Much more than meat alone: The role of cervids in Pre-Columbian subsistence strategies in Panama

María Fernanda Martínez-Polanco

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Much more than meat alone: The role of cervids in Pre-Columbian subsistence strategies in Panama

María Fernanda Martínez-Polanco

DOCTORAL THESIS

2021

Dedicated to
My grandparents
Sara María & Ali Hernando
Rosa Esther & Diomedes
who planted the seed

María Fernanda Martínez Polanco

Much more than meat alone: The role of cervids in Pre-Columbian subsistence strategies in Panama

Doctoral thesis

Directed by
Dr. Florent Rivals

Department of History and Art History

UNIVERSITAT
ROVIRA i VIRGILI

Tarragona, 2021

UNIVERSITAT
ROVIRA i VIRGILI

I STATE that the present study, entitled "Much more than meat alone: The role of cervids in Pre-Columbian subsistence strategies in Panama", presented by María Fernanda Martínez Polanco for the award of the degree of Doctor, has been carried out under my supervision at the Department History and Art History of this university.

Tarragona, October 5 2020

Doctoral Thesis Supervisor,

Florent Rivals

Contents

Acknowledgments........13
Abstract........15
Résumé........15
Resumen........16
Resum........16
Graphical abstract........17
1. Introduction........18
2. Theoretical background........20
3. Research context........23
3.1. Environmental context: Parita Bay and Pearl Island Archipelago........23
3.1.1. Parita Bay........23
3.1.2. Pearl Island Archipelago........24
3.2. Archaeological context: Human settlement in Pre-Columbian Panama........25
3.2.1. Hamlet Agriculture period: Late Preceramic (6000-2500 BCE) and Early Ceramic (2500-500 BCE)........25
3.2.1.1. Cerro Mangote (AG-1)........26
3.2.1.2. Playa don Bernardo (PDB)........30
3.2.2. Village Agriculture and Social Differentiation period (500 BCE-1520 CE)........32
3.2.2.1. Sitio Sierra (AG-3)........34
3.2.2.2. Cerro Juan Díaz (LS-3)........36
3.3. New World cervids........40
3.3.1. White-tailed deer (*Odocoileus virginianus* Zimmermann 1780)........43
3.3.1.1. Whitetails populations in islands........44
3.3.2. Central American red brocket (*Mazama temama* Kerr, 1792)........44
3.3.3. Amazonian Brown Brocket deer (*Mazama nemorivaga* Cuvier, 1817)........45
3.3.4. Red Brocket deer (*Mazama americana* Erxleben, 1777)........45
3.4. White-tailed deer in pre-Columbian times........46
4. Objectives........48
4.1. General objective........48
4.2. Particular objectives........48
5. Materials and Methods........49
5.1 Materials........49
5.1.1. Zooarchaeology and Taphonomy........49
5.1.2. Mesowear and Microwear........49
5.1.3. Stable isotope analysis........50

5.1.4. Geometric morphometrics 50
5.2. Methods 50
5.2.1. Zooarchaeological analysis 50
5.2.1.1 Anatomical representation 50
5.2.1.2 Age and sex 52
5.2.1.3 Skeletal representation profiles 53
5.2.2. Taphonomical analysis 54
5.2.2.1. Bone breakage: Fragmentation and fracture 54
5.2.2.2. Butchering 55
5.2.2.3. Surface alterations 56
Anthropic modifications 56
Non-anthropic modifications 58
5.2.2.4. Bone artefacts manufacture 59
5.2.2.5. Post-depositional modifications 59
5.2.3. Mesowear and Microwear analysis 60
5.2.3.1.The teeth 60
5.3.2.2. Mesowear analysis 60
5.3.2.3. Microwear analysis 61
5.2.4. Stable isotope analysis 63
5.2.4.1. Laboratory Protocol 65
5.2.5. Geometric morphometrics 65
6. RESULTS 67
6.1. Behind white-tailed deer teeth: A micro- and mesowear analysis from three Panamanian pre-Cololumbian archaeological sites 67
6.2. Following white-tailed deer to the hilltop: A zooarchaeological and taphonomic analysis of deer hunting at Cerro Mangote, a Late Preceramic (7800-4600 cal yr BP) site in central Pacific Panama 77
6.3. Zooarchaeological and taphonomical study of the white-tailed deer (Cervidae: *Odocoileus virginianus* Zimmerman 1780) at Sitio Sierra, a pre-Columbian village in Pacific Coclé province, Panama, with an evaluation of its role in feasts 90
6.4. Crafting white-tailed deer (*Odocoileus virginianus*) bone and antler at Cerro Juan Díaz (LS-3), Greater Coclé Culture Area, Panama 108
Abstract 108
Key words 108
6.4.1. Introduction 108
6.4.1.1. Presentation of the site 109

6.4.1.2. White-tailed deer bone and artifacts Operation 1/1B 111
6.4.2. Materials and methods 112
6.4.2.1. Materials 112
6.4.2.2. Methods 112
6.4.3. Results 115
6.4.3.1. Zooarchaeological analysis 115
6.4.3.2. Taphonomic analysis 117
6.4.4. Discussion 118
6.4.4.1. Another workshop at Cerro Juan Díaz (LS-3) 120
6.4.4.2. Deer bone-antler workshops and specialization 120
6.4.5. Conclusion 120
Acknowledgments 121
References 121
Notes on contributor 126
6.5. Living on a continental island: Interactions between a dwarf deer (*Mazama* sp.) and a Mid-Holocene community (6.2-5.6 cal yr BP) on Pedro González island (*Pearl Island Archipelago, Panama*) 127
6.5.1. Results 127
6.5.1.1. Taphonomical analysis 127
6.5.1.2. Tooth mesowear 133
6.5.1.3. Tooth microwear 134
6.5.1.4. Scratch variability 135
6.5.1.5. Stable isotope analysis 135
6.5.1.6. Geometric morphometrics 136
6.5.2. Discussion 137
6.5.2.1. Dwarf deer accumulation purpose 137
6.5.2.3. Dwarf deer taxonomy 138
6.5.3. Conclusion 139
6.6. Data summary 140
7. Discussion 143
7.1. White-tailed deer as an environmental indicator 143
7.2. White-tailed deer hunting and seasonality at Parita Bay 143
7.3. Insular dwarf deer populations 144
7.4. Cervid accumulations purposes 146
7.5. White-tailed deer management 148
7.6. White-tailed deer hunting as a subsistence strategy at Parita Bay: Much more than meat alone.... 151

8. Conclusions and outlook 154

References 157

> *We shall not cease from exploration, and the end*
> *of all our exploring will be to arrive where*
> *we started and know the place for the first time.*
> *T. S. Eliot*

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Abstract

This research has the objective to understand the hunting activities of the white-tailed deer (*Odocoileus virginianus*) and dwarf deer (*Mazama* sp.) as a subsistence strategy in Pre Columbian Panama. From pre-ceramic groups to complex politicized societies located in the area of Parita Bay (Cerro Mangote [7800-4600 cal yr BP], Sitio Sierra [2200 -500 cal yr. BP] and Cerro Juan Díaz [300 BCE - 1600 CE]) and Pearl Island archipelago (Playa don Bernardo [6200-5600 cal yr BP]). In order to better understand human and deer relation across time and space, it was proposed a multiproxy approach to study deer samples, that includes zooarchaeology, taphonomy, mesowear, microwear, stable isotopes analysis and geometric morphometrics. The white-tailed deer was dietarily and culturally by far the most important mammal at the Late Preceramic Cerro Mangote. By studying the deer sample from Sitio Sierra it can be concluded that ritual activities mediated the feasts where deer meat was the principal course. The refuse feature in Operation 1/1B at Cerro Juan Díaz clearly represents the waste of a deer bone and antler workshop. In the case of Playa don Bernardo, human intervention produced heavy impacts on terrestrial mammals including insular extirpation of the dwarf deer between 5700 and 2300 cal yr BP. The white-tailed deer was an animal with restricted access because of its polysemic ritual significance at Parita Bay in particular within the Greater Coclé semiotic system. The zooarchaeological record of Parita Bay evidences that human groups did not rely upon white-tailed deer, they had a broad-spectrum diet. The study of white-tailed deer in the archaeological record of this area did not evidence an intensification in deer hunting, the presence of deer is constant along the human occupation sequence and even modern times.

Résumé

L'objectif de cette thèse de doctorat est de comprendre la chasse du cerf de Virginie (*Odocoileus virginianus*) et du cerf nain (*Mazama* sp.) comme stratégie de subsistance au Panama préhispanique, de la période pré-céramique à la période de différenciation sociale dans la baie de Parita (Cerro Mangote [7800-4600 cal BP], Sitio Sierra [2200-500 cal BP] et Cerro Juan Díaz [300 BCE - 1600 CE]) et dans l'archipel des îles Perlas (Playa Don Bernardo [6200 -5600 cal an BP]). Afin de mieux comprendre la relation entre les cerfs et les groupes humains, une méthodologie *multiproxy* a été proposée comprenant archéozoologie, taphonomie, micro- et méso-usure dentaire, analyse des isotopes stables et morphométrie géométrique. Le cerf de Virginie est l'espèce la plus importante dans le site précéramique tardif de Cerro Mangote. L'étude des restes de cerfs à Sitio Sierra nous a permis d'observer que cet animal était le plat principal des banquets, probablement animés par des activités rituelles. Le dépotoir de l'opération 1B du gisement de Cerro Juan Díaz a montré qu›il avait été produit par les déchets des activités de fabrication d'artefacts et d'ornements en os, bois et dents de cerf. Dans le cas de Playa don Bernardo, les résultats indiquent que l'impact de l'arrivée des communautés humaines sur l'île ont eu des conséquences irréversibles sur la faune locale, y compris l'extinction du cerf nain de l'île, entre 5700-2300 ans cal BP. Le cerf de Virginie était probablement une espèce à accès restreint étant donné sa signification rituelle polysémique dans la baie de Parita, en particulier dans la période de différenciation sociale. Le registre archéozoologique de cette zone ne montre pas que les groupes humains dépendaient de la consommation de cerfs pour survivre, ces groupes avaient une alimentation à large spectre qui a favorisé la conservation de cette espèce jusqu'à ce jour.

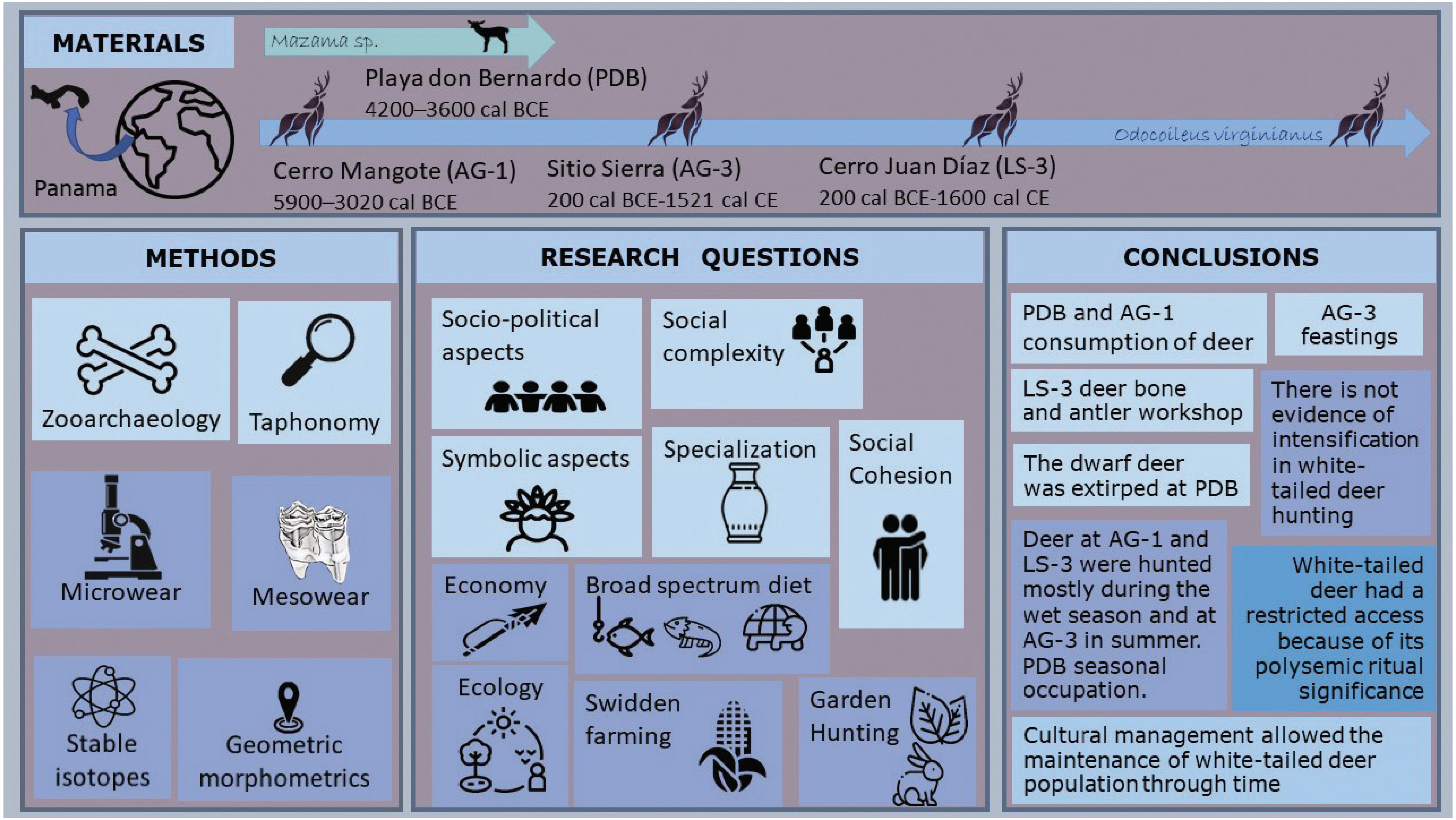
Resumen

El objetivo de esta investigación es entender la cacería del ciervo de cola blanca (*Odocoileus virginianus*) y del ciervo enano (*Mazama sp.)* como una estrategia de subsistencia en el Panamá Prehispánico, desde el periodo Precerámico hasta el periodo de diferenciación social en la Bahía de Parita (Cerro Mangote [7800-4600 cal yr BP], Sitio Sierra [2200 -500 cal yr. BP] *y* Cerro Juan Díaz [300 BCE - 1600 CE]) y en el Archipiélago de la Perlas (Playa don Bernardo [6200-5600 cal yr BP]). Con el fin de entender mejor la relación entre los ciervos y los grupos humanos se propuso una metodología *multriproxy* que incluyó zooarqueología, tafonomía, microdesgaste y mesodesgaste dental, análisis de isotópos estables y morfometría geométrica. El ciervo de cola blanca es la especie más importante en el yacimiento del precerámico tardío de Cerro Mangote. El estudio de los restos de ciervo en Sitio Sierra permitió observar que este animal fue el plato principal en los banquetes lo cuales probablemente estuvieron mediados por actividades rituales. El basurero de la operación 1B del yacimiento Cerro Juan Díaz evidenció que este se había producido como desechos de las actividades de manufactura de artefactos y ornamentos elaborados con huesos, astas y dientes de ciervo. En el caso de Playa don Bernardo las evidencias señalan que los impactos de la llegada de las comunidades humanas a la isla produjeron impactos irreversibles en la fauna local, entre ellos la extinción del ciervo enano de la isla, entre 5700-2300 años cal BP. El ciervo de cola blanca probablemente fue una especie con acceso restringido dado su significado ritual polisémico en la Bahía de Parita en particular en el periodo de diferenciación social. El registro zooarqueológico de esta zona no evidencia que los grupos humanos dependieran del consumo de los ciervos para sobrevivir, estos grupos tenían unas dietas de amplio espectro que favoreció la conservación de esta especie hasta nuestros días.

Resum

L'objectiu d'aquesta investigació és entendre la cacera del cérvol de cua blanca (*Odocoileus virginianus*) i del cérvol nan (*Mazama* sp.) com una estratègia de subsistència al Panamà Prehispànic, des del període Preceràmic fins el període de diferenciació social a la Bahía de Parita (Cerro Mangote [7800-4600 cal yr BP], Sitio Sierra [2200 -500 cal yr. BP] i Cerro Juan Díaz [300 BCE - 1600 CE]) i a l'Archipiélago de la Perlas (Playa don Bernardo [6200-5600 cal yr BP]). Amb la finalitat de copsar millor la relació entre els cérvols i els grups humans s'ha proposat una metodologia *multriproxy* que ha inclòs zooarqueologia, tafonomia, microdesgast i mesodesgast dental, anàlisi d'isòtops estables i morfometria geomètrica. El cérvol de cua blanca és l'espècie més important al jaciment del preceràmic tardà de Cerro Mangote. L'estudi de les restes de cérvols a Sitio Sierra va permetre d'observar que aquest animal fou el plat principal en els banquets, els quals probablement van estar vinculats a activitats rituals. L'abocador de l'operació 1B del jaciment Cerro Juan Díaz va evidenciar que s'havia format a partir dels materials de desfeta de les activitats de manufactura d'artefactes i ornaments elaborats amb ossos, banyes i dents de cérvol. En el cas de Playa don Bernardo, les evidències assenyalen que els efectes de l'arribada de les comunitats humanes a l'illa van produir impactes irreversibles en la fauna local, entre els quals hi hauria l'extinció del cérvol nan de l'illa, entre 5700-2300 anys cal BP. El cérvol de cua blanca probablement fora una espècie amb accés restringit donat el seu significat ritual polisèmic a la Bahía de Parita, en particular en el període de diferenciació social. El registre zooarqueològic d'aquesta zona no evidencia que els grups humans depenguessin del consum dels cérvols per sobreviure; aquests grups tenien unes dietes d'ampli espectre que van afavorir la conservació d'aquesta espècie fins els nostres dies.

Graphical abstract



MATERIALS

Panama

Mazama sp.

Playa don Bernardo (PDB)
4200–3600 cal BCE

Odocoileus virginianus

Cerro Mangote (AG-1)
5900–3020 cal BCE

Sitio Sierra (AG-3)
200 cal BCE-1521 cal CE

Cerro Juan Díaz (LS-3)
200 cal BCE-1600 cal CE

METHODS

- Zooarchaeology
- Taphonomy
- Microwear
- Mesowear
- Stable isotopes
- Geometric morphometrics

RESEARCH QUESTIONS

- Socio-political aspects
- Social complexity
- Symbolic aspects
- Specialization
- Social Cohesion
- Economy
- Broad spectrum diet
- Ecology
- Swidden farming
- Garden Hunting

CONCLUSIONS

- PDB and AG-1 consumption of deer
- AG-3 feastings
- LS-3 deer bone and antler workshop
- There is not evidence of intensification in white-tailed deer hunting
- The dwarf deer was extirped at PDB
- Deer at AG-1 and LS-3 were hunted mostly during the wet season and at AG-3 in summer. PDB seasonal occupation.
- White-tailed deer had a restricted access because of its polysemic ritual significance
- Cultural management allowed the maintenance of white-tailed deer population through time

1. Introduction

More than 40 years of archaeological research in Panama has revealed a wealth of information about human populations having inhabited the Isthmus of Panama for more than 13,000 years (Cooke and Ranere, 1992; Cooke et al., 2013; Ranere and Cooke, 2020). Most of the material resulting from these archaeological researches, now stored at the Smithsonian Tropical Research Institute (STRI) in Panamá City, is made of well-preserved and well-documented faunal remains (Cooke et al., 2007; 2008; 2016). This collection can be apprehended from two perspectives, continental sites on one hand and insular sites on the other hand. While in continental assemblages of animal bones, the white-tailed deer (*Odocoileus virginianus*) is by far the most abundant species, in island samples, the brocket deer (*Mazama* sp.) is the only represented cervid according to current state of taxonomic knowledge (Cooke et al., 2016; Buckley et al., 2017). In chronological terms, these samples are ranging from c.8000 years B.P. to up to the Spanish conquest in the XVIth century (Cooke, 2005; Cooke et al., 2007; 2008).

The two cervid species, white-tailed deer and brocket deer, are an important part of the subsistence strategies that allowed human groups to extract matter and energy from the environment (Earle, 1980). Hunting is a subsistence strategy that has an impact on the animal populations consumed and in the communities of which they are part (Ojasti, 2000). Environmental, socio-political and technological factors could cause changes in subsistence strategies (Earle 1980). Taking that into account, it could be expected different subsistence strategies towards deer populations not only because of complexification of the societies tending to extirpate themselves from the nature through the development and intensification of agriculture, but also because environmental differences between the mainland and the islands.

This research seeks to understand the hunting of the white-tailed deer (*Odocoileus virginianus*) and dwarf deer (*Mazama* sp.) as a subsistence strategy, in Pre Columbian Panama in the area of Parita Bay and Pearl Island archipelago through the study of the archaeofaunal material of Cerro Mangote (7800-4600 cal yr BP), Playa don Bernardo (6200-5600 cal yr BP), Sitio Sierra (2200 -500 cal yr. BP) and Cerro Juan Díaz (300 BCE - 1600 CE). Specifically, this study search to answer the following questions: 1. How cervids allow us to reconstruct ancient paleoenvironments? 2. Are there differences between inland and mainland deer populations? 3. Which was the purpose of cervid accumulations in each one of the archaeological sites? 4. Are there changes in deer hunting across time? and 5. Are there hunting seasonality patterns in the archaeological sites?. By answering these questions, it is expected to contribute to the knowledge of the Pre Columbian subsistence strategies in Panama.

In order to respond to these questions, a multi-proxy methodology was selected. A standardized zooarchaeological and taphonomical analysis was designed with the purpose of comparison between and within sites. At the same time detailed mesowear, microwear, and stable isotope analyses were performed to deep down into the diet of these cervids. Finally, a geometric morphometric analysis was used to study inland and mainland deer populations. A complete description of the materials and methods employed in this thesis are presented in chapter 5.

To answer the research questions, the results section is presented as a compendium of three papers published in international peer-reviewed journals, a book chapter, and a final section still unpublished. The first one is entitled “Behind white-tailed deer teeth: A micro- and mesowear analysis from three Panamanian pre-Columbian archaeological sites” and was published in Quaternary International (Martínez-Polanco et al., 2019). The aim of this paper was to use tooth microwear and mesowear analyses in order to infer the duration and seasonality (wet versus dry season) of human interactions with white-tailed deer at three Panamanian archaeological sites with different chronologies and unequal population size and density – Cerro Mangote (AG-1), Sitio Sierra (AG-3), and Cerro Juan Díaz (LS-3).

The second one is entitled “Following white-tailed deer to the hilltop: A zooarchaeological and taphonomic analysis of deer hunting at Cerro Mangote, a Late Preceramic (7800-4600 cal yr BP) site in central Pacific Panama", this one was also published in Quaternary International (Martínez-Polanco et al., 2020). The objective of this paper was to describe deer hunting patterns at Cerro Mangote in order to identify hunting management strategies. To achieve so, we propose a multi-proxy zooarchaeological and taphonomical analysis.

The third paper is "Zooarchaeological and taphonomical study of the white-tailed deer (Cervidae: *Odocoileus virginianus* Zimmerman 1780) at Sitio Sierra, a pre-Columbian village in Pacific Coclé province, Panama, with an evaluation of its role in feasts". This one was published in Archaeological and Anthropological Sciences (Martínez-Polanco and Cooke, 2019). The aim was to seek feasting traits in a Panamanian archaeological site —Sitio Sierra— through a zooarchaeological and taphonomical analysis of white-tailed deer remains.

The fourth paper is entitled "Crafting white-tailed deer (*Odocoileus virginianus*) bone and antler at Cerro Juan Díaz (LS-3), Greater Coclé Culture Area, Panama". This one is a book chapter (Martínez-Polanco et al., 2020) that compiles the presentations of the 13th Meeting of the Worked Bone Research Group (WBRG) of the International Council for Archaeozoology (ICAZ). This paper addresses the crafting of tools and ornaments made of white-tailed deer bone and antler based on a single feature within an extensive village-cum-cemetery known as Cerro Juan Díaz (LS-3).

Closing the results chapter, a section dedicated exclusively to Playa don Bernardo is presented. These results are not published yet. This chapter is entitled "Living on a continental island: Interactions between a dwarf deer (*Mazama* sp.) and a Mid-Holocene community (6.2-5.6 cal yr BP) on Pedro González island (Pearl Island Archipelago, Panama)". In this chapter will be presented all the results of the taphonomical study of the dwarf deer found at Playa don Bernardo, as well as the microwear, mesowear, isotope and geometric morphometric results. The aim of these analyses was 1. to describe deer accumulation at Playa don Bernardo; 2. to study the Pearl Island dwarf deer's ancient diet; 3. to make inferences about current Pearl Island dwarf deer taxonomy, and 4. to evaluate Mid-Holocene human impacts on Pedro González island.

In order to facilitate the lecture of the discussion section, at the end of the results it is presented a data summary in which the most relevant results presented in each paper are summarized. In the seventh chapter the research questions of this thesis are discussed and in the eight chapter the conclusions are presented.

2. Theoretical background

Subsistence strategies allow a human group to extract matter and energy from the environment (Earle, 1980). Hunting is a subsistence strategy that impacts both the exploited animals' populations, and the communities in which the hunters lived (Ojasti, 2000). However, human impacts are not always negative, because people learn how to manage animal populations for their own benefit. Zeder (2015) defines management as "the manipulation of the conditions of growth of an organism, or the environment that sustains it, in order to increase its relative abundance and predictability and to reduce the time and energy required to harvest it". A wild population of a given species can be managed in order to increase its numbers -- if it is beneficial -- or to decrease them -- if it is harmful. Management also enables harvesting a given species on a regular basis, as well as monitoring the favorable and unfavorable behavior it might present, such as suddenly moving elsewhere, or becoming too aggressive (Sinclair et al., 2006). The strategy of sustainable harvesting consists of culling an animal population at the same rate at which it increases under natural conditions (Sinclair et al., 2006), i.e., people need to apply hunting strategies that allow animals to be extracted without decreasing the population. Some examples of management are: (1) hunting a constant proportion of animals each year, (2) fixing a harvesting season, (3) establishing hunting areas, (4) focusing hunting on males rather than females, and (5) orienting hunts towards older rather than younger age groups (Sinclair et al., 2006).

An indirect practice for managing a wild animal population is to manage its food sources (Ojasti, 2000; Sinclair et al., 2006). Linares (1976) proposed the concept of "garden hunting", which refers to the hunting and consumption of animals that are attracted to plants that grow in gardens. Feeding by animals on garden produce has two major effects: (1) animal populations increase more than under natural conditions, and (2) animals are easier to catch or hunt, for example, by using pit-falls and traps, which do not interfere directly with tending gardens.

Environmental, socio-political and technological factors could cause changes in subsistence strategies (Earle, 1980). However, Earle (1980) argues that the key variable for the understanding of changes in subsistence strategies is human population density; consequently, an increase or decrease in human population will affect the use of resources. The increase of the population could generate two simultaneous processes: 1. Intensification of existing strategies - process involving the reduction of the best preys - and 2. Diversification towards new strategies (Earle, 1980). Diversification of diets as increasingly costly species were added to support a larger population. Both trends increased the amount of labor dedicated to procuring food (Johnson and Earle, 2000). Intensification can be defined as the ability of a human population to obtain more food in a given unit of time and space. This is a process in which efficiency is increased to extract more resources (Betts and Friesen, 2004)

However, to understand hunting strategies, it is necessary to study the social and the symbolic aspects of hunting. Taking into account that, hunters make choices of what to seek and what to kill. They do not necessarily conceive these goals in the narrow terms of protein and calories. Human nutritional needs are complex and flexible (Rusell, 2012). Human decisions could respond to ecological factors but also there are other aspects that must be taken into account. People may choose not to hunt or eat certain animals because of food taboos, mythological associations or personal relationships with that species or category of animals (i.e spirit masters of the game species) (Rusell, 2012).

All hunter "animal choices" were embedded in wider social, environmental, and technological contexts (deFrance, 2009). The choices that people made could vary according to the circumstances and the role of the same animal could change depending of the context (i.e Food taboos mark gender differences, age distributions, and reproductive and productive stages) (Rusell, 2012). According to Rusell (2012) taboos could shape hunting decisions much more powerfully than do cost-benefit utility considerations. For example, in stratified societies dietary restrictions are the way to restrict certain foods to the elite, for instance, when hunting is reserved for some individuals or the consumption of certain animals in particular moments, such as feasts.

Feasting is customarily considered by New World archaeologists to be a primary behavioral correlate of elites in pre-European chiefdom-level societies, However, feast occur at every level of socioeconomic complexity, in egalitarian, transegalitarian, chiefly and state societies, although they play different roles (Hayden, 2001; Russo, 2004). Feasting is of greatest importance in transegalitarian groups (groups between egalitarian foragers and complex chiefdoms), because in these groups feasts provide a platform for advertising and consolidating the authority that comes from prestige at social gatherings (Rusell, 2012). The universal ethnographic record shows that other social typologies, such as "tribal" societies in the tropical landscapes of New Guinea and New Ireland, indulge in this widespread cultural pattern, frequently in the context of ancestor veneration (Rappaport, 1984; Bolyanatz, 2000). In the archaeological record of the Southeast of the United States (South Carolina, Georgia, and Florida) circular to U-shaped accumulations of oyster shell or rings of other shells (between 50 and 250 m in diameter) were rerecorded during the late Archaic (5000–3000 B.P.). These special features imply considerable organizational effort, and draw attention to the fact that feasts play an important role in the egalitarian fisher/hunter communities of Late Archaic coastal societies (Russo, 2004; Thompson et al., 2011).

Hayden (2001:28) minimally defines a feast as any sharing between two or more people of special foods (i.e., foods not generally served as daily meals or offered for a special purpose or occasion). According to the same author, feasting comprised various behaviours principally designed to create or maintain important social relationships: 1. Mobilize labour, 2. Establish cooperative relationships within groups or exclude other groups, 3. Create cooperative alliances between social groups, 4. Invest surpluses and generate profits, 5. Attract desirable mates, labor, allies or wealth exchanges, 6. Create political power through the creation of a network of reciprocal debts, 7. Extract surplus produce from the general populace for elite use, 8. Solicit favours, and 9. Compensate for transgressions (Hayden, 2001).

Hayden (2001) divides feasting into four broad categories: 1. Minimally distinctive feasts, 2. Promotional/alliance feasts, 3. Competitive feasts, 4. Tribute feasts. He argues that several feasting traits may be distinguished in archaeological contexts some of which are related to special locations and/or facilities for holding feasts, to spacious storage facilities, and to unusually commodious cooking facilities (Hayden, 1996; 2001; Masson, 1999; Brown, 2001; Clarke, 2001; Kirch, 2001; Wiessner, 2001; Vega-Centeno Sara-Lafosse, 2007; Twiss, 2008; Hull, 2014). Hayden (1996) also proposes that wealth or status may be displayed during a feast with prestige or ritualized items, and with serving accoutrements of unusual quality (See: Hayden, 1996; Junker, 2001; Perodie, 2001; Wiessner, 2001; Twiss, 2008).

Wealth includes valuables used in display, ritual and exchange and special, rare or highly desired subsistence products. While, subsistence goods include food, drugs, and production technology used to meet basic household needs (Brumfiel and Earle, 1987). The objects made from bone was a powerful symbol of status and prestige and could represent the prestige value of the animal in the spiritual or symbolic world (deFrance, 2009).

Animal bone objects or artifacts usually are produced by a specialist. Specialized artisans are usually a minority of the group, and they dedicate most of their time to the manufacture of their products, which prevents them from dedicating themselves to other basic subsistence activities, being forced to exchange their crafts for basic products (Brumfiel and Earle, 1987). That means that specialization involves economic differentiation and interdependence. The definition of specialization focused on differential participation on economic activities (Costin, 1991).

According to Costin (1991) specialization is a complex notion that involves a number of dimensions of variation. 1. The affiliation of the specialist (independent or attached); 2. The nature of the product (subsistence goods, wealth items or services); 3. The intensity of specialization (part-time or full-time); 4. The scale of the production unit (individual industry, household industry, workshop industry, village industry, or large scale industry); 5. The volume of output per individual specialist.

In the archaeological record, the most common evidences of specialization are: 1. the presence of raw materials; 2. The concentration of manufacture debris; 3. The abundance of tools and 4. facilities associated with production (Costin, 1991). Gates St-Pierre et al. (2016) signals the importance to consider animals as a source of raw material as much as a source of food when studying the anatomical representation and the spatial distribution of bones on a site. Meanwhile, Rusell (2012) notes that small numbers of limited body parts used as artifacts or found in special contexts may signal a tabooed and ideologically important animal, rather than one hunted occasionally at a distance from the settlement as would be a more typical interpretation.

Political development is usually accompanied by an intensification of elite-sponsored artisanal production. This is because the production, exhibition, and distribution of wealth are politically important activities is through and use that leaders define their own social statuses and those of others, and at the same time define it with all their rights and obligations (Johnson and Earle, 2000)

3. Research context

3.1. Environmental context: Parita Bay and Pearl Island Archipelago

3.1.1. Parita Bay

The volcanic active Pacific coast of Parita Bay is the most north-westerly extension of the much more extensive Panama Bay. Politically, Parita Bay belongs today to the provinces of Herrera and Coclé, and, geographically, it represents the north-eastern corner of the Azuero Peninsula (Figure 3.1).

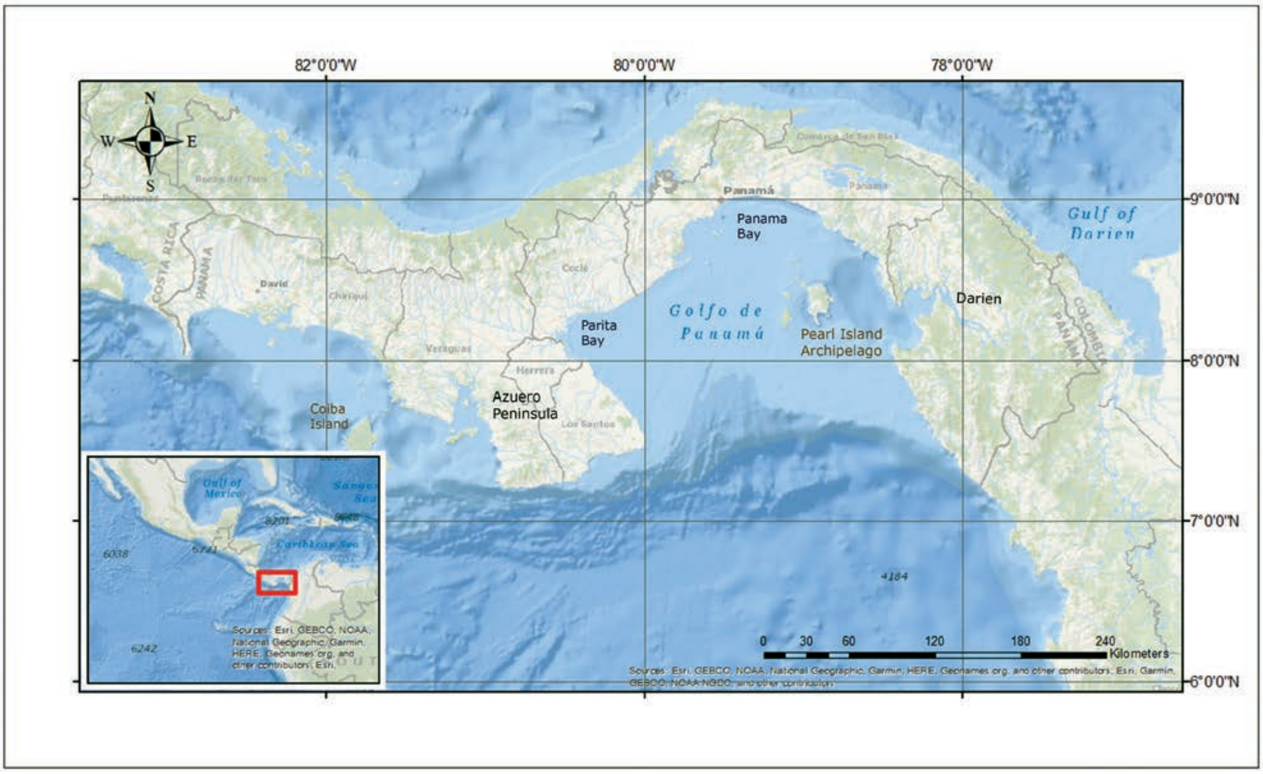


Figure 3. 1Key points geographical localization: Azuero Peninsula, Parita Bay, Pearl Island Archipelago, Panama Bay, Darien coast and Coiba island.

Known in popular parlance as the dry crescent (*Arco Seco*). The term dry crescent refers to the fact that strong north-south trade winds accentuate desiccation during the usually 4 to 5 month dry season in this region (Cooke et al., 2008). All over the isthmus, wet season precipitation is heavily influenced by orography, and, in the vicinity of Parita Bay, convectional up-lift, and electric storms are less pronounced than elsewhere in the country. During the wet season (May-December), the landscape is green and lush, and seasonal swamps form in low-lying areas. Fresh water is provided by rivers, which rise in the central mountain range (*Cordillera Central*), or down the north-south hilly spine of the Azuero Peninsula . During the sunny dry season (strongest in January-April) the water table falls dramatically and evapo-transpiration is very rapid. Some streams (but not the largest rivers) dry out, and vegetation cut for clearing fields burns quickly (Cooke et al., 2008). By April, the landscape has become brown and parched (Cooke et al., 2008). Vegetation history has documented an early Holocene onset of fire-induced forest removal in the central Pacific lowlands and foothills, except for gallery forests included some tall trees (*e.g.* barrigón (*Bombax barrigon*) and higuerón (*Ficus* spp.)) (Figure 3.1), which remain lush and tall along stretches of major rivers, such as the Santa María, Parita and La Villa, in whose watersheds the referred three sites are located (Piperno, 2011). Surviving wooded patches contain many fire-tolerant taxa that have xeromorphic characteristics (*i.e.*

microphyllous leaves, thorns, leaves, and thick bark) as well as drought-adapted tree species, such as chumico (*Curatella americana*), and nance (*Byrsonima crassifoloia*), which often occur in large stands (Linares, 1977: Figure 3.2).

Figure 3. 2 Vegetation examples of Parita Bay. a. Barrigón (Bombax barrigon) Image: M.F. Martínez-Polanco, April 2015, Cocle province; b. Gallery woods along Santa Maria River in the late dry season. Image: M.F. Martínez-Polanco, April 2015, Cocle province. c. Wine Palm (Acrocomia aculeata). Image: R. Cooke, 1975, Cocle province. d. Corozo (Attalea butyracea). Image: R. Cooke, 1975, Cocle province e. Wine palms (Acrocomia aculeata). Image: R. Dickau, 2005. Ancón, Panama City. f. Corozo gunzo (Attalea butyracea). This palm species was planted around pre-Columbian settlements. Image: R. Cooke, 1975, Cocle province.

3.1.2. Pearl Island Archipelago

Pearl Island Archipelago is located in Panama Bay 50–135 km from Panama City, but only 40 km from the Darien province coast (Figure 3.1). It is composed of ~200 islands. The biggest is Isla del Rey (234 km²). The second-largest in Central America after Coiba (490 km²) located also in Panama (Figure 3.1). The islands of the archipelago were connected to the mainland during marine transgressive stages of the last glacial period, they were isolated from the continent, and each other, only during the warmer periods of glacial cycles when ocean levels they were approaching the current ones (Peltier, 2002; Rohde, 2019). During the ice ages and most of the thaws, they would have been hills on coastal plains (Redwood, 2020). They are platform islands (Cooke et al., 2016; Martín et al., 2016).

Pedro González (14.9 km²) is the third-largest island in the archipelago. The wet tropical forest would be the potential vegetation of the island (Figure 3.3). On the island, mangroves are scattered on rocky substrates and sandy areas. Most of the small freshwater streams are seasonal. Reefs and coral patches are scattered throughout the island. The current climate of the archipelago is characterized by a short and intense dry season (January-April), and a period of heavy rains (May-December). The archipelago's multi-year climate variability is defined by the interface between the intertropical convergence zone (ITCZ) and the El Niño oscillation (ENSO) (Cooke et al., 2016).

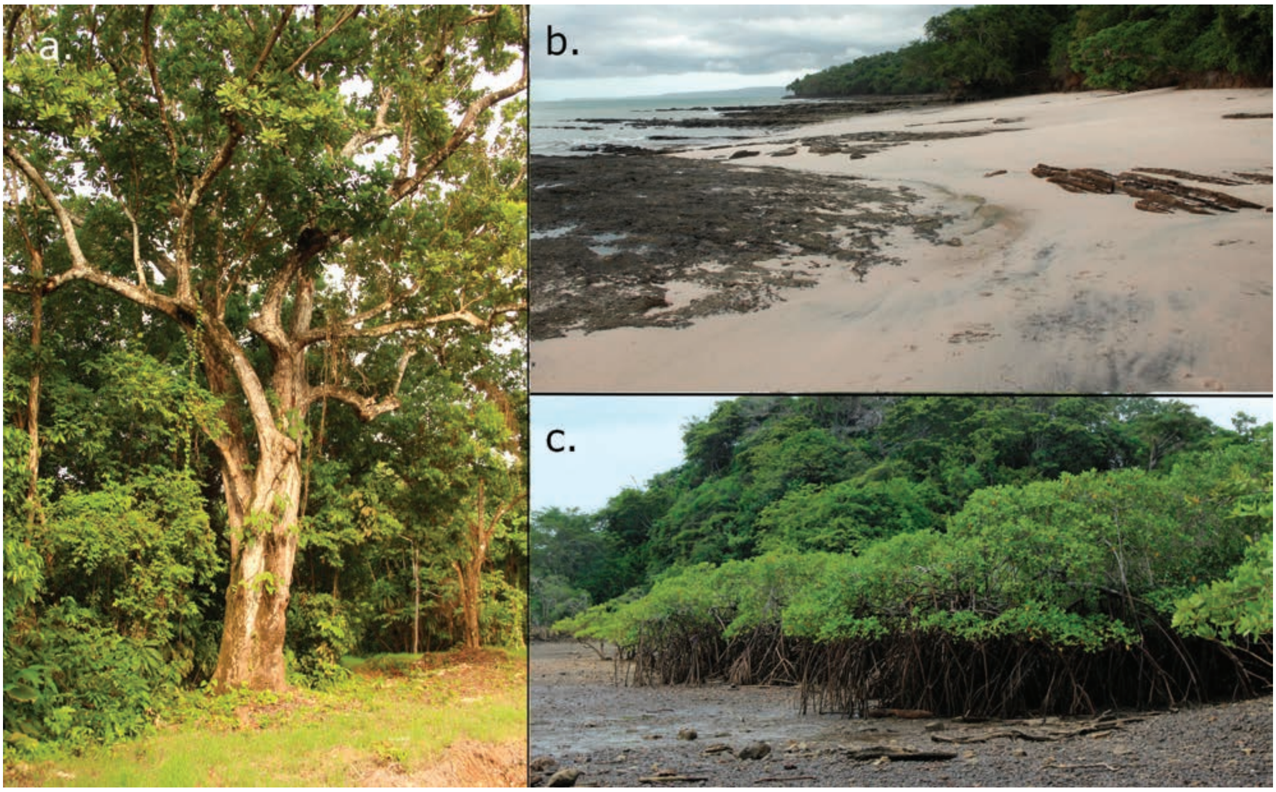


Figure 3. 3 Espavé (Anacardium excelsum). Image: M.F. Martínez-Polanco, May 2014, Pedro González; b. Rocky substrates and sandy areas at Pedro González. Image: M.F. Martínez-Polanco, May 2014; c. Mangroves at Pedro González. Image: M.F Martínez-Polanco, September 2015.

3.2. Archaeological context: Human settlement in Pre-Columbian Panama

In the next section, the cultural chronology of the area will be presented by using Cooke et al. (2013a) proposal.

3.2.1. Hamlet Agriculture period: Late Preceramic (6000-2500 BCE) and Early Ceramic (2500-500 BCE)

Archaeological and paleoecological studies of Panamanian Pacific regions and archaeological sites cover times from the Paleoindian occupations during the Late Glacial period until the initial Spanish contact (Cooke and Ranere, 1992b; Huard, 2013; Ranere and Cooke, 2020). They provide detailed reconstructions of human impacts on the environment (Piperno, 2006; 2011). Paleoindians using fluted projectile points (11.200-10.000 cal BCE) were roaming the landscape when the atmosphere was drier and cooler and when the Pacific littoral zone was an arid, thorny scrubland (Piperno and Pearsall, 1998). Lake core sediments raised from Lake La Yeguada in the Pacific foothills (650 m a.s.l.) indicate that human groups began burning and clearing forests at the Pleistocene/Holocene boundary. Evidence of human perturbation of local vegetation intensified after 7000 BP with the advent of swidden farming (i.e. Piperno, 1984; 2011; Piperno and Jones, 2003). Swidden farming is an agricultural system in which temporary clearings are cropped for fewer years than they are allowed to remain fallow (Sánchez, 1976). The strikingly clear layers of charred vegetation and soil depletion are noteworthy given the small and scattered human settlement activity at this time (Piperno, 2006). Exogenous cultigens were adopted after ca 8000 cal BCE according to microbotanical data from the Aguadulce rock-shelter (AG-13, 20 m a.s.l.) and Cueva de los Ladrones (LP-1, 300 m a.s.l.). The inventory included lerén (*Calathea allouia*), arrowroot (*Maranta arundinacea*), bottle gourd (*Lagenaria siceraria*), maize (*Zea mays*), manioc (*Manihot esculenta*) and squash (*Cucurbita moschata*) (Piperno, 2005; 2011). Native yam was added later by about 5700 BP. Sites within ca 20 km from the active marine shore benefitted from a mixed subsistence strategy of hunting, fishing and farming resulting in multiple grades of alteration to the flora and fauna on the landscape between

6000 and 2500 BCE (Cooke et al., 2013b). The collection of wild or tended american oil palm fruits (*Elaeis oleifera*) was practiced intensively at the Aguadulce Shelter where seasonal swamps would have offered an accessible habitat for this oil-rich species (Dickau, 2010).

In this thesis, two archaeological sites of this chronology were studied: Cerro Mangote (AG-1) and Playa don Bernardo (PDB) (figure 1). In the next section these two sites will be presented.

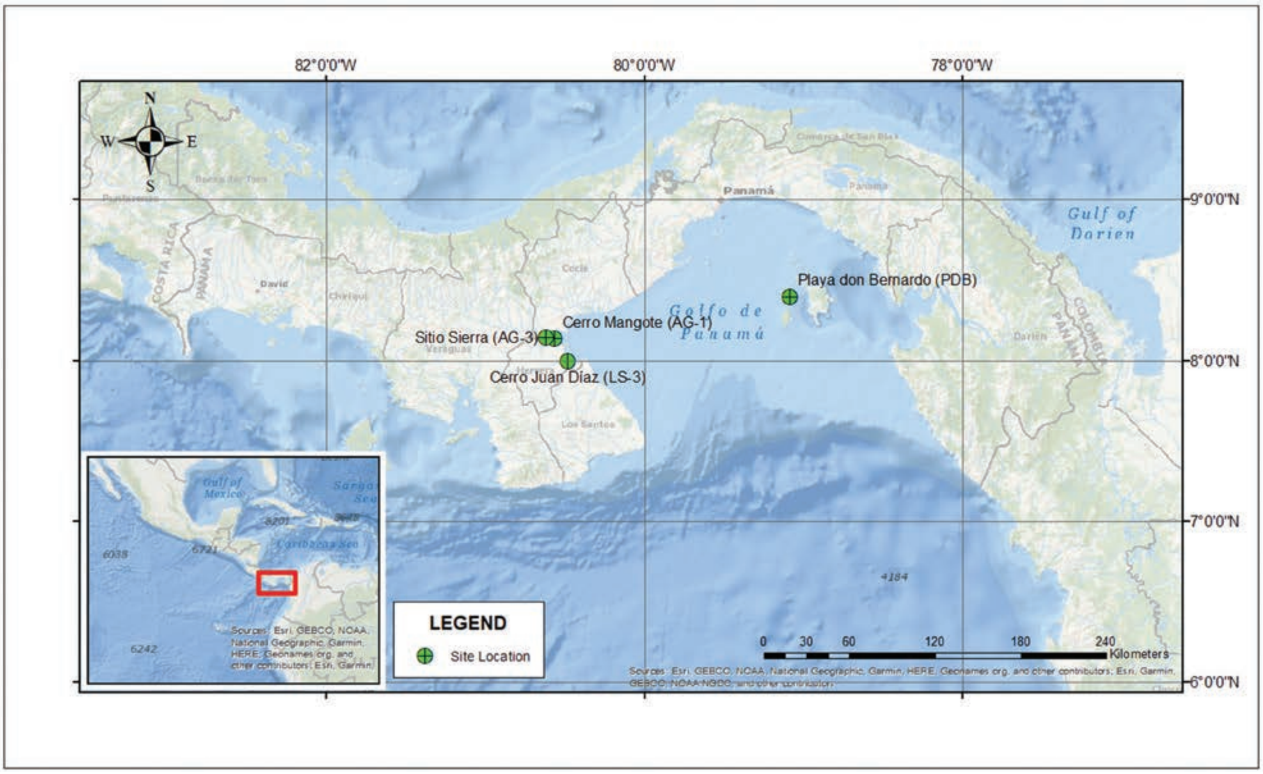


Figure 3. 4 Archaeological sites geographical location.

3.2.1.1. Cerro Mangote (AG-1)

This site is located in Coclé province on the central Pacific coast of Panama (Figure 3.4). A noteworthy variety of vertebrate remains and cultural materials, consisting mostly of lithics, was recovered there (McGimsey 1956; Cooke and Ranere 1992a, 1992b; Ranere 1979). It is a Late Preceramic habitation site with a large midden component that contains abundant remains of marine invertebrate exoskeleton (mostly crabs and mollusks). After its abandonment by the Late Preceramic residential occupants, Cerro Mangote continued being used as a burial ground for peoples using Early Ceramic and Middle Ceramic pottery wares. These ceramic-using people likely resided at the Cerro Girón (Co-2/AG-2) site, which is located very close to the northern (Coclé) bank of the River Santa Maria (Ladd, 1964).

The nature of Cerro Mangote's location is relevant for the understanding the Late Preceramic residence pattern: on top of a 48 m-high hill on the north bank of the Santa María River, at the inland edge of a high tidal flat, or "albinas" (now [2020] largely turned into commercial shrimp tanks) (Figure 3.5). Inland from the hill, the present-day environment comprises sugarcane fields, cattle pastures, remnants of wooded savannas, and swamps and ox-bow lakes, which represent earlier undated meanders of the river (Cooke and Ranere, 1989: Figure 1). Today the site's eastern edge is 8 km from the active marine shoreline of Parita Bay. However, sedimentation at the mouth of the Santa Maria River has moved the coastline seaward at a rate of nearly 1 km every thousand years (Barber, 1981; Clary et al., 1984), so that at the time Cerro Mangote was first occupied, the shoreline was only 1-2 km distant (Ranere, 1979; Cooke, 1984; Cooke and Ranere, 1992a; 1999)

Archaeological remains are distributed in an area measuring 70 m (east-west) by 25 m (north-south) on the north slope of the ridge just below the crest. Two archaeological investigations were carried out, the first one, by McGimsey in 1955 and 1956, and the second one by Ranere in 1979 (McGimsey, 1956; Ranere, 1979; McGimsey et al., 1986; Cooke and Ranere, 1992c).

McGimsey's excavation strategy consisted of opening two trenches and four pits. The west trench was 6 m long and 1 m wide and the east trench was 8.5 m long and 1 m wide. The pit dimensions varied from 1 x 1 m to 2 x 2 m. Sterile red clay and rock were found at a depth of 180 cm in the south end of the site and 90 cm in the north end (McGimsey, 1956; McGimsey et al., 1986).

Table 3. 1. Radiometric dates from Cerro Mangote (AG-1) (Ranere, 1979; Cooke and Ranere, 1992c).

Zone	**Sample**	**Lab. Sample #**	**14C date**	**Cal BP**
Red	Charcoal	Y-458d	6810±110	7845–7465
Brown	*Protothaca*	TEM-206/ Beta-1703	6710±175	7964-7165
Brown	*Crassostrea*	TEM-208/ Beta-1704	4650±165	5302-4437

The objective of Ranere's excavations was to expose undisturbed deposits in two or three excavation units measuring 1 x 2 m in order to collect samples of flora, archaeofauna, charcoal, lithics, and other cultural materials in addition to the sediments themselves. Upon arrival at the site, Ranere and his crew discovered a number of large open looter's pits. These pits were cleaned out and their walls straightened in order to examine them for undisturbed deposits. In total, four units were excavated in 1979 measuring 1 x 3 m, 1 x 3 m, 1 x 2.5 m and 1 x 1.5 m. All undisturbed deposits were excavated with hand tools by natural strata divided into 10 cm sputs for every strata thicker than 10 cm. All deposits were screened on site through ¼ inch mesh (6.35 mm). In a number of undisturbed 10 cm spits, ca 50 liters of deposits were screened using 1/8 inch (3.175 mm) mesh. In addition, 15 liters from each excavation level were water sieved back in the field laboratory. Seven column samples of sediments from the excavations were also collected.

Figure 3. 5. a. McGimsey preparation to excavations 1956. Image: McGimsey archive. b. Detailed of McGimsey excavation 1956. Image: McGimsey archive. c. Cerro Mangote 1956. Image: McGimsey archive. d. Ranere excavation 1979. Image: R. Cooke, 1979. e. Detailed of Ranere excavation 1979. Image: R. Cooke, 1979.

Ranere interpreted the stratigraphy of Cerro Mangote as having two major culture-bearing zones: the "red zone" and the "brown zone". During the red zone occupation, the intensity of human activities was not enough to change the natural character of the red clay sediments. The red zone was radiometrically dated by a single charcoal sample to 4810 ± 110 BP (7845 – 7465 cal BP). The more intense human occupation in the brown zone altered soil composition by incorporating more significant quantities of organic materials. Two radiometric charcoal dates bracket its occupation between 6670 ± 215 BP (Beta-1219) [7964-7165 cal BP] and 5555 ± 110 BP (Beta-1218) [4146-3591 cal BP) (Ranere, 1979; Cooke and Ranere, 1992c).

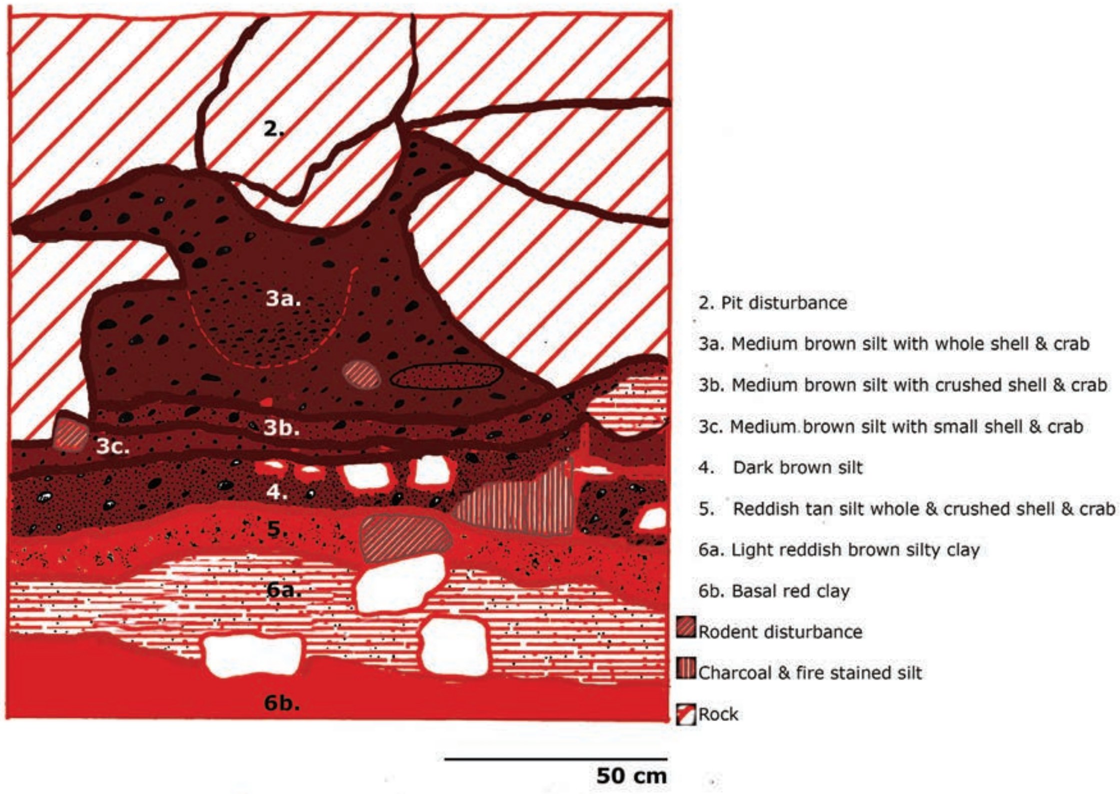


Figure 3. 6. Stratigraphy of Cerro Mangote (Ranere 1979).

The description of the stratigraphy (Figure 3.6) of Cerro Mangote follows Ranere (1979):

Layer 2: A layer of silt 10-15 cm thick caps the pit fill zone and represents the post-occupational deposit at the site.

Layer 3a.-3b: A series of horizontally bedded lenses composed in large part of shells, crab remains and bones, often heavily crushed, lies over the red silty clay layer. Known as the "brown zone", this is the densest occupational refuse on the site. This zone is not a single depositional unit, however, since the inhabitants constantly cut pits into each other, so that the upper 80-100 cm of the "brown zone" consists of pit fill of one sort or another.

Layer 4: A layer of light red silty clay, approximately 20 cm thick. overlies the red clay layer. Occupational debris is more abundant than in the previous layer.

Layer 5: A layer of red clay from 25 cm to over 100 cm thick overlies the andesite boulders. The base of this deposit is culturally sterile, but the upper portion contains the earliest cultural materials at the site.

Layer 6a.-6b: Andesite boulders underlie all sediments at the site; in places, these boulders are exposed on the surface, while in other areas they are buried by more than 2.5 m of deposits.

The most common artifact remains from Cerro Mangote are chipped stone tools and the flakes resulting from their manufacture. The flakes and cores from which they are struck are made of a variety of cryptocrystalline silicates, including petrified wood and, more rarely, quartz crystal and andesite. Flakes are removed from irregular cores and bifacial cores with hard hammerstone percussion. These flakes are then used for a variety of tasks, usually with no further modification. Where present, secondary retouch normally consists of steep unifacial flaking along the flake edge. Additional tools in the lithic assemblage include choppers, chopper-grinders, one-hand manos, edge ground cobbles, boulder milling stone bases, nutting stones, a fragment of cobblestone bowl, and a stone disc. An important feature of the stone tool assemblage are "edge ground cobbles," e.g. hand-sized river cobbles that were used for pounding and grinding on their edges, rather than on the flatter areas of the tool (McGimsey 1956; Ranere 1975, 1979; Cooke and Ranere 1992b). These tools are commonly found in Late Preceramic and Early Ceramic occupations at a large number of sites in Central Panama.

The zooarchaeological record of the site contains terrestrial taxa that customarily frequent mud flats, mangroves, riverine woods and open areas in the close vicinity of the site (Cooke et al., 2007). The most frequently hunted mammals were raccoons (*Procyon lotor*) and white-tailed deer (*Odocoileus virginianus*). Black and green iguana (*Iguana* spp.) were also common in the site's middens. The best represented birds are coastal waders (*Scolopacidae* spp.) and white ibis (*Eudocimus* sp.) (Cooke et al., 2013). Estuary-tolerant taxa dominate the fish remains and include: marine catfish (*Ariidae* spp.), snook (*Centropomus* spp.), corvinas (*Cynoscion* spp.), toadfish (*Batrachoides* spp.), and small-sized Pacific sleepers (*Dormitator latifrons*) (Cooke and Ranere 1989, 1992b, 1992a, 1999). Two particularly interesting zooarchaeological finds were reported at Cerro Mangote, one being the presence of the distal tips of two manatee ribs (*Trichechus manatus*). Manatees do not exist today on the Pacific coast of tropical America nor did they in the past. This fact demonstrates that these specimens were brought to the site from the Caribbean coast (Cooke and Ranere, 1992c). The second find is the oldest record for a domestic dog (*Canis lupus familiaris*) in Central America, represented by a humerus of a form that, subjectively, recalls a collie-like breed (Cooke and Ranere, 1992a).

McGimsey's team recovered 67 human individuals in the 1955 and 1956 excavations, and Ranere's team 12 individuals during the 1979 tests (McGimsey, 1956; Ranere, 1979; McGimsey et al., 1986). Nevertheless, associated artifacts and radiocarbon dates suggest that most of the human burials at the site likely post-date the Late Preceramic midden, perhaps by thousands of years (McGimsey et al. 1966:27; McGimsey et al. 1987:151; Huard 2013: Table 2.2).

3.2.1.2. Playa don Bernