near residences in the site core and epicenter or suburbs[12]. These results are intriguing because they hint at corn-growing not only in areas between settlements in the rural periphery, but also in areas close to residences in all areas of the site. Further evidence is needed to properly interpret these findings, including a broader program of coordinated phosphate, $\delta^{13}C$, and archaeobotanical testing to clarify the origins of the various signatures. In-field gardening with organic amendments including corn pro-

[9] Epicentral non-residential sampling was conducted as part of a grid test across the entire site epicenter, and the phosphate level for two flat, non-architectural areas were the highest of all samples taken (Emery 1999). Epicentral residential sampling was conducted as part of a broader midden test-pitting study by Foias' team (Ramírez *et al.* 2000). Site periphery phosphates were analyzed in association with the broader geoarchaeological soil classification research by Terry's team. Test excavations of Group E2E were conducted by Moriarty (personal communication 2003) and reported on by Jensen [«Subsequent test pit excavations at one site (Group E2E), located on the edge of large upland area, did not find extensive cultural deposits.» (Jensen *et al.* n.d.)].

[10] Microbotanical and residue analyses will eventually be used to clarify causes of phosphate variability and pinpoint those that relate to land use (Jones 1994; Pearsall 1990; Piperno 1988).

[11] Corn is a C_4 plant that, along with other grasses, is enriched in ^{13}C in comparison to leafy forbs and forest trees that incorporate relatively greater proportions of ^{12}C during photosynthesis. Corn growing leaves a residual ^{13}C enriched signature in humic matter of the soils of agricultural fields.

[12] The ^{13}C data will eventually be published in a separate paper by Webb et al, but for the moment these results are presented in Jensen *et al.* n.d.: «…the measurements of humin within these profiles [CJ7 and CJ8 which are on hilltop plateaus in the site periphery on the east transect] provides distinctive signatures that likely originated from maize production … Similar results are also found in KJ1 and KJ5, which are located near additional outlying structures and in the flat area adjacent to the site core».

duct waste might well create signatures identical to middens originally containing only now-deteriorated organic wastes.

Use of Animal Resources

The second set of biotic data on the ancient use of natural resources at Motul de San José is gathered from an analysis of animal remains recovered in the archaeological deposits at the site. The ancient Maya had only one domestic animal, the dog, during the Late Classic period. So the majority of their animal protein came from wild fauna, hunted and fished presumably from within the Motul catchment. The Motul zooarchaeology collection currently numbers over 1000 identified non-intrusive remains and over 8000 total specimens including intrusives and unidentified remains. Identification is on-going, as is excavation, so this assemblage will continue to grow and all analyses should be considered preliminary.

Ranked in order of frequency in the archaeological record, the favored Motul animal prey included the white tailed deer, the large river clam, and the river turtle (Table 1). Mammals and mollusks dominate the sample, but many of the mollusk remains are from marine shell used for adornment, not food (distance to the coast precludes the use of marine molluscs as a food source at inland sites). The white tailed deer is clearly the favorite mammal, but dogs, armadillos, peccaries, agoutis, pacas, and rabbits were also common.

In total, this is not an unusual taxonomic assemblage for a Late Classic Maya site, and it represents resources from a broad assortment of microenvironmental zones relatively accessible to the site (Figure 3). Species like the river turtle and crocodile likely came from the Lake Peten Itza a few kilometers away, while the presence of wild cats indicates harvest in high canopy rainforest, and that of armadillos and rabbits suggest hunting in more open, savanna regions nearby. In combination this suggests that the larger Motul hunting territory (including local territories surrounding subsidiary sites) was approximately 196 km^2, or a 7 km radius. This is the shortest distance that would encompass both lake systems large enough for crocodiles and open savannah areas more likely to be the habitat for armadillos and rabbits. It is likely, though, that most of the animal resources for domestic use were procured within the smaller catchment of 36 km^2 (a 3 km radius).

Table 1. List of all Motul fauna in taxonomic order with primary habitat preference listed for main taxa.

