Chapter 6
Maya Hunting Sustainability: Perspectives from Past and Present

Kitty F. Emery and Linda A. Brown

Abstract This discussion will present evidence from two research projects, one zooarchaeological and the other ethnozoological, to address questions of sustainability in past and present Maya hunting practices. Zooarchaeological studies of animal remains from archaeological sites across the Maya region reveal some evidence of unsustainable hunting practices, primarily associated with larger and more politically complex settlements. However, these studies do not point to regional overhunting, biodiversity reduction, or extinctions, indicating that ancient Maya hunting was sustainable over 2,000 years. A second study investigates modern highland Maya hunting ceremonialism and reveals complex attitudes to wild animal harvesting. Belief in an "Animal Guardian" who determines hunting quotas and appropriate hunting behavior may link to an embedded conservation ethic. However, zoological harvest information gathered from the remains of hunted animals deposited at hunting shrines suggests that modern hunting practices may not reflect that ethic. Together, the two datasets are used to explore issues of complexity in past and present hunting activities. In each study, potentially sustainable practices become less-so under certain circumstances, particularly those causing stress on previously stable animal management systems. Some thoughts are offered on the difficulties and benefits of disseminating these complex results to different audiences. The value of understanding the factors that drive both sustainable and unsustainable practices far outweighs the disadvantages of presenting potentially unpalatable

K.F. Emery, Ph.D. (✉)
Florida Museum of Natural History, University of Florida,
117800 Dickinson Hall, Museum Road, Gainesville, FL 32611, USA
e-mail: kemery@flmnh.ufl.edu

L.A. Brown, Ph.D.
Anthropology Department, The George Washington University,
2110 G St., NW Washington, DC 20052, USA
e-mail: labrown@gwu.edu

information about indigenous environmental resource management. The difficulty lies in presenting the research to each stakeholder in terms and contexts that are appropriate to understanding the implications of the data.

Introduction

Zooarchaeologists and other environmental archaeologists are motivated in large part by our hope that the archaeological record of ancient peoples and environments can provide useful lessons about how we should manage our modern relationships with the environment and particularly animal communities (Albarella 2001; Frazier 2007; Lyman and Cannon 2004). We hope that our investigations will assist indigenous and local communities in their quest for sustainable animal exploitation in the same locations and habitats that we have studied (for an example of modern studies of animal exploitation in the Maya area, see Naranjo and Bodmer 2007; Naranjo et al. 2004). We also hope, in a broader perspective, that our data will provide generalized models for sustainable living for all human groups. We are not alone in the hopes that our research will provide a broad panoply of benefits, and in fact conservation biologists have begun explicitly emphasizing approaches that maximize multiple benefits (see, Robinson 2010). By understanding the long tenure of the Classic Maya civilization in the fragile environments of Mesoamerica, we might learn better techniques for supporting large human populations, dense settlements, and natural resource exploitation in such areas. However, the goal and its realization are separated by a long trail of hurdles, some in the realm of science, others in the realm of communication and miscommunication.

In this chapter, we present a comparison of hunting sustainability among the ancient and modern Maya based on ecological models applied to animal bones recovered from lowland and highland archaeological sites and highland historical and modern sites (Fig. 6.1, Table 6.1). This comparison is based on Emery's zooarchaeological work on ancient Maya hunting and its effects on lowland Maya animal populations, and Emery and Brown's comparative ethnozoological research on modern hunting ceremonialism among the highland Tz'utujil and Kaqchikel Maya. Here, we discuss the results in a context of the difficulties to using ecological models of modern sustainability on archaeological datasets, the further challenges to questioning the intentionality and driving forces behind sustainability, and finally the very real question of appropriate dissemination of these complex research results to various audiences.

Two of the contextual difficulties to this research are commonly discussed in the environmental archaeology literature, that of the use of analogies and models, and that of the connection between our evidence and the real "intent" or mindset of an ancient peoples. The third, the difficulties of dissemination, is the theme of this volume but is rarely discussed in scientific presentations. However, in order to realize our goals and hopes about the "lessons" our data can provide, we must be cognizant of the hurdles faced by our research when it leaves our hands. These "lessons" have the
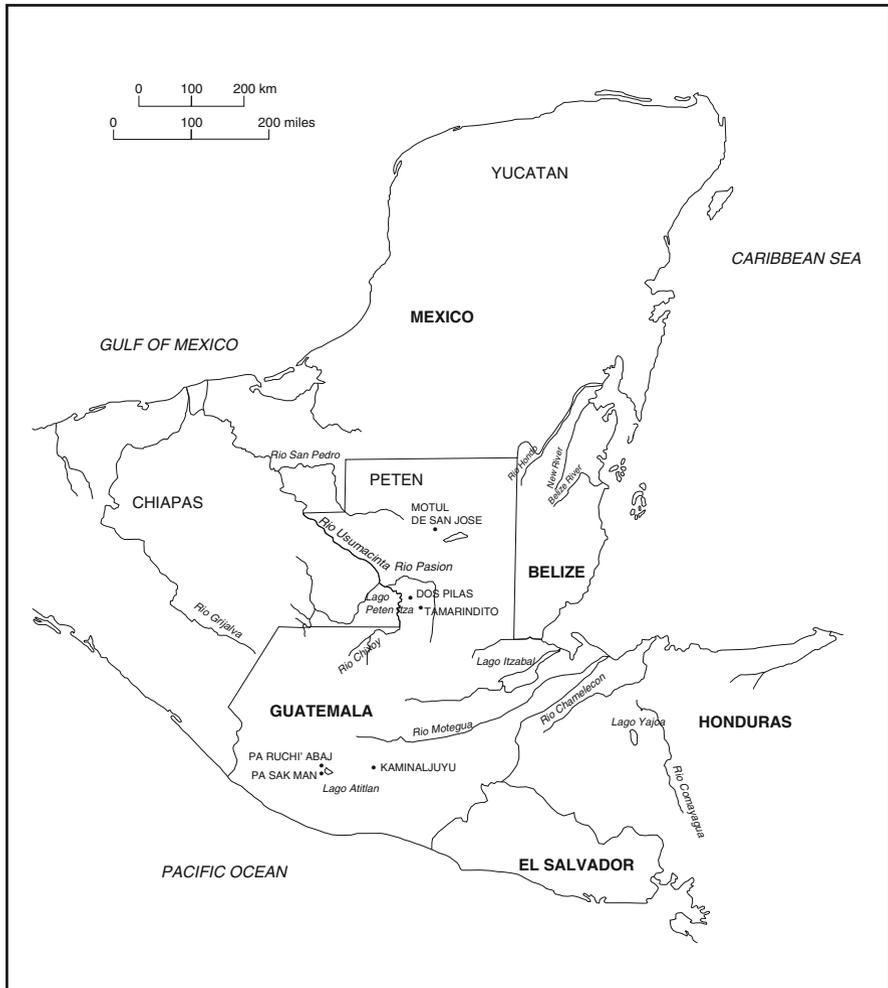
Fig. 6.1 Map of the Maya area with study sites marked (map by Emery)

real potential to be misunderstood, misrepresented, and misused by all the audiences they reach. We are all likely familiar with these stories, but here is Emery's – an experience that informs this paper and her subsequent research efforts.

Several of Emery's recent studies have attempted to evaluate the impact of ancient Maya hunting on the animal populations of the region. Emery compiled a large comparative zooarchaeological database and tracked first the effects of ancient Maya hunting within a single region or "hunting patch" – the Petexbatun political unit or polity (Emery 2008b) – and also those same effects across the Maya low-lands as a broader and more heterogeneous region (Emery 2007). In these studies she tested for reductions in the availability of favored prey by applying basic animal

Table 6.1 Generalized chronology of Maya prehistory

Period	Dates
Colonial	AD 1519–1821
Late Postclassic	AD 1200–1519
Early Postclassic	AD 1000–1200
Terminal Classic	AD 800–1000
Late Classic	AD 600–800
Early Classic	AD 300–600
Terminal Preclassic	AD 100–300
Late Preclassic	300 BC–AD 100
Middle Preclassic	900–300 BC
Early Preclassic	1800–900 BC

Dates are from Adams and MacLeod (2000) and Sharer and Traxler (2005). Period beginning and ending dates vary somewhat between sites in the Maya area

biology measures and foraging ecology, a model used by conservation biologists to track modern hunting sustainability in modern situations. Her results revealed no evidence of reductions in biodiversity or availability of game prey, although in some areas there was evidence that significant harvest pressure had been put on the most valued species, white tailed deer. This suggested that although the ancient Maya did not consistently overhunt their prey base, in some circumstances, particularly when political pressures were high, they did overhunt the local deer populations around some sites.

Emery presented these results in what she assumed to be a balanced manner, with careful consideration of the scientific hurdles to such analyses, in two widely read peer-reviewed journals within the biological sciences. She also presented her data informally to researchers affiliated with governmental (the Consejo Nacional de Areas Protegidas de Guatemala or CONAP) and nongovernmental (Wildlife Conservation Society) organizations, as well as to several Maya colleagues and informants in Guatemala. Her hope was to connect the data with the conservation biologists and local practitioners who were simultaneously determining best-practice in bush-meat hunting in the Petén lowlands where the work had been conducted. She was therefore initially pleased to receive media attention to her work, but then was horrified by the evident lack of comprehension or sensitivity with which the media-writers handled the results. From Reuters Guatemala came the headline: "Ancient Maya Elite Binge on Big Game, Loved Furs" (http://uk.reuters.com/article/idUKN1248947920071112). The Newspaper USA Today took an entirely different (and more accurate) reading in "Did Environmental Disasters Play Role in Mayan Decline" (http://www.usatoday.com/tech/science/columnist/vergano/2008-11-08-mayan-decline_N.htm). Interestingly, Al Gore's blog then somewhat misinterpreted the USA Today article by stating that "A new study suggests the Mayan civilization might have collapsed due to environmental disasters" (http://blog.algore.com/2008/11/looking_back_to_look_forward.html). Even the National Geographic

News "Maya Rituals Caused Ancient Decline in Big Game," who's reading of the research was much more balanced, presented the work alongside the classic image of jaguar sacrifice at Copan (http://news.nationalgeographic.com/news/2007/11/071115-maya-sacrifice.html). So much for carefully balanced presentation of what was in essence a heuristic exploration using ecological models and animal bones as proxy! The situation could be simply a source of head-shaking amusement at the inaccuracies of the press. Unfortunately, the reality is that these misrepresentations are the messages that are most widely available to the modern Maya and other residents of the area (Reuters Guatemala). They are also the ones that are used in portraying the Maya [the movie Apocalypto (Gibson 2006) for example, or "Collapse" by Jared Diamond (2004)], and in providing political support for conservation efforts (Al Gore's blog).

In conversations with conservation biologists and the Maya hunters, Emery also perhaps missed the mark in ensuring that her research was fully understood. The biologists continue to find it difficult to accept the role of archaeological data in providing baselines and models for modern animal conservation (for full discussions see Frazier 2007; Lyman and Cannon 2004). Although for ecological discussions on the importance of conservation research in human-managed ecosystems see such works as Gardner et al. (2010). The Maya hunters were also somewhat dubious of the relevance of Emery's information, for reasons that will be discussed later in this paper. However, she continues to feel it is important to fully share her data with the scientific communities (both anthropological and biological), the general public (unfortunately via the media), and the local practitioners and environmental conservationists. Therefore, in this paper we present a new analysis of modern and historic Maya hunting impacts that we compare to Emery's studies of ancient assemblages. We also discuss the importance of presentation of the full dataset, with clear discussions of the potential difficulties in the analysis, and with an eye to the audience and their understanding of the topic and methods.

Research Background

Our research is based in the geographic region that was once the Maya heartland, now including the countries of Mexico (from the Isthmus of Tehuantepec south), Guatemala, Belize, and Honduras (the northwestern half). This region was undoubtedly occupied from earliest Paleoindian times, but the first evidence of "Maya" activities occurs in the Preclassic ~2000 BC. The ancient Maya are most commonly recognized by the massive constructions of their densely settled cities in the tropical forests, the "temples in the jungle." The Classic Maya civilization is also characterized by literary and artistic accomplishments, by a mastery of calendrics and mathematics, and the early development of statehood with hereditary rulership and a fully hierarchical society at least by Late Preclassic (300 BC to AD 100). The Late Classic florescence of the southern lowlands with its divine kings, immense cities, large populations, and complex economic systems, met with a social and political

disruption in the Terminal Classic (AD 800–1000) and into the Postclassic (AD 1000–1500 and contact). This "collapse" may have been associated with landscape and climatic changes, but was certainly characterized by population shifts, cessation of monumental construction and abandonment of many sites in the southern lowland core, and sweeping economic and political changes. The Maya people and many aspects of their culture have survived these internal shifts, the arrival of the Europeans, modernization, and civil strife including attempted genocide, to remain one of the dominant indigenous cultures in Mesoamerica today (Menchu 1983).

Particularly in the southern lowland heartland of Classic Maya florescence, the populations of the past were higher even than they are today, the cities were hubs of social and economic activity, and a political elite competed for high-status goods, including symbolically important animals. In the highlands of Guatemala and southern Mexico, and the northern Yucatan lowlands, the modern population now far outnumbers the ancient population but these areas were also densely populated and intensively used in the past. The Maya region, including southern lowland semitropical forests, northern lowland xeric landscapes, and volcanic deciduous forest uplands, together encompasses one of the world's biodiversity hotspots, containing the second largest proportion of endemic vertebrates in the world (DeClerck et al. 2010:Table 6.1; Myers et al. 2000:857, Table 6.1). Despite seemingly overwhelming odds for unsustainable environmental interactions during the 2,000 years of Maya occupation, three decades of zooarchaeological research has provided no evidence of animal extinctions or even local extirpations (Emery 2007) such as we see in many other areas (e.g., Steadman 2006). As described above, zooarchaeological studies of hunting impact have provided no proof of long-term or consistent unsustainable animal use over the period of occupation of the Maya region. Similarly, later landscape analyses based on animal–habitat correlations did not find evidence for pan-Maya area deforestation although it is clear that forest-cover was regionally variable (Emery and Thornton 2008a, b). It is most likely even in areas where primary forest-cover was depleted, that secondary forests were well managed to retain biodiversity (Ford and Emery 2008; Ford and Nigh 2009). Together, these results indicate an overall tendency toward sustainable land and animal use among the ancient Maya although the site-level details also emphasize the negative effects of extreme population growth, political competition, and external stressors such as climate change (Emery and Thornton, in press).

However, implicit in the definition of sustainability is the idea of intentionality. And here our research has turned to ethnozoology, the study of modern indigenous and local animal use practices.

Highland Ethnozoology

This interest in modern and historic hunting practices grows out of collaborative research between Emery and Brown, focusing on Brown's studies of modern hunting ceremonialism in the Atitlán area or region of Guatemala (Fig. 6.2). Hunting shrines,
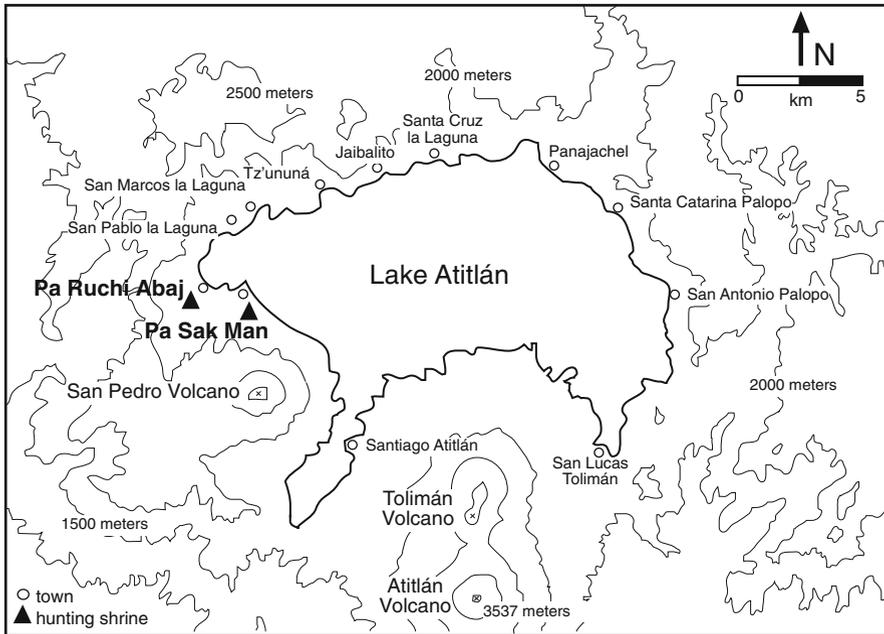
Fig. 6.2 Map of Lake Atitlán, Guatemala with shrine sites marked (map by Brown)

the first of their type to be correctly identified in the Maya region, were first described by Brown in her study recording sacred sites/wilderness shrines in the Tz'utujil, K'iche' and Kaqchikel areas of highland Guatemala. Brown's larger research project resulted in the identification, description, and mapping of over 100 shrine sites, 40 of which are located around Lake Atitlán (Brown 2002, 2004, 2005; Brown and Romero 2002). Brown has identified 17 hunting shrines around Lake Atitlán associated with the communities of Santiago Atitlán, San Pedro la Laguna, San Juan la Laguna, San Pablo la Laguna, Tz'ununá, San Antonio Palopó and the archaeological site of Chuitinamit (Brown 2006). Many of these are abandoned, but some are still in active use by the modern hunters of the region for various rites associated with hunting and wild game. Each is associated with a stone landscape feature (the doorway into the mountain), altars and hearths for ritual performance, and a cache of skeletal remains of hunted animals (Figs. 6.3 and 6.4).

Brown has shown that for the modern highland Atitlán Maya, hunting is a highly ceremonialized activity linked to a strong animistic belief in an Animal Guardian or *dueño* (owner) of wild or game animals who resides in the mountains and hills and protects and regenerates the wild animal populations (Brown 2004, 2005; Brown and Emery 2008). This is one of many beliefs associated with a concept of the cyclical regeneration of life force that in hunting ceremonies ensures animal population regeneration through return of animal parts by hunters to the Animal

Fig. 6.3 Overview of portion
of Pa Sak Man rock shelter
showing bone cache behind
rock wall and under boulders
(photo by Brown)

Guardian (Brown 2005:140). In 2006 and 2007, Brown and Emery joined forces
on a collaborative zooarchaeological and spatial archaeology study of three of these
shrines in which we defined the material correlates of the ritual practices associated
with hunting ceremonialism (Brown and Emery 2008).[1] Subsequently, Emery and
her students used these correlates to examine archaeological assemblages for evi-
dence of similar ancient hunting shrines (Anderson 2009; Emery et al. 2007, 2009).
The work presented here represents our first attempt to use the animal remains from
the hunting caches in search of markers for hunting sustainability.

   Brown has shown that contemporary Tz'utujil and Kaqchikel hunters conduct
pre- and post-hunt rituals to ensure personal safety and success in the pursuit of wild
game. Many pre- and post-hunt rituals take place at hunting shrines associated with
sacred landscape features, usually caves or rockshelters, openings into the rocky

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[1] We mapped and defined activity areas at each of three active communal shrines with the assis-
tance of hunters and ritual practitioners. We recorded zooarchaeological data such as species,
element, age, sex, side, and modifications on all remains, and linked these to the specific activity
areas at each shrine. More recently we have been using these data to search for hunting shrines in
the archaeological record which might indicate a continuity of these beliefs and practices into the
ancient history of the Maya (Emery et al. 2009).

Fig. 6.4 A ritual practitioner prepares an offering of sugar, copal incense, and candles on a stone altar before investigations at a hunting shrine (photo by Brown)

hillsides and mountains where the Guardian of the Animals is believed to reside (Brown and Emery 2008: 315). At these locations, hunters often bring offerings to the Guardian with the hope that he will grant permission to take the lives of animals that reside in his forest domain.[2] After a successful hunt, the bones from the hunted animal are carefully curated and returned to the hunting shrine as part of the post-hunt ritual that also included offerings of thanks and material objects (Brown 2005:132). The process of butchering, handling, and returning animal bones to the hunting shrine in an appropriate manner is part of the social obligation that hunters have to the Animal Guardian (Anderson 2009; Brown and Emery 2008: 311, 314). It allows the hunters to prove they have followed the instructions of the animal guardian and have not hunted too many animals.[3] More importantly to this discussion, it also returns the deceased animal's life force to the Guardian who then uses the curated bones to repopulate the forests and ensure a steady, sustainable supply of forest game. This process is linked to the Maya cycle of death and rebirth called *jaloj-k'exoj* (Carlsen and Prechtel 1991:32–36) in which life-cycle changes (*jal*) are

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[2] In Santiago Atitlán, the Tz'utujil Maya make pre-hunt offerings and hunting permission requests to the animal guardian in the *Cofradía* San Juan where they have transformed a colonial-period statue of Saint John the Baptist into the Guardian of the Animals (Carlsen 1997:98).

[3] As the caretaker of wild fauna, specifically land mammals, the *dueño* protects the creatures of the forest making sure hunters do not abuse them or take more creatures then needed. If hunters do not maintain all ceremonial protocol, the animal guardian exacts revenge that can result in illness or even death of the person (Brown and Emery 2008).

linked to the transfer and continuity of life (*k'ex*). Brown (2005:140) suggests that the bones are "planted" as seeds for the later "flowering of the dead" (Carlsen and Prechtel 1991) as part of a symbolically linked requirement to replace an animal's life (*jal*) through regeneration (*k'ex*) using the animal's bones.

Brown argues convincingly that this belief system and the practices associated with it might have prehistoric antecedents (Brown 2005:138). The belief in an animal guardian is geographically widespread within the Maya region and into Mexico and Honduras. Historic, Colonial, and Postclassic documents trace a long historic continuity in hunting ceremonialism, and hunting-related rites are evident in even the earliest Classic Maya depictions and writings. A close relationship between the modern Animal Guardian, the Colonial Suhui Dzip, the Postclassic God Y/Uuc Zip, and the Classic period T'zip has been well documented in the literature (for more details, see Emery et al. 2009).[4]

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[4] In her extensive review, Brown notes ethnographic accounts of an animal guardian among the Yukatek, Mopan, Huastec, K'iche', Tzeltal, and the Tz'utujil Maya (all examples are from Brown 2005:138). The Chortí of Guatemala receive instructions from the guardian of the deer in a dream before their hunt (Wisdom 1940:72–73). The Yukatek Maya provide maize offerings to the forest spirit known as T'zip, the supernatural protector of deer, to ensure hunting success (Redfield and Villa Rojas 1934:140). The Mopán Maya of Belize burn copal offerings to the morning star as the owner of animals (Thompson 1930:142). Among the Huastec Maya of Veracruz, pre-hunt rituals include the ceremonial opening of a corral with an enclosed deer skull which signifies the release of a deer from the "master of the animals" (Alcorn 1984:88). The Huichol of northern Mexico offer rites to the divine owner of deer (Myerhoff 1974:201). Brown offers many more examples.

Brown and Emery (2008) also report that in the Guatemalan highlands, Archbishop Pedro Cortes y Larraz (1958 [1768–1770]:119–120) referred to hunting rituals where burned offerings were made around a deer carcass to a deer lord named Xaqui Coxol and he noted that the deer bones were carefully guarded to avoid the anger of Xaqui Coxol. Sapper (1897:268) recorded a deer-hunting ritual and offering of the head to Tzultakah (lord of the forest and guardian of animals) by Tzeltal Maya of Chiapas. Colonial period indigenous texts such as the sixteenth-century K'iche' Popol Vuh also document an animal guardian (Tedlock 1985:51, 76–77).

Several researchers have linked the modern and historic descriptions of the animal guardian to depictions of God Y in the codices, a god associated by many researchers with hunting and wild animals, particularly deer. God Y is evident in the Madrid Maya codex (Tozzer 1941:155, n. 780; Vail 1997:75; Zimmermann 1956), in various hunting almanacs, using deer accessories such as a deer headdress, antlers, and deer-ear ornaments (Bill 1997:114; Vail 1997), or with a deer, in both the Madrid (Taack 1973; Vail 1997) and the Maya Dresden codex (Colas 2006:83; Taube 2003:473, 475, Figures 7b-c). *God Y's name is read as Uuc Zip or 7 Zip in Yucatec orthography* (Davoust 1997; Taube 2003:473), and the deer is sometimes described as *yatan* or "wife" of *Uuc Zip*. Gabrielle Vail (1997, 2005) and others (Bill et al. 2000; Bricker 1991; Colas 2006; Taube 1988) link God Y with the hunting god *Suhui Dzip* described by Diego de Landa (Tozzer 1941).

In Classic Period iconography, Taube (Taube 1997, 2003) has described the deer guardian *T'zip* depicted as a wrinkled old man with deer-like attributes including deer ears, antlers, and lips, as well as hunting clothing and accoutrement such as a grass skirt, broad-brimmed hat, or a conch shell trumpet (Brown 2005:139). Known depictions of *T'zip* are found on Classic Period ceramic vessels (Taube 2003:Fig. 26.7e,g) and in the painted murals of Bonampak (Taube 1997). Epigraphic references to *T'zip* are found in stone inscriptions at Copan (Taube 2003:Fig. 26.7c) and Dos Pilas (Taube 2003:Fig. 26.7b).

However, the apparent sustainability ethic that is embedded in the lore of the Guardian is not necessarily equivalent to an explicit model of sustainable hunting among the hunters. In interviews with the modern Atitlán hunters, we have been told that they take any animal that "offers" itself because those animals were sent by the Guardian[5] (Brown and Emery 2008:312). During our informal conversations with the Maya ritual practitioners and hunters in 2007, it became obvious that the hunters do not specifically associate their activities with an attempt to maintain healthy animal populations although they are clearly aware of appropriate hunting methods since they also discussed the importance of avoiding breeding females and juveniles. When we discussed our archaeological findings with them, they were interested, but when we suggested that they too could learn from the studies, they reassured us that such information was unnecessary since the Animal Guardian determined appropriate hunting culls.

In a separate study in 2005, Brown and Emery conducted additional interviews with both indigenous (Itzaj) and local (Kekchi migrants from the highland) hunters in the Petén lowlands as an incidental part of other research on the practices of animal acquisition, use, and discard (Emery 2008a; Emery et al. 2009). The Itzaj Maya have been resident in the region since before the Postclassic period, likely having originated in the northern Yucatan. The Kekchi migrants are displaced highlanders who moved to the region beginning in the 1940s. In that study we interviewed 16 hunters, four of whom were specialist/full-time hunters, two recent migrants who were accustomed to hunting with tourists as well as for their own communities, and two traditional Itza hunters (Emery 2005 Unpublished Interview Notes). We found that although all had heard of the Animal Guardian or a similar being (both Itzaj hunters and one Kekchi hunter), none commented on following the same practices of either nonselective hunting or bone caching. The Itzaj hunters made explicit statements of conservation ethics about both hunting and other environmental resource uses, noting that they do not hunt females during and following the breeding season (or, at all if they are considered a "menstruating" species such as the small agouti), that they do not hunt juvenile individuals, and that they do not take more than a few individuals at a time.[6] They were apparently unaware of, or uncaring of, the various "official" hunting regulations stated by the local wildlife officials (such as CONAP). The migrant Kekchi Maya were more specific about appropriate hunting seasons,

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[5] Formal interviews by Brown and informal discussions with Emery in 2007

[6] Clear prey age and sex preferences are made by both the specialized hunters and the farmer/hunters. None of the hunters preferentially will hunt an immature animal of any game class except when hunting crias to take as pets (Emery personal experience and Jorge). All the hunters agree that males are preferred over females when hunting large game either because the males are bigger (Gabriel) or because the females might have young (Gabriel, Guadeloupe, Jorge) and may continue producing (Cornelio). Less emphasis is put on sex of small game and although males are still preferred (Guadeloupe, Cornelio), "they don't stop to check" (Guadeloupe). Interestingly, one informant (Cornelio) commented that only males are taken when hunting sereques and micos because "the female menstruates and they're too much like little women". (All from Emery 2005 Interview Notes)

target catches, and the like, suggesting that they were well aware of "official" hunting regulations and may not have been entirely accurate in their discussion of hunting methods (Emery 2005 Unpublished Interview Notes).

Overall, this new insight presented us with an intriguing question that we test in this paper. Would the modern traditional practices, couched in symbolic and animistic terms and yet so clearly embedded in a long cultural history of respect for animal populations, prove to be more sustainable than the ancient practices? We hypothesized that these hunters, despite their stated lack of agency in prey choice at least in the highlands, were in fact following a generations-old set of mores and customs designed to limit overhunting and that foraging model tests of resource depression would reveal the prey population to be overall larger, less diverse, and more mature than the ancient prey. To be forthcoming about our own biases, we sincerely hoped to find clear evidence of sustainable activity in the modern assemblages because this would allow us to present our results in a positive light to the hunters who were so willing to participate in our research.

A Comparison of Ancient and Modern Hunting Sustainability

The Comparative Samples

This paper describes the Atitlán cache remains in terms of foraging ecology and other sustainability measures that are used in zooarchaeological studies and that are often used in modern ethnographic and conservation biology studies of hunting sustainability. These measures are then compared to archaeological samples.

The Atitlan Cache Assemblages

We use samples from two of the three shrines that we studied in collaboration in 2007 (Brown and Emery 2008). Both were well preserved and reflective of the activities that created them. The third shrine we investigated had been partially destroyed by a rock-fall and our analyses were incomplete. The two shrines used in this analysis were also similar in that the hunters professed to return all the bones of the skeletons of all the game they hunted (Brown and Emery 2008:313). The hunters noted that every bone returned was regenerated by the Animal Guardian as a new animal, so it was important to return even the smallest toe bone. Bones were curated after hanging in baskets at the hunters' homes and were returned on a regular basis, sometimes determined by calendrics or auspicious events (Brown and Emery 2008:314).

The first shrine used in this comparative analysis is Pa Ruchi Abaj, a communal hunting shrine associated with the town of San Juan la Laguna. The site, a flat shelf nestled in front of a massive outcrop and surrounded by large boulders, is completely covered by bone remains that appear to be a single faunal cache representing a

dense cap of primarily mammalian bones at least half a meter thick (Brown and Emery 2008:307; Emery et al. 2007). We calculated that the remains contained in this cache were in excess of 600,000 (Brown and Emery 2008:318; Emery et al. 2007). The cache/performance space is approximately 3 m × 3 m, fronted by a retaining wall and in situ boulders, and reaching back into two alcoves on either side of the outcrop. A single hearth lies partially on flat ground and partially on a flat boulder-top at the front of the site, separated by a few centimeters from the trailing edge of the deposit. An altar composed of several flat rocks separates the north alcove from the open space in front. Pa Ruchi Abaj is currently abandoned, although there was some evidence that it is currently undergoing reclamation and limited use. Brown's ethnographic research found that most residents of San Juan la Laguna did not remember a time when Pa Ruchi Abaj was in use. The exception was one 89-year-old resident who remembered attending a post-hunting ceremony at Pa Ruchi Abaj when he was about 10 years of age (Brown 2006:13). This suggests that primary use of the site was at least 80 years ago.

The second shrine used for comparative analysis of hunting sustainability here is Pa Sak Man (Brown and Emery 2008:308). This is one of three hunting shrines recorded around San Pedro la Laguna, and is an active communal shrine site located approximately 400 m south of the town. The site consists of a west-facing rock shelter used for various types of ceremonies including hunting rites. The most conspicuous features at Pa Sak Man are the bone deposits. Two main fauna caches are present, one of which consists of hundreds of bones carefully placed under an alcove within the southern part of the shelter. A smaller primary feature was found on an elevated ledge in the east part of the shelter. Additionally, bones were tucked into various small alcoves along the rock shelter's back wall. The shrine also contained an altar area, sacrificial offering hearths, and a cleared maintained performance space. Hunters discussed using this site both for pre-hunt requests for hunting permission and for post-hunt caching and other dedicatory rites (Brown Unpublished Interview Notes).

The Archaeological Assemblages

The results of the cache analysis are presented in comparison with ancient examples from both the highlands and lowlands. We compare the hunting cache assemblage with animal remains from archaeological sites – the largest highland Preclassic center (Kaminaljuyu), a large lowland political capital of the Classic period (Dos Pilas), a mid-size lowland political capital of the same period (Motul de San Jose), and a Classic period secondary center under the rulership of Dos Pilas (Tamarindito). Kaminaljuyu was chosen because it is a highland center, but the sample is small and less useful in comparative terms (Emery et al. in press). Dos Pilas was chosen because it is one of the sites Emery has studied and presented in other publications (Emery 2007, 2008b, 2010), however, this is a large political center and the assemblage is representative of both elite activity (particularly in the Late Classic) and bone artifact crafting (particularly in the Terminal Classic). Therefore we have also

chosen to include two other sites studied by Emery: Motul de San Jose, a smaller though still important political capital (Emery 2003, in press) and Tamarindito, a secondary center that was not as politically active as either capital site (for full details for Tamarindito and other Petexbatun sites, see Emery 2010).

Methods of the Comparison

All samples were identified by Emery and her students using identical methods, most using the comparative collections at the Florida Museum of Natural History, University of Florida. The hunting shrine remains were identified on-site using a digital archive of the FLMNH comparative collections since these were ritually valued sites and the practitioners requested that all remains stay on site. We were permitted to collect the remains for analysis and then return them to their cache locations following identification.

All remains, modern and archaeological, were identified to the lowest possible taxonomic level. Taxonomy is based on the latest nomenclature available from http://www.itis.gov. We also analyzed element, element portion, side, age, sex, and modifications. All analyses are accompanied by full contextual information. This presentation does not provide full details of the analyses as these are available in the publications cited above. Here, we present a full list of species with counts for NISP (Number of Identified Specimens). This measure provides a maximum estimate of the number of animals represented in the sample. It presents an inflated value for species with very numerous skeletal elements. In our comparative analysis this is true only for the armadillo with its enormous number of scutes. For that reason, in this analysis, scutes are excluded (for more details, see Grayson 1984; Reitz and Wing 2008).[7]

This investigation is based on the results of various measures conducted for each time period at each site. These include the ratio of large to overall game species, diversity (heterogeneity), age profiles, and taxonomic vulnerability. Each of these measures is an attempt to evaluate the long-term sustainability of hunting practices. To estimate the effect of hunting on the local populations, we do not include any exotic taxa in these analyses. Since all of these sites are located inland, all marine species are exotic to their location and are therefore not included. We also do not

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[7] We cannot provide a direct quantification of the actual number of animals that contributed to our samples because the processes of use, deposition, and preservation are so variable that it is impossible to accurately predict the correlations between the animals used and the animal bones recovered. The NISP provides a count of all specimens analyzed but this measure over-represents animals that have very numerous skeletal elements as well as those with very well preserved elements (e.g. between robust bivalve shells and the fragile and delicate cranial bones of a fish). However, our comparisons are based on taxa from a single class, mammals, that are relatively similar in terms of preservation and recovery. Therefore, the NISP provides an accurate assessment of relative frequency in this study.

include the domestic dog since a domesticated species is not affected by hunting pressure although it was clearly eaten in the past (see for example, Clutton-Brock and Hammond 1994; Valadez Azúa 2000).

We begin with an evaluation of harvest efficiency based on models developed and used in foraging ecology (Stephens and Krebs 1986) and applied to zooarchaeological data (Broughton 2001; Broughton et al. 2007). These studies have shown that humans, like other predators, attempt to maximize the efficiency of meat return by focusing on the preferred ("highest ranked") species. Broughton (1994:502) has shown that overall prey size can be used as a direct proxy for prey rank although the relationship between size and nutrient return is not an absolute correlate. When the high ranked or largest and most easily hunted prey are overexploited, these populations are reduced and the prey become less available to the hunters and less efficient to harvest (Broughton 2001; Madsen 1993). This reduction is termed a resource depression. Ethnobiological and ecological studies show that hunters faced with a resource depression typically turn to a wider diversity of smaller bodied prey. In zooarchaeological terms therefore, high foraging efficiency is represented by a dominance of large, easily hunted, prey species. The adverse impact of high foraging efficiency, or overhunting of these favored prey, can be seen in two ways: (1) the relative reduction of large prey taxa and increase in smaller prey taxa, and (2) the increase in diversity of prey taxa overall.

We measure foraging efficiency here as the ratio between the number of remains identified as top-ranked species by size (white-tailed deer, peccaries, brocket deer, tapirs and large cats) and those identified as all other mammalian taxa combined [Σ large mammals/Σ(large mammals + all mammals)]. We estimated the diversity of past hunted prey as taxonomic heterogeneity using Simpson's (1949) index of heterogeneity [$N(N-1)/\Sigma n(n-1)$] where n = specimen count/taxon, N = total specimen count. These measures have been used frequently in archaeological studies (Cruz-Uribe 1988; Leonard and Jones 1989).

We also consider the effects of hunting on specific taxa and individuals within populations. Hunting practices that minimize the effect on a population's ability to reproduce are those that are the most sustainable. Animal populations are most severely impacted when hunters reduce the proportion of breeding females, do not permit juveniles to reach full maturity, or allow the population to reach levels below which reproduction is unlikely to be sufficient to fully (or healthily) repopulate the group. Here we measure the proportion of juvenile individuals within the animal remains, specifically evaluating the proportion of pre-breeding-age juvenile elements as shown by completely unfused epiphyses, unerupted teeth, and other markers of juvenile status. There is insufficient evidence in these zooarchaeological samples to compare sex of the hunted population although that would be very useful.

Ecologists determine animal population vulnerability to exploitation using data on rate of population increase, longevity, and generation time (Bodmer et al. 1997; Robinson and Redford 1991; Robinson 2000, 2001). In general terms, long-lived species with low natural productivity (low rates of natural population increase and long generation times) are most vulnerable to harvest. In addition, species with larger body sizes are generally slow to reproduce and often have low rates of natural

productivity. These species are more vulnerable in situations of reduced population density as a result of hunting pressure, and when habitats become less available, for example as a result of deforestation (Bodmer et al. 1997; Naranjo and Bodmer 2007). Unfortunately, ecological information on the specific rates of reproduction and longevity is rare for the lowland Maya region (although, see Novack 2003) despite work by the WCS and other conservation biologists in the area (for example, see Thornton et al. in press; Zeller 2007). Needless to say, there is no equivalent specific data for the ancient animal populations. Therefore in order to determine which species should be considered most "vulnerable" to harvest pressure, we rely on generalized information on species productivity (r_{max} or intrinsic rate of natural increase), longevity (as age at last reproduction), and generation time (as age at first reproduction) as compiled from the literature for various neotropical regions (Bodmer et al. 1997; Mugaas et al. 1993; Novack 2003; Novack et al. 2005; Robinson and Bennett 2000, 2004; Robinson and Redford 1986, 1991; Slade et al. 1998; Zapata Rios 2001).[8]

As shown in Table 6.2, the vulnerable taxa of the ancient and modern Maya world primarily include the cats (jaguar, puma, and perhaps ocelot), monkeys (both howler and spider), and the large-bodied tapir. More stable taxa include rabbits, squirrels, opossums, white-tailed deer, raccoons, the peccaries, the paca and agouti, the coati, and the armadillo. Taxa such as brocket deer and tamandua are also considered vulnerable using some measures, but are not consistently considered as such, so we do not include them here.

This study is biased by the comparison of highland and lowland assemblages. These are two different ecosystems with different animal population dynamics. The cultural groups, despite all being Maya, are also quite different in many ways, and we are unable to know what differences might have existed over the very long period of archaeological prehistory. In addition, the human population distributions would have been very different over time with the highest population densities having occurred in the Late Classic lowlands, probably even higher than the modern densities in the villages surrounding the modern/historic caches. In addition, investigation methods differed between assemblages. Most or all of the remains were recovered in the modern assemblage while the ancient assemblages were likely much less representative of the entire hunted prey group.

In addition to comparing samples between cultural regions, we also attempt to compare between the hunting shrines. The shrine of Pa Ruchi Abaj was likely the oldest (memory of grandfathers using the site, but little recent activity) and Pa Sak Man the youngest (modern activity even during our studies). At the shrines only mammals were included in the animals to be returned for curations (we were also taken to a fishing shrine, but unfortunately the remains of fish and other water fauna

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[8] Data from other neotropical areas, although not as accurate as data from the specific region from Novack 2003 and Novack et al. 2005, are likely be within the range of population variation to be expected in comparing modern to ancient populations.

Table 6.2 Table of data used in estimating the vulnerability of the primary game species of the Maya

	Body mass (kg)	Longevity (age of last reproduction)	Generation time (age of first reproduction)	Intrinsic rate of natural increase (r_{max}, = age of first last reproduction and annual birthrate)	Comparative species
Howler monkey	6.5[b]	25[b]=long	4.5[b]=old	0.17[b]=more vulnerable [g]	
Lowland tapir	149[b]	23[b]=long	3.7[b]=old	0.2[b]=more vulnerable [g]	*(Tapirus terrestris)*
Jaguar	69[c]	14[c]=long	3.5[c]=old	0.23[c]=more vulnerable	
Spider monkey	8[b]	25[b]=long	2.5[b]=intermediate	0.24[b]=more vulnerable [g]	
Puma	37[b]	11[b]=long	2.7[b]=intermediate	0.3[d]=more vulnerable	
Brocket deer	17[a]	8[b]=short/12[e]	1.1[b]=young	0.4[b]=somewhat vulnerable (less vulnerable [g])	
Ocelot	10[c]	10[c]=short	1.5[c]=intermediate	0.46[c]=somewhat vulnerable	
Tamandua	6[a]	18[b]=long	2[b]=intermediate	0.48[b]=somewhat vulnerable	
White nosed coati	3[a]	7[c]=short	2.5[a]=intermediate	0.62[f] from weight, 0.56 from generation=less vulnerable	
Paca	6[a]	12[b]=long	1[b]=young	0.67[b]=less vulnerable	
Armadillo	5[a]	8[b]=short	2[b]=young	0.69[b]=less vulnerable	
White-lipped peccary	29[a]	13[b]=long	1.5[b]=intermediate	0.84[b]=less vulnerable[g]	
Agouti	3[a]	10[b]=short	0.7[b]=young	1.1[b]=less vulnerable[g]	*(Dasyprocta leporina)*
Collared peccary	17[a]	13[b]=long	0.9[b]=young	1.25[b]=less vulnerable[g]	
Raccoon	5[e]	16[e]=long	0.8[e]=young	1.34[f] (from weight) 0.53 from generation=less vulnerable	*(Procyon lotor)*
White-tailed deer	35[a]	10[b]=short	0.5[b]=young	0.73[b]=less vulnerable	
Opossum	1[d]	very short[d]	Young[d]	2.92[b]=less vulnerable	*(Didelphis marsupialis)*
Squirrels	0.33[b]	<5[f]=very short	1[f]=young	3.28=much less vulnerable	*(Sciurus carolinensis)*
Rabbits	1[b]	2[b]=very short	0.2=very young[b]	11.51[b]=much less vulnerable	*(Sylvilagus floridanus)*

These values are often used by ecologists to derive quantitative measures of species vulnerability. However, several vital variables are unknown in the archaeological record (such as population density which impacts rate of reproduction and survivalship), so the values are used here only for qualitative assessment

[a]Novack (2003)
[b]Robinson and Redford (1986)
[c]Zapata Rios (2001)
[d]Robinson (2000): Table 6.2
[e]Mugaas et al. (1993)
[f]Slade et al. (1998)
[g]Bodmer et al. (1997)

cached there are cached underwater and are no longer in situ). Therefore, we base our calculations on a subsample from each site that includes only the local mammals, because this is the group that was included by hunters in the highland caches. Thus, the results of these measures for zooarchaeological samples will differ from published results that included full assemblages and/or assemblages only from dietary/residential deposits.

This comparison is not ideal for several reasons: first, that the environments and therefore available resources are so different as discussed above (and in view of that, it is interesting that the proportionate representation is actually quite similar). Second, that dogs are the only domesticated animal in these assemblages and were treated differently before and after Colonial intrusion.[9] In the historic/modern hunting caches, dogs are explicitly excluded as a domestic animal – the hunting caches are for wild game only. Dogs are included in all the sacred events as hunters in their own right, blessed at the cofradía and charged with appropriate behavior on all hunts (Brown and Emery 2008). And third, that the hunting caches explicitly contain only mammals, and no mammals below the size of a pocket gopher (Brown 2006; Emery et al. 2007). However, despite these differences, the taxonomic analysis suggests that through time and between habitats, the Maya have used a very similar corpus of animals in their daily life. Since our comparative analyses exclude dogs, all non-mammals, and all mammals below the size of a pocket-gopher, we are confident that these present enough similarities to allow the comparison to inform our understanding of hunting practices.

Results

Taxonomic Comparisons

A first basic comparison of taxa used and their proportions within each assemblage (Table 6.3) shows considerable overlap in taxa used despite differences in time-period and environment. At all sites mammals are predominant, though reptiles are also very common at the ancient sites (the historic/modern sites have only mammals). When combined, mammals represent 89% (Dos Pilas), 58% (Motul de San Jose), 49% (Tamarindito), 80% (Kaminaljuyu), with reptiles representing 3% (Dos Pilas), 7% (Motul de San Jose), 43% (Tamarindito), 0.04% (Kaminaljuyu). Exotic mollusks and marine fish are present in high proportions at all the ancient sites [5% (Dos Pilas), 4% (Motul de San Jose), 0.41% (Tamarindito), 0.12% (Kaminaljuyu)].

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[9] Dog is likely to have been managed differently at the various sites. It is one of the most frequently encountered species at Preclassic Kaminaljuyu as it is at many Preclassic sites across Mesoamerica (Clutton-Brock and Hammond 1994; Wing 1978). At Kaminaljuyu dogs are generally found in association with elite and ritual deposits, several times accompanying burials (Emery et al. in press; Kidder et al. 1946). Again, this seems to be a Preclassic trend (Rosenswig 2006; Teeter 2001). Dogs are less often found in ritual deposits in the later lowland sites.

Table 6.3 Relative values of NISP for taxa

Taxon	Dos Pilas	Motul de San Jose	Tamarindito	Kaminaljuyu	Pa Sak Man	Pa Ruchi Abaj	Total
Brachyura (crabs)	0.02	0	0.10	0	0	0	0.01
Mollusca (mollusks)	0.09	0.15	0	0	0	0	0.07
Mollusca, marine	0.91	1.51	0	0	0	0	0.71
Tellina (tellins)	0.01	0	0	0	0	0	0
Olividae (olives)	0.08	0.33	0	0	0	0	0.10
Oliva sayana/reticularis (lettered/netted olive)	0.34	0.15	0.10	0	0	0	0.20
Oliva porphyria (tent/camp olive)	0.01	0	0	0	0	0	0
Olivella (dwarf olives)	0.18	0.30	0	0	0	0	0.14
Prunum apicinum (Atlantic marginella)	0.54	0.35	0	0	0	0	0.33
Jenneria pustulata (Jenner's pustulate cowry)	0	0.03	0	0	0	0	0
Cassididae/Strombidae (helmets/conchs)	1.36	1.35	0	0	0	0	0.91
Strombus alatus (Florida fighting conch)	0.01	0.03	0	0	0	0	0.01
Strombus gigas/costatus (queen/milk conch)	0.03	0.03	0	0	0	0	0.02
Dentaliidae (tusk shell)	0.03	0.05	0.10	0	0	0	0.03
Pachychilus (jute)	0	4.39	0.10	0	0	0	0.75
Pomacea flagellata (apple snail)	0.03	6.34	0.93	0	0	0	1.13
Dinocardium r. vanhyningi (robust cockle)	0.01	0	0	0	0	0	0
Pteria/Pinctada (pearly oysters)	0.07	0	0	0	0	0	0.03
Spondylus (thorny oysters)	1.63	0.18	0.10	0	0	0	0.85
Unionidae (river clams)	0.03	0.13	0	0	0	0	0.03
Psoronaias ("thick" river clam)	1.29	4.19	1.14	0	0	0	1.40
Vertebrata (vertebrates)	1.32	12.33	2.38	14.91	1.72	1.21	4.67
Rajiformes/Myliobatiformes (rays)	0.02	0.03	0.10	0	0	0	0.02
Osteichthyes (bony fish)	0.03	0.38	0.52	1.37	0	0	0.24
Lepisosteus (gars)	0	0	0.10	2.94	0	0	0.31

(continued)

Table 6.3 (continued)

Taxon	Dos Pilas	Motul de San Jose	Tamarindito	Kaminaljuyu	Pa Sak Man	Pa Ruchi Abaj	Total
Cichlasoma (American cichlids)	0	0.05	0	0.08	0	0	0.02
Centropomus (robalos and snooks)	0	0	0	0.08	0	0	0.01
Lutjanus/Serranidae (snapper/grouper)	0	0	0	0.08	0	0	0.01
Tetrapoda (4 limbed vertebrates)	0	0.90	0	0	0	0	0.15
Bufo/Rana (toad/frog)	0	0.08	0.31	0	0	0	0.03
Ranidae	0.03	0	0.10	0	0	0	0.02
Reptilia	0	0.15	0.41	0	0	0	0.04
Squamata (lizards/snakes)	0	0.35	0.10	0	0	0	0.06
Iguanidae (iguanas, chuckwallas)	0	0.03	0	0	0	0	0
Serpentes	0.01	0.40	0.10	0	0	0	0.08
Crocodylus (crocodiles)	0.01	0.08	0.10	0	0	0	0.02
Testudines (turtles)	1.38	1.38	20.97	0	0	0	1.79
Kinosternidae (mud/musk turtles)	0.05	0	0.10	0	0	0	0.03
Kinosternon (small mud/musk turtles)	0.06	0.20	2.07	0.04	0	0	0.15
Staurotypus triporcatus (giant musk turtle)	0.08	0.23	1.03	0	0	0	0.12
Dermatemys/Staurotypus	0.86	0.15	1.96	0	0	0	0.54
Dermatemys mawii (Central American river turtle)	0.06	3.18	14.36	0	0	0	1.16
Trachemys scripta (common slider)	0.14	1.40	2.17	0	0	0	0.40
Aves (birds)	0.17	0.25	0.21	0.12	0	0	0.15
Aves, large not Meleagrididae (hawk, macaw sized)	0	0.08	0.31	0	0	0	0.03
Aves, intermediate (parrot, jay sized)	0	0.05	0	0	0	0	0.01
Aves, small (perching bird sized)	0	0.13	0	0	0	0	0.02
Anas strepera (gadwall)	0	0	0	0.04	0	0	0
Galliformes, small (fowls)	0.01	0.05	0	0	0	0	0.01
Meleagrididae (quail and turkey)	0	0.03	0.52	0	0	0	0.03
Colinus (quails)	0.03	0.03	0	0.04	0	0	0.02

Meleagris (turkeys)	0	0.15	0	0	0	0	0.03
Passeriniformes (perching birds)	0	0.05	0	0	0	0	0.01
Mammalia (mammals)	71.42	15.26	23.66	56.56	0	0.36	45.18
Mammalia, very large	0.02	0.08	0.21	0	0.30	0.07	0.07
Mammalia, large	7.62	17.67	1.86	11.43	9.13	1.93	9.33
Mammalia, intermediate	0.27	7.99	2.07	7.04	14.01	9.84	4.65
Mammalia, small	0.05	1.40	0.21	0.54	0.03	0.86	0.38
Didelphidae (opossum)	0.02	0.30	0.21	0	0.24	0.14	0.11
Tamandua mexicana (northern tamandua)	0	0.13	0	0	0.07	00	0.03
Dasypus novemcinctus (nine-banded armadillo)	0.05	1.10	0.31	0	17.38	6.92	2.83
Chiroptera (bats)	0.01	0.05	0	0	0	0	0.01
Alouatta/Ateles (howler/spider monkey)	0	0	0.10	0	0.03	0	0.01
Carnivora (carnivores)	0.02	0.10	0.10	0	0.03	0	0.03
Procyonidae (raccoons and coatis)	0	0	0	0	1.52	0.64	0.23
Nasua narica (white nosed coati)	0	0	0	0	2.39	3.35	0.50
Procyon lotor (Northern raccoon)	0	0	0.10	0	1.11	0.14	0.15
Canidae/Felidae	0.38	0	0.31	0	0	0	0.20
Canidae (dog family)	0	0.08	0	0	0.03	0	0.02
Canis lupus familiaris (domestic dog)	1.07	1.18	0.93	4.27	0	0	1.21
Urocyon cinereoargenteus (gray fox)	0.01	0.03	0.21	0.04	0.03	0	0.03
Felidae (cat family)	0.08	0.05	0.21	0	0	0.14	0.07
Felidae, large (jaguar, puma)	0.97	0.13	0.52	0	0.17	0.14	0.56
Felidae, intermediate (large ocelot, jaguarundi)	0.35	0	0	0	0.10	0	0.19
Felidae, small (margay, small ocelot)	0.14	0	0.10	0	0	0	0.08
Panthera onca (jaguar)	0.19	0.05	0	0	0	0	0.11
Leopardus pardalis (ocelot)	0	0.05	0.21	0	0.07	0	0.03
Tapirus bairdii (Baird's tapir)	0.01	0	0	0	0.44	0.29	0.08

(continued)

Table 6.3 (continued)

Taxon	Dos Pilas	Motul de San Jose	Tamarindito	Kaminaljuyu	Pa Sak Man	Pa Ruchi Abaj	Total
Artiodactyla (even-toed ungulates)	0.86	0.30	1.14	0	7.54	14.69	2.36
Tayassuidae (peccaries)	0.19	0.28	2.89	0	9.40	7.92	1.92
Tayassu tajacu (collared peccary)	0	0	0	0	1.11	0.14	0.15
Cervidae (deers)	2.26	0.68	0.62	0.12	1.18	5.56	1.77
Odocoileus virginianus (white-tailed deer)	2.41	7.54	5.99	0.21	29.37	42.30	8.98
Mazama (brocket deers)	0.06	0.88	1.55	0	0.03	0.93	0.30
Rodentia (rodents)	0.02	0	0.62	0	0.10	0	0.05
Rodentia, intermediate (pocket gophers, squirrels)	0.02	0.03	0.21	0	0	0	0.02
Rodentia, small (mice, rats)	0.32	2.38	3.62	0	0	0	0.71
Sciuridae (squirrels)	0	0.03	0	0	0	0	0
Geomyidae (pocket gophers)	0	0.05	0.10	0	0	0	0.01
Orthogeomys (giant pocket gopher)	0.02	0.05	0	0.04	0	0.07	0.03
Agoutidae/Dasyproctidae	0.02	0	0.21	0	0.47	0.43	0.10
Agouti paca (paca)	0.19	0.13	0.41	0	1.48	0.86	0.37
Dasyprocta punctata (agouti)	0.04	0.13	0.83	0	0.03	1.07	0.14
Sylvilagus (rabbits)	0	0.33	0	0.04	0.47	0	0.12
Total NISP	11,802	3,990	968	2,415	2,969	1,402	23,546
Summarized categories							
Exotic mollusks and fish	5.20	4.31	0.41	0.17	0	0	3.37
Local mollusks (freshwater)	1.35	15.04	2.17	0	0	0	3.31
Local fish	0.03	0.43	0.62	4.47	0	0	0.57
Turtles	2.64	6.54	42.67	0.04	0	0	4.19
All reptiles	2.66	7.54	43.39	0.04	0	0	4.40
Galliform birds	0.03	0.25	0.52	0.04	0	0	0.08
All birds	0.20	0.80	1.03	0.21	0	0	0.30

Dogs	1.07	1.18	0.93	4.27	0	0	1.21
Wild cats	1.75	0.28	1.03	0	0.34	0.29	1.02
Peccaries	0.19	0.28	2.89	0	10.51	8.06	2.07
Deer	4.74	9.10	8.16	0.33	30.58	48.79	11.05
All artiodactyls	5.80	9.67	12.19	0.33	48.64	71.54	15.47
Large and Intermediate Rodents	0.28	0.40	1.76	0.04	1.99	2.43	0.68
All Mammals	89.10	58.42	49.48	80.29	98.28	98.79	

Taxonomic nomenclature follows http://www.itis.gov. Individual taxa are presented above, combined taxonomic groups are presented below. Human remains and intrusive land mollusks were not consistently recovered so are not included in these counts. Exotic mollusks are listed, but are not considered in the comparison. Armadillo scutes are excluded because these overwhelm the samples

Note: very large mammal (tapir/manatee sized, over 100 kg); large mammal (15.1–100 kg, peccary/deer/large cat sized); intermediate mammals (large/int mammal = 7–15 kg, monkey, canid, int cat sized; medium = 2.1–6.9 kg, paca, small cat, kinkajou, tamandua, armadillo, procyonid, fox sized; int/small mammal = 1–2 kg, rabbit, opossum, agouti sized); small mammal (under 1 kg, cricetid rodent, bat sized)

Local fish and birds (primarily game birds such as quail and turkey) are also fairly common at all ancient sites and at most non-cache sites turtles are very abundant.[10] When combined, turtles represent 3% at Dos Pilas, 6% at Motul de San Jose, 43% at Tamarindito, though only 0.04% at Kaminaljuyu where local fish (4%) are also frequent. In almost all cases, with the significant exception of Kaminaljuyu where dogs are the most common taxa, the dominant species are the large artiodactyls (deer and peccaries). When combined, these represent 6% (Dos Pilas), 10% (Motul de San Jose), 12% (Tamarindito), and 71% and 49% of the modern assemblages at Pa Ruchi Abaj and Pa Sak Man respectively.[11] Domestic dogs are very common in all ancient deposits, but are not included in the modern deposits because they are not considered part of the "wild game" component. However, the other intermediate carnivores, raccoons and coatis, are very frequent in the modern deposits.

Foraging Efficiency and Prey Vulnerability in the Cache Deposits

As described above, the foraging efficiency model suggests that predators will generally optimize their resource intake by pursuing large-bodied prey preferentially until these are no longer available. When the efficiency of these prey is less than optimal, predators will diversify their resource use to include a wider range of taxa and thereby expand their dietary breadth. They will also focus more widely on smaller-bodied prey in the face of increasing difficulty in obtaining the larger-bodied prey.

The results of our comparison between the relatively older hunting cache at Pa Ruchi Abaj and that from the still-active site of Pa Sak Man shows that the proportion of large mammals to all mammals is lower in the more modern assemblage: 0.74 at Pa Ruchi Abaj vs 0.60 at Pa Sak Man (Table 6.4, Fig. 6.5). As mentioned above, large-bodied prey are considered to include deer, peccary, tapirs, and the largest cats, the jaguar and puma. This result indicates that smaller-bodied preys have become a more frequent addition to the resource base. In addition, the diversity of the assemblage is higher in the modern versus the historic assemblage: 3.39 at Pa Ruchi Abaj vs 4.15 at Pa Sak Man. This indicates that there has been an expansion of the hunting breadth of the Atitlán hunters over the last few generations. The specific species that seem to have been used at Pa Sak Man but not in the past at Pa Ruchi Abaj include rabbits, gray fox, small carnivores (weasels and the like), howler monkey, and tamandua. These are all relatively small taxa and are often rare or more vulnerable to hunting pressure (see later discussion).

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[10] This analysis is based on NISP which over-represents taxa with higher numbers of bony elements such as the turtle. The turtle has been conservatively estimated in all cases, but these values should be considered high. In all comparative analyses, the use of only mammals will render most taxonomic differences due to NISP irrelevant. However, the numerous scutes of the armadillo have been eliminated from the analysis as well since these also affect the comparisons when using NISP.

[11] Because these two sites contain only mammals, artiodactyls represent a significantly higher proportion than at other sites. In all comparative analyses, the use of only mammals will counteract this difference

Table 6.4 Calculations used in the analysis of hunting impact on the historic/modern hunting caches of the Guatemalan highlands

	Pa Ruchi Abaj	Pa Sak Man	
	Historic	Modern	Total
Total mammals	1,385	2,918	4,303
Σ NISP large mammals/Σ NISP large mammals $+ \Sigma$ total mammals	0.74	0.60	0.64
Evenness (D/S)	0.21	0.20	0.18
Diversity ($N(N-1)/\Sigma\, n(n-1)$)	3.39	4.15	4.00
% juvenile all	24.51	32.56	n/a
% vulnerable species of all mammals (tapir, felids, monkeys)	0.65	1.13	0.98
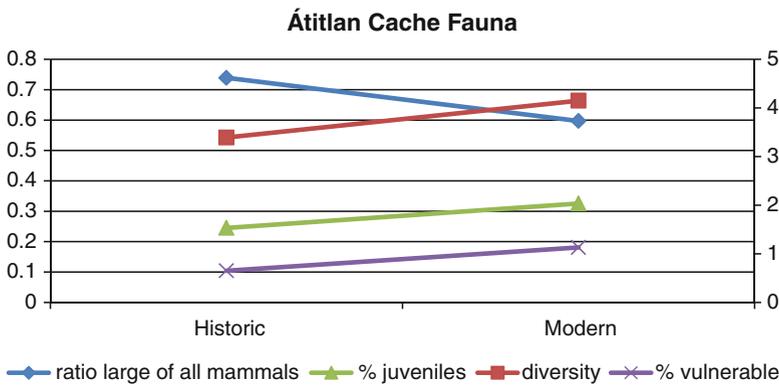
Fig. 6.5 Chart of all measures used to track exploitation of the Atitlan hunting cache animals

We have used two measures of prey vulnerability, both described in more detail above. In the first measure of prey vulnerability, we quantify the proportion of juvenile individuals (pre-breeding age) as an indication of the impact the hunters will have on the breeding ability of the animal population. In the second measure of prey vulnerability, we compare the frequency of "vulnerable" taxa (those with low natural productivity and large body sizes) with the more "stable" taxa (those with high productivity and smaller body sizes).

In the cache assemblages the proportion of both juveniles and vulnerable species is higher in the more modern cache at Pa Sak Man, than in the older cache at Pa Ruchi Abaj. While Pa Ruchi Abaj had only 25% juveniles and 0.65% vulnerable species, Pa Sak Man had 33% juveniles and 1.13% vulnerable species. These findings suggest that the impact of hunting in this fashion will be more detrimental to the overall prey base, but it may also indicate that the less-vulnerable species and individuals are no longer available. In other words, these results might be telling us either that the hunters using the more modern cache at Pa Sak Man are less sustainable in their hunting practices than were the past hunters using the Pa Ruchi Abaj cache,
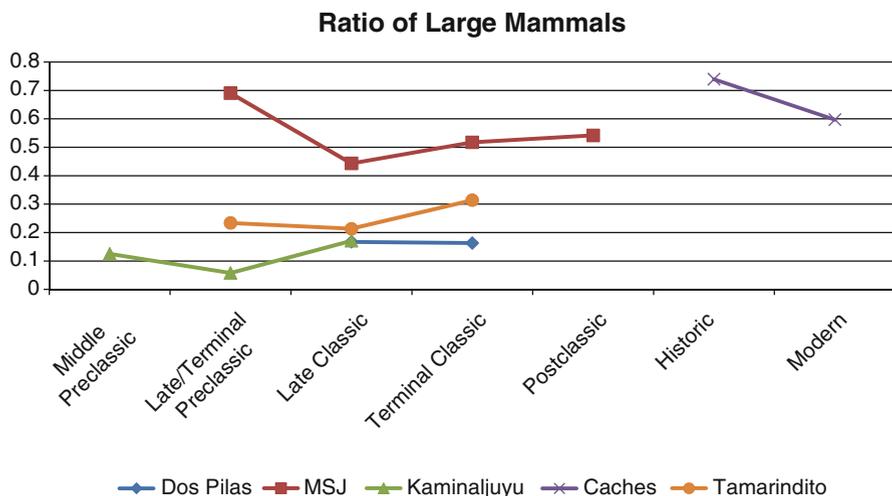
Ratio of Large Mammals

Fig. 6.6 Ratios of large mammals to all mammals in all bone assemblages

or that there are simply fewer of the large-bodied, mature, stable taxa available to the modern hunters than there were to their grandfathers. In terms of the taxa of the Maya highlands, this suggests that deer, peccary, and tapirs are less numerous and less available to the more modern hunters than they were in past generations.

Comparing Caches to Archaeological Assemblages

Figures 6.6 and 6.7 illustrate the comparative analysis of large mammal ratios and taxonomic diversity. Table 6.5 provides an overview of the results of this broader comparison between caches and archaeological assemblages. Overall, in both measures the historic/modern caches are very similar to the archaeological assemblages. The ratio of large mammals varies from 0.60 to 0.74 in the caches and from 0 to 0.69 in the pre-Columbian examples, while diversity varies from 3.39 to 4.15 in the caches and from 1 to 4.99 in the pre-Columbian examples. For each measure, the historic/modern cache samples are at the high end of the ranges.

Taxonomic diversity varies widely between time periods represented across all samples. However, the patterns are somewhat consistent (Fig. 6.8). Taxonomic diversity is quite low in Preclassic assemblages and at all sites reaches a peak during the Late Classic period, falling again in the Terminal Classic. The site of Motul de San Jose provides the only Postclassic assemblage and diversity is very similar between that assemblage and the older of the two cache assemblages 3.19 at Motul de San Jose vs 3.39 at Pa Ruchi' Abaj. This suggests a continued rise in taxonomic diversity among hunted fauna from the Terminal Classic onward, though it is important to emphasize the long span of time and space that separates the lowland
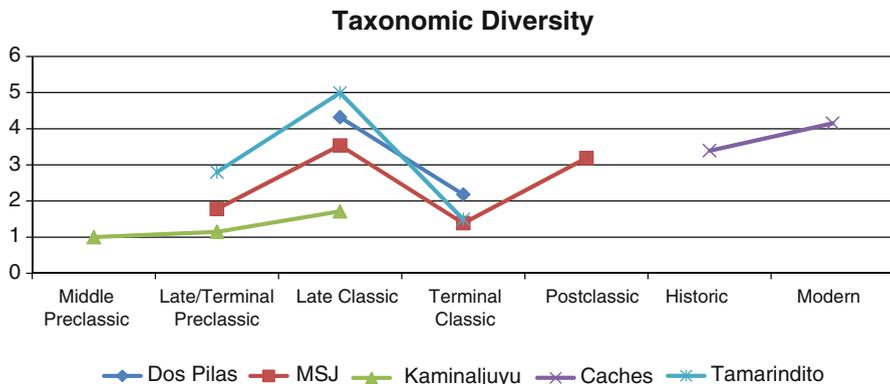
Taxonomic Diversity

Fig. 6.7 Mammalian diversity (heterogeneity) for all mammalian assemblages

Peten Motul de San Jose site (1200 AD) from the highland historic caches (likely last intensively used within the past 50–100 years).

The comparative analysis of use of large game is not as clear. The results appear different for each site examined. At the highland site of Kaminaljuyu, large mammals are least abundant at the end of the Preclassic (the period of greatest population and political activity) and are more so during the Late Classic (a time of minimal resettlement but very limited activity). At the Petexbatun sites of Tamarindito and Dos Pilas, change is limited, with somewhat fewer large game in the Late Classic period of greatest settlement and political activity, and more large game represented at Tamarindito during the final phase of limited occupation in the Terminal Classic. At Motul de San Jose, large game are most abundant during the period of first occupation in the Preclassic, least in the Late Classic, the period of florescence in this polity, and increasing quantities again into the Terminal Classic and Postclassic when settlement was limited. The correlation appears most significant with population size and political activity rather than with absolute time period. This accords well with Emery's earlier studies of hunting activities (Emery 2008b).

It is the combination of these two factors, hunting pressure on large game and taxonomic diversity, that are supposed by the foraging efficiency model to indicate foraging pressure or non-sustainable hunting. However, the two measures do not correlate well in this study. At Kaminaljuyu while large game ratios drop and diversity rises at the end of the Preclassic, the same is not true during the Late Classic. Large game and highly diverse taxa were being used in the later period when populations were small, though fewer large game and a diverse taxa were used when human populations were high. At Motul de San Jose, the drop in large game during the highly politically active period of the Late Classic is indeed accompanied by a rise in taxonomic diversity and the subsequent rise is associated with a drop in taxonomic diversity in the Terminal Classic. However, in the Postclassic, when human populations were very small, the hunters brought in both large game and diverse taxa. These combinations suggest that although the earliest hunters of the Maya world concentrated on large game to the exclusion of other animals, these activities

Table 6.5 Calculations used in the analysis of hunting impact on the archaeological assemblages. Note that totals include undated materials (and are therefore sometimes larger than totals for dated assemblages only). Missing data indicate that either no remains or insufficient remains were recovered from this site for this time period to allow analysis

Kaminaljuyu	Middle Preclassic	Late Preclassic	Terminal Preclassic	Late Classic	Terminal Classic	Post Classic	Total
Total mammals	64	466	121	82	–	–	1,939
ΣNISP large mammals/ΣNISP large mammals + Σtotal mammals	0.13	0.06	0	0.17	–	–	0.15
Evenness (D/S)	1	0.38	1	0.57	–	–	0.23
Diversity ($N(N-1)/\Sigma n(n-1)$)	1	1.15	1	1.71	–	–	1.16
% juvenile all	–	28.57	–	–	–	–	n/a
% vulnerable species of all mammals (tapir, felids, monkeys)	0	0	0	0	–	–	0
Dos Pilas							
Total mammals	–	–	–	771	9,744	–	1,0515
ΣNISP large mammals/ΣNISP large mammals + Σtotal mammals	–	–	–	0.17	0.16	–	0.16
Evenness (D/S)	–	–	–	0.27	0.17	–	0.19
Diversity ($N(N-1)/\Sigma n(n-1)$)	–	–	–	4.32	2.18	–	3.37
% juvenile all	–	–	–	23.68	23.28	–	n/a
% vulnerable species of all mammals (tapir, felids, monkeys)	–	–	–	3.63	1.86	–	1.99
MSJ			[Late/Terminal]				
Total mammals	–	–	42	1,634	373	131	2,331
ΣNISP large mammals/ΣNISP large mammals + Σtotal mammals	–	–	0.69	0.44	0.52	0.54	0.46
Evenness (DS)	–	–	0.36	0.20	0.08	0.27	0.07

			[Terminal Classic/Postclassic]		
Diversity ($N(N-1)/\Sigma n(n-1)$)	—	1.78	3.54	1.43	3.19	3.38
% juvenile all	—	0	18.82	22.22	14.29	n/a
% vulnerable species of all mammals (tapir, felids, monkeys)	—	0	0.80	0.27	0	0.60
Tamarindito						
Total mammals	—	77	225	51	—	479
Σ NISP large mammals/Σ NISP large mammals + Σ total mammals	—	0.23	0.21	0.31	—	0.30
Evenness (D/S)	—	0.47	0.33	0.37	—	0.27
Diversity ($N(N-1)/\Sigma n(n-1)$)	—	2.80	4.99	1.49	—	4.57
% juvenile all	—	5	27.71	0	—	n/a
% vulnerable species of all mammals (tapir, felids, monkeys)	—	1.30	2.22	0	—	2.51

Prey Vulnerability
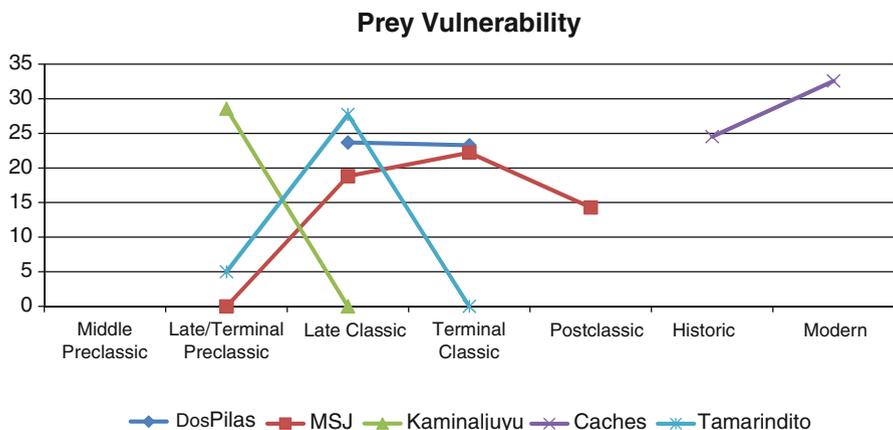
Fig. 6.8 Proportion (% NISP) of all mammals considered most vulnerable to exploitation in all mammalian assemblages

Percent Juvenile Individuals
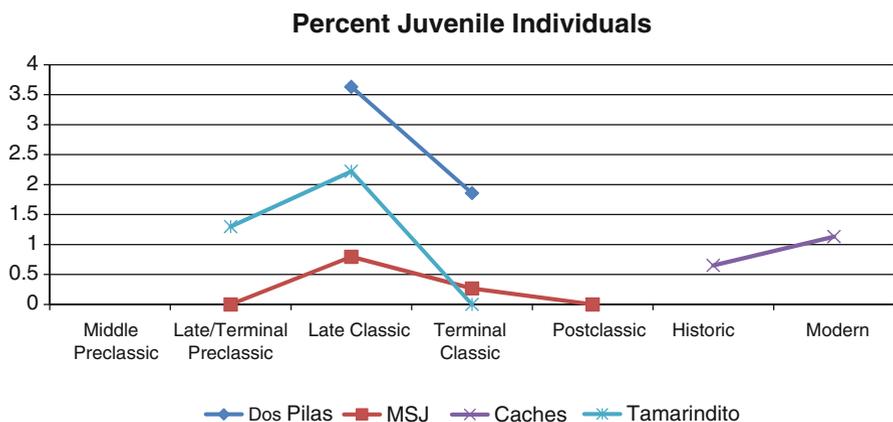
Fig. 6.9 Proportion (%NISP) of mammalian elements classifiable as juvenile by lack of fusion and/or diaphyseal/metaphyseal characters in all assemblages

reduced the availability of large game, requiring that they increase the diversity of their prey base. During later periods a diverse prey base appears to have been favored even when large game animals were more available. Both diversity and proportion of large game are very high in the Postclassic and historic caches. The effects of modern activities, though, have led to a further increase in taxonomic diversity of the hunted prey that coincides with a drop in the proportion of large game brought in by the hunters.

Another approach is to look at the vulnerability of the prey species (Fig. 6.8) and age classes (Fig. 6.9). Again, the cache results are quite consistent with the larger

regional study of archaeological remains.[12] The proportion of vulnerable species in the cache deposits (0.65–1.13) is within, but at the lower end of the range compared to that found in the archaeological deposits (0–3.63). Overall, in the archaeological assemblages the proportion of vulnerable species hunted during the very early and very late periods is quite low in comparison to the periods of highest human populations and political activity. It is important to note that the most vulnerable species of the Maya area are those same species that were used by the Maya as symbolic markers of wealth, status, and power. Large cats such as jaguars and pumas, monkeys, colorful large jungle birds such as macaws, parrots, toucan, and the like, were all hunted and displayed by the ruling nobility and the wealthy elite. It should come as no surprise that during the periods of greatest political activity (and competition) these species were more intensively hunted. Since the hunting of many of these species is now illegal (although it does still continue with frequency), it is also not surprising that the overall proportions of these animals are not as high in the later hunting caches.

As the second measure of vulnerability, juveniles are also found in quite similar proportions in the ancient and historic/modern assemblages. Here though, juveniles are somewhat more frequent in the more modern assemblages (24.51–32.56%) than in the archaeological (0–28.57). In the archaeological assemblages, juvenile remains are also found to be at highest proportions during the periods of highest political activity (Late/Terminal Preclassic at Kaminaljuyu and Late Classic at the lowland Maya sites). The one exception is a slightly higher proportion of juveniles in the Terminal Classic than in the Late Classic at Motul de San Jose. The proportion of juveniles is also fairly stable at Late Classic and Terminal Classic Dos Pilas although there is a drop. By the historic period the proportion of juveniles has risen again and it continues to rise into the modern period.

Discussion

How might this all come together then? In comparative terms the historic and modern Maya bring in relatively more large game, a relatively high diversity of taxa though few vulnerable species and quite high proportions of juveniles. In combination this is a mix of "markers" for sustainable practice since high numbers of large game and proportions of juveniles are not sustainable prey, while high diversities and low proportions of vulnerable species provide a sustainable prey base. In fact, the data are likely showing the effects of past choices as well as the intentions of the hunters.

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[12] No remains of vulnerable species were found in the Kaminaljuyu samples examined here (Emery et al. in press). However, burials and caches at the site examined in earlier studies by other researchers did contain vulnerable species such as cats (including jaguars, pumas, ocelots, jaguarundi, and margay cats) and monkeys (both howler and spider monkeys) (Kidder et al. 1946). These were not quantified in the publications, so we are not able to include Kaminaljuyu in this analysis.

The centuries of hunting by ever-greater numbers of hunters as reflected in the historic/modern caches has had its impact on prey populations. Hunters have likely been forced to reduce the proportion of large game and mature individuals that they bring in, relying on a wider diversity of taxa as the result of diet breadth expansion, greater proportions of juveniles, and larger numbers of vulnerable prey.

The archaeological Maya were faced with similar situations. As human populations and political competition grew around ancient cities, hunters were forced to bring in fewer large game animals, relying generally on a higher diversity of prey and younger individuals. However, they undoubtedly caused greater impacts on their animal neighbors by selectively preying on vulnerable species during periods of high political activity, something that is not reflected in the modern caches. Removal of these vulnerable, and often keystone, species, impacts entire ecologies, throwing population dynamics into disarray.

Do the modern Maya, often held up as those with the "insider knowledge," really hunt in a manner sustainable under the modern conditions of human–environment interactions? Did the ancient Maya, castigated in scientific tomes and public displays alike as environmental berserkers, really hunt in a manner significantly different from that of their modern counterparts? Clearly the answer is much more complex and the "lessons" to be gleaned are more difficult to pry from the data than we might hope.

This result then brings us back to the questions of this volume – whether it is ethical or appropriate to publish our data. There is no doubt that Emery's experiences with public representations of her scientific presentations is at least in part the result of the conflicting motivations of different groups – any data or story can be manipulated to serve the purposes of the teller. The question of environmental management is loaded with political, social, and symbolic import and the same data can be used to argue for the inherent sustainability of indigenous strategies (based on millennia of trial and error) or the inherent incompatibility of human resource exploitation and the natural environment (based on a Boserup model of unchecked human expansion). As anyone who listens to modern politico-speak is well aware today, this is a fact of human nature.

However, it is important to recognize that a significant hurdle to ethical presentation of data lies in the difficulty of presenting complex "conclusions" that rest on models and proxy evidence. Science is the art of hypothesizing, interpreting, and predicting. Rarely is it simply a source of straight-forward facts. In the case of sustainability studies, there is no simple "measure" of sustainability beyond the basic definition which is extraction without reduction of the resource base (and even that definition is debated, see Robinson 2001). Sustainability is understood only within the context of the specific organisms and ecosystems involved and the stage of their relationship in a dynamic history. Wildlife biologists/ecologists can measure the relative proportion of prey species in hunts over time, or the proportions of one or more sex or age groups, and interpret the difference as the result of sustainable or unsustainable activity. However, they use those counts as proxy for a much more complex relationship that changes gradually over time, and their interpretations are based on the extent to which the change mirrors their predictions of sustainable activity

as stated in our initial hypotheses. And those predictions are based on models of interactions between community members that themselves are based on repeated observations of similar situations, never the identical situation. This process of scientific analysis is so inherently understood by the researchers and writers of scientific papers, that we forget that our readers or listeners are sometimes unaware of this process or of what our "data" actually represent: not facts, and rarely more than educated guesses (or more politely stated, "models" and "heuristic devices"). We present our results within the context of our expected audience. When Emery presented her data primarily to the biological community, it allowed her to assume a certain degree of familiarity with the scientific method for her original readers, but she ignored the potential for misinterpretation by the non-scientist or even non-biologist who have been taught to expect "facts" and "data" from the specialists, not models and best-guesses.

In addition, in presenting her data to Maya colleagues, Emery neglected to take into account an even more fundamental difference – the recognition of agency, intent, and purpose among the actors of the constantly evolving dialogue between humans, animals, and landscapes. For the Tz'utujil Maya of highland Guatemala, to whom she naively presented her "facts," humans are only one, and often a very minor one, in a closely linked group of decision-makers. Animals present themselves as prey and hunters take those animals only when the ancestor spirit or literally, Owner or Guardian of the Animals, judges it appropriate (see Chacon, this volume, for similar beliefs among the Amazonian Achuar). Her "facts" were initially received as either so well-known as to be laughable (predator/prey relationships), or ridiculous (in assuming that the hunter has any managerial role in resource availability). This was eye-opening to say the least!

We are not able to determine whether the highland and lowland Maya of Guatemala understand their impact on the local game populations or believe that, as long as proper protocols are followed with regard to the Animal Guardian, the game is inexhaustible. (Needless to say, we are interested in following up these studies with more such investigations.) However, it was clear that Emery's results, as she presented them, were of little practical use to her Maya friends and informants. Sustainability studies are often criticized because they neglect the component of "intent" – that an activity is only sustainable if its intention is sustainability over the long term. We argue that this is not the case in animal groups and should not necessarily be considered the case in human groups. The development of an effective, responsive, and implicit system of hunting practices and beliefs does not require that the hunter believe themselves the only agent in the management equation, any more than a predator must believe themselves to be the managers of their prey to co-exist in a sustainable relationship.

In this paper, we have presented some of the potential and pitfalls of our own research into the sustainability of ancient Maya hunting activities as a basis for exploring the ethics and methods for presenting the results of such work. We are still not sure what the solution is to the hurdles to presentation of our data to our sister-disciplines, to the public, and to our informants, friends, and colleagues in our study-regions. However, we can answer Richard Chacon's basic question about whether

it is ethical to present our results – we believe it is absolutely imperative that we do so! Eventually, these data from the archaeological record will allow us to better manage our future. We can no more refuse to publish the result than we can cut off access to cancer-curing plants for fear of the possibility of causing some harm in the experimentation phase. It is our obligation to share our data with the scientific community, with the public, and most importantly with those who directly or through their ancestors have provided us with the data. However, and this is an enormous "however", we are responsible for considering the nature of our presentation in terms of the context of the recipient. We must consider the manner of our presentation beyond the simple question of language (and how many of us consider even that?) to think about fundamental cultural differences (between scientists and layfolk as much as between different cultural or social groups).

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