Motul Animals	NISP	Favored Habitat
Marine molluscs	80	Exotic
Molluscs	44	
Freshwater snails	40	Rivers/Lakes
Crocodiles	5	Lakes
Turtles	21	Rivers/Lakes
Mud and Musk Turtles	5	Rivers/Lakes
Sliders	8	Rivers/Lakes
Large River Turtle	102	Lakes
Reptiles	1	
Birds	5	
Small Galliform birds	2	Disturbed Forest
Turkeys	1	Disturbed Forest
Mammals	181	
Mammals (intermediate)	108	
Mammals (large)	150	
Mammals (small)	7	
Armadillo	12	Savanna
Opossum	3	Disturbed Forest/ Residential
Canids	5	
Domestic Dog	18	Residential
Gray Fox	1	Disturbed Forest/ Canopy Forest
Jaguar	2	Canopy forest
Ocelot	1	Canopy forest
Wild Cats	4	Canopy forest
Peccaries	11	Disturbed Forest/Field
Deers	4	
Brocket Deer	16	Disturbed Forest/ Canopy Forest
White Tail Deer	159	Disturbed Forest/Field
Pocket Gopher	1	Disturbed Forest/Field
Squirrels	1	Canopy forest
Small Rodents	9	
Pacas	3	Disturbed Forest/Field
Agouti	2	Disturbed Forest/ Canopy Forest
Rabbits	8	Savanna
TOTAL	1020	

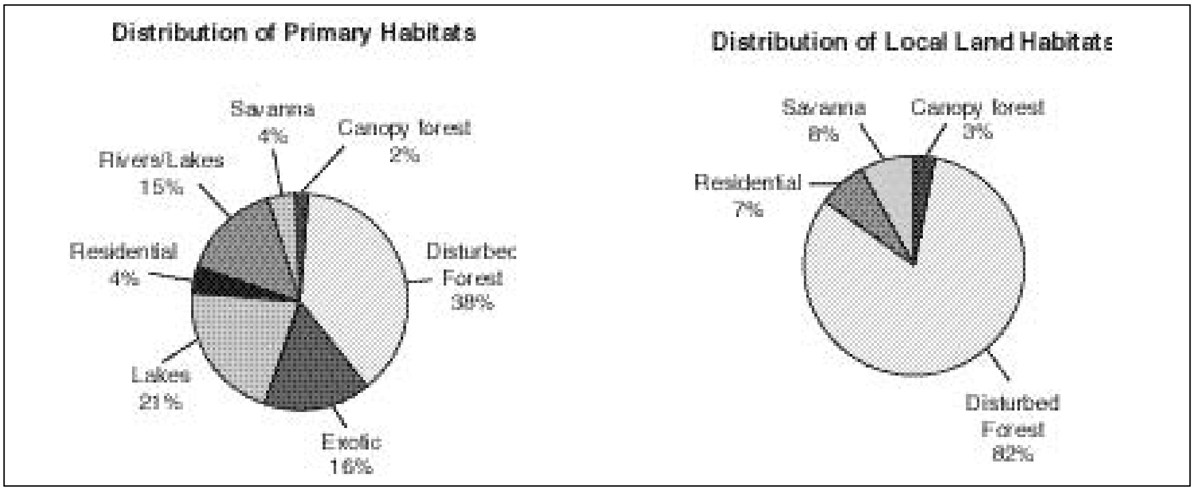

Figure 3. Relative distribution of taxa from all habitats, and of all local terrestrial habitats to provide information on hunting catchment. Calculations based on percent NISP for taxa for which specific habitats can be defined. Broader categories such as «Mammalia» have been excluded.

The earlier information on agricultural land use provides additional data in our understanding of patterns of wild resource acquisition. While most of the Motul monumental core was densely settled, settlement mapping in the suburban epicenter and periphery reveals lower settlement densities. Settlement density across the region is variable, but averages 250 structures/ km^2 in the monumental core, 125 structures/ km^2 in the site suburbs or epicenter, and 79 structures/ km^2 in the periphery[13]. Some proportion of the unoccupied area may have been continuously or sporadically forested. However, the evidence for corn agriculture in all of the Motul soils leads us to question the overall extent of agricultural activity. Possibly all the unoccupied territory of the Motul periphery was in active or rotating agricultural production.

A closer review of the animal taxa recovered as zooarchaeological remains in the Motul deposits indicates that these have come primarily from disturbed environments (such as secondary growth after agricultural planting). Considered as proportions of all habitat types (including exotics), almost 40% of the fauna prefer disturbed or secondary growth environs, or agricultural field edges. Considered as a proportion of only local land habitats, that number rises to over 80%. Only 2 to 3% of the fauna come from canopy forest habitats, with a similar number coming from savanna habitats. In combination, these results support the suggestion from the corn isotopic analysis that most of the Motul surroundings were in agriculture despite the fragility of the upland soils and the relatively poor potential of the lowland areas. Hunting was likely carried out by farmers primarily on an opportunistic basis within and around their *milpas* - though likely in the lowland *bajos*, since true synanthropists (those animal attracted to residences and people) are fairly uncommon in the Motul assemblage, and fewer animals would have been found around in-field gardens. This «garden hunting» pattern is very common in all forested areas of the world and is both opportunistic and fairly sustainable over the long term.

Interestingly, some species do not come from the direct Motul region. Although these represent a smaller proportion of the total hunted prey than do the animals from local habitats, their presence suggests they were hunted by residents of the satellite centers, such as Trinidad, close to the lake Peten Itza, and Chachaklum, close to the savannah environs. Whether the animals were brought into Motul as part of a trade system or as tax for the elite is unclear. Motul was also part of a larger resource area and was likely active in both the import and export of exotic products as adornments and status markers but possibly also as domestic and subsistence resources. Moriarty's work

[13] Calculated from Moriarty (2002a, 2002b). Monumental core = 100 structures/0.4km^2 = 250; Epicenter (mapped park) = (200-100 = 100) structures/(1.2-0.4 = 0.8)km^2 = 125; Near Periphery (transects) = 175structures/2.2 km^2 = 79.

at La Trinidad, a subsidiary site located on the banks of the lake Peten Itza, have shown this to be a port town likely providing an important transfer point for imports and exports.

USE AND DISTRIBUTION OF NATURAL RESOURCES AT MOTUL

Acquisition of natural resources is however, only the first stage to the puzzle. We also need clear material evidence of the use of natural resources by community members. For this aspect of the research into Maya natural resource economics, we ask how natural resources are distributed through the community hierarchy at a Classic Maya site. Again, combined environmental archaeology methods can be used to recover evidence of differential access to plant and animal resources and to reconstruct the extent to which the products were used within a household - in other words, whether the products were modified in the household, processed there, stored there, or actually consumed there. These differentials in household consumption of natural resources can then be used to reveal patterns in the control or ownership of these resources through the community.

This stage of the analysis requires information on patterning in archaeological plant and animal remains in residential deposits, primarily middens and occupational surfaces. Although much of this research is still very preliminary, zooarchaeological analysis in combination with house-floor residue analyses suggests a valid route to understanding the basic parameters of resource use by the ancient Motul residents.

Animal Use

Zooarchaeological remains have been recovered from all deposit types at Motul, including high and low status residences, and ritual and occupational deposits. The remains are unequally distributed across the site, with the majority recovered in two elite residential groups in the monumental core, where excavations were most intense (Table 2). Archaeological interest has highlighted these remains, but we can

Table 2. List of zooarchaeological remains recovered from various proveniences, defined as epicenter, core, or periphery. Counts are listed as NISP.

Group	Deer NISP	Limbs NISP	Marine Exotics* NISP	Ritual Species** NISP	Savanna Species*** NISP	Total NISP
MSJ 2	99	38	16	11	10	404
MSJ 15	42	13	101	0	6	334
MSJ 4	2	2	1	0	0	4
MSJ 1	2	4	0	0	0	14
MSJ 7	6	2	1	0	0	10
MSJ 10	1	1	0	0	0	11
MSJ 13	1	1	0	0	0	4
MSJ 16	1		0	0	0	3
MSJ 17	5	2	0	0	0	18
MSJ 18	0		0	0	0	2
MSJ 19	2	1	0	0	0	14
MSJ 29	0	1	0	1	0	5
MSJ 30	0		0	0	0	7
MSJ 31	0		1	0	0	5
MSJ 32	0		0	0	0	3
MSJ 33	0		0	0	0	3
MSJ 34	1		0	0	0	2

* shell and stingrays
** crocodile and jaguars
*** rabbit and armadillo

calculate density per unit of soil to overcome the excavation bias. After recalculation, these two elite residences are still the loci of a large proportion of the faunal remains, significantly greater than are found in any core or periphery location. This distribution might be a result of preservational differentials between core and periphery, but assuming it is not, it is still difficult to understand exactly what this distribution indicates about elite use of (or ownership of) these resources. Does it represent a greater access to, for example, dietary resources, secondary products (decorative adornments) made from animal products, or other products such as blood used for rituals? It is even possible (although unlikely, with meat products) that these residences were in fact temporary storage repositories for redistribution.

The same two residences are where we find most of the large limb bones of both deer and peccary (food favorites of the Maya elite), suggesting that in fact the elite of Motul had preferential access to dietary favorites (Table 2). However, it is important to recognize the significance of alternative secondary uses of animal bones, particularly the heavy long bones of these two largest common species. In both elite structures, the proportion of artifactual remains to unmodified remains is much higher than it is for most other loci, suggesting in fact that the over-representation is in secondary products - that is, ownership at a secondary resource level, not a primary one.

Intriguingly, however, the proportion of bone working debris is much higher in structures of a secondary status than it is in the upper-echelon elite residences themselves (Table 3). This indicates that in these secondary status groups, bone remains in the trash may also not indicate ownership of animal meat resources, but temporary use of those animal resources for secondary production. Important support for this model of animal ownership at primary and secondary levels lies in the distribution of both exotic (marine molluscs) and ritual species (crocodile, jaguar, etc.). In both cases, these products are again much more frequent in the highest status residences than in any secondary or lower status location (Table 2).

In combination, this preliminary zooarchaeological research suggests that primary control over the acquisition of animals likely lay with the domestic farmers, and that primary meat consumption might also have been under domestic control. However, secon-

Table 3. List of zooarchaeological remains recovered from various proveniences, ranked by status (most to least elite). Counts are listed as NISP and as density/unit excavated.

Group	Frequency (%NISP)	Density (NISP/Unit)	Artifact Frequency (% of Total)	Debitage Frequency (% of Total)
MSJ 2	36.89	4.25	22.77	32.00
MSJ 15	47.56	6.41	71.29	32.00
MSJ 4	0.72	2.00	0.50	0.00
MSJ 1	1.81	3.33	0.99	12.00
MSJ 7	1.08	6.00	1.98	8.00
MSJ 10	1.99	1.57	0.50	0.00
MSJ 13	0.90	1.67	0.00	8.00
MSJ 16	0.36	1.00	0.00	0.00
MSJ 17	3.07	2.13	0.50	0.00
MSJ 18	0.36	2.00	0.00	0.00
MSJ 19	1.63	2.25	0.00	0.00
MSJ 29	0.90	1.67	1.49	0.00
MSJ 30	0.54	1.00	0.00	0.00
MSJ 31	0.72	1.00	0.00	4.00
MSJ 32	0.54	1.50	0.00	0.00
MSJ 33	0.54	1.00	0.00	4.00
MSJ 34	0.36	1.00	0.00	0.00

dary production, at least of bone artifacts, and possibly of other animal products (hides, tallows, etc.) may have been in the hands of the secondary elite, while control over final product ownership rested with the nobility of the site.

It remains very difficult to distinguish actual ownership or consumption of animal meats, fats, and blood from the recovery of its bony remains in zooarchaeological assemblages. In the southern Maya lowlands, environmental archaeology is hampered by both abandonment behavior and poor preservation of organic remains. Ancient Maya occupation surfaces were typically cleaned before abandonment and are therefore devoid of floral and faunal debris. At the same time, high humidity and rapid soil nutrient transfer allow the preservation of only the most robust organics, even in the middens and fill where the remains are typically found. Organic remains are almost invisible in lowland Maya archaeological deposits. A solution to this methodological problem lies in the recent resurgence of interest in geoarchaeological chemistry and its application to household archaeology.

Charting Distribution through Residue Analysis

The recovery of plant remains from house-floors, middens, or any other deposit at Motul de San José has been difficult. In fact, Wyatt has reported that despite flotation of many large soils samples (two to ten liters) from various deposit types, no macrobotanical remains have been recovered (A. Wyatt, personal communication 2002). It is probable that these remains simply have not been preserved in the soils of the site. Animal remains are recovered from most deposit types at the site, and are fairly well preserved in comparison with other lowland sites. However, the total amount of the recovered animal remains is minimal in comparison with the number of animals that must have been hunted and used by the large Motul population over the period of occupation of the site.

The Motul de San José Project has incorporated an innovative new geochemical testing method into the repertoire of more traditional macro-remain analyses in order to track and recognize patterning in otherwise invisible organic resources. Geoarchaeological chemical prospecting, particularly using phosphate markers, is now common in Mesoamerican household archaeology. Phosphates, heavy metals, and trace elements are readily detected and quantified to provide information for archaeological prospecting and activity area studies. Recently, Terry has made strides in the use of inorganic heavy metals and trace elements as indicators of craft activities and residues at lowland Maya sites.

Another set of chemical tests —analyses of specific organic residues such as proteins, fats, starches, and organic carbon and nitrogen— have even greater potential, however, for the study of plant and animal resource use by the southern lowland Maya. Researchers, particularly in northern Mexico, have developed a range of tests for organic chemical residues in archaeological occupational surfaces. This work has shown that organic residues become trapped in plaster and hard-packed soil floors and do not leach over time, and that post-abandonment detritus does not affect the record sealed within the floor surfaces. These methods have been well tested in other regions , but until now have not been attempted in the southern Maya lowlands.

Our preliminary tests of these analytical techniques at the site of Motul de San José suggest that measures of organic residues in house-floors may provide a viable avenue for investigation of otherwise invisible evidence for plant and animal use even in the poor preservational conditions of the southern lowland rainforests. Foias' team has systematically sampled plaster floors from the elite residences and well-preserved occupational surfaces wherever these are encountered (using a 25 cm grid). Analysis of heavy metal distributions using these samples has been successful , but more importantly, preliminary tests for organic residues are intriguing. Phosphate distributions (known to be stable in soils) are complemented but not duplicated by distributions of albumin, a protein-based residue indicative of animal flesh and blood (Figure 4). This suggests variable patterns of preparation, use, or storage of plant vs. animal products in the households of the Motul elite. Tests of fatty acid distribution have not been as successful, but regardless, the evidence indicates that some organics do remain trapped in Motul's plaster floors, and these will have enormous potential where other remains are absent.

Needless to say, the chemical record preserved in floor surfaces is a «signature» of combined traces, and the real information lies in the overlap. Phosphates are well correlated with organic materials. While albumin residues come from solutions containing proteins; fatty acids are the residue of substances formed by oils, fats or resins; and carbohydrates are the result of spilled substances with high starch and sugar levels. Some heavy metals and trace elements are also

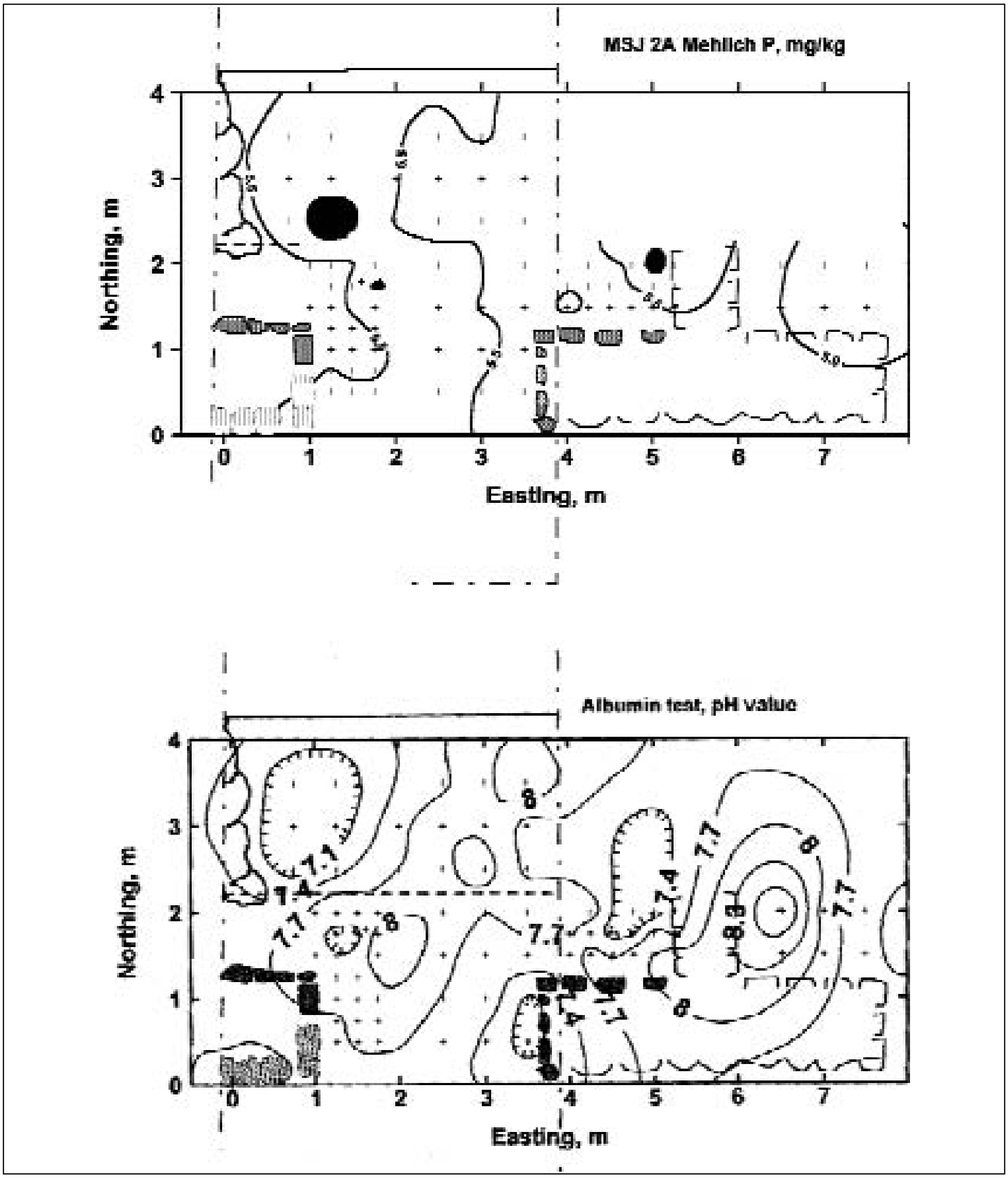

Figure 4. Distribution of phosphates and albumin across the occupation surface of Structure 2, an elite residence in the Motul de San Jose epicenter (Data provided by Richard Terry 2001).

indicative of certain activities. Fernández *et al.* have found that high alkalinity, potassium, and magnesium are associated with ash and lime water from maize preparation. The combination of phosphates and carbohydrates might reveal organic plant materials; a signature combining phosphates with high alkalinity and potassium might indicate maize preparation; and albumin, iron, and fatty acids together might reveal animal product residues. With the addition of complementary studies, we will combine data from inorganic and organic chemical residues to strengthen the interpretive value of our results.

CONCLUSIONS

At the Classic Maya site of Motul de San José, Guatemala, interdisciplinary environmental archaeology is aimed at recreating the economics of ancient natural resource use through the study of patterns of acquisition, use, and distribution of environmental resources. Zooarchaeology, archaeobotany, and geoarchaeology have been combined to reconstruct the flow of natural resources into ancient Motul de San José, the use of these resources by community members, and the movement of natural resource products out of the community through trade. Research is on-going, but preliminary results suggest that these methods can enhance our understanding of Maya economies and environments.

In combination, the conclusions that we can reach using environmental archaeology in concert with traditional archaeological research are intriguing, even at this preliminary stage. For the residents of Motul de San José, remote subsidiary sites like Chachaklum, La Trinidad, etc. likely provided non-local animal resources, such as lake fish, turtles, and crocodiles, as well as species from savanna habitats not found in the Motul precincts. Possibly plant products grown in these other habitats were also provided by the residents of these more distant sites. The site of Trinidad undoubtedly played a broader role as intermediary for trade in many exotics, including coastal products, such as marine shell and stingray spines, that are found in the Motul zooarchaeological assemblages.

The vast majority of the basic natural resources were however available from within the Motul core and periphery. Soils analyses have shown that much of the Motul region had highly fertile soils suitable for corn and mixed crop agriculture. These were more or less susceptible to over-farming and erosion, but were clearly farmed as either in-field or out-field gardens throughout the region. The fact that the preponderance of the animals found in the Motul middens could easily be found in close proximity to agricultural fields suggests that animals were opportunistically hunted by Maya farmers. Most intriguing is the suggestion from soil research that all Motul householders, whether rich or poor, living within the site epicenter or outside it, maintained household gardens including corn among their products.

Our analyses of the process of use and secondary production of animal products suggest that the movement of products through the Motul community was neither simple nor predictable. It is likely that, although lower status householders procured animals for their own food, animal products like bone and hides may well have been supplied to the wealthier residents of the site core for production into tools, adornments, and the like. These products may then have been provided as a tertiary step to the final users, the elite nobles of the site. Whether a similar stepwise procurement system was in place for food products is difficult to ascertain. Certainly the animal evidence suggests that the noble elite were in control over externally acquired exotics such as marine shell, but interestingly, they may have had less control over products from subsidiary sites within the polity.

Eventually, with the addition of macro- and microbotanical analyses in combination with research on food production and storage artifacts, we may be able to reconstruct far more accurately the movement of these often invisible products through the social system of the Motul community. These environmental archaeology methods hold considerable promise in our quest to explore the economics of natural resource use in the ancient Maya world. To reconstruct resource acquisition, we must find evidence of ownership or control over the source locations, in this case the land itself as the provider of both agricultural and wild products. The clues to ownership may well lie in associative patterning between land use and settlement type, although the complexity of this link is clear. Once resources arrive in a community, they are processed, distributed, secondarily reprocessed, stored, and finally consumed. Only the details of household use will provide the robust archaeological data to understand who really owned these materials, and for what purpose. Since environmental products are those most susceptible to degradation in the archaeological record, our job is even more complex, but the methods of residue analysis are opening new doors every day.

Finally, it is important to reiterate that the study of the economics of natural resource use is important in Maya archaeology for several reasons: First, our assumptions of the process of control of the domestic economy are poorly supported by archaeological evidence. Second, understanding the mechanics of control over non-renewable resources will allow us to better approach models of cultural growth and collapse in the Maya world. And finally, the more we understand about ancient use of the fragile tropical rainforest environment, the better equipped we shall be to deal with current struggles in the same arena.

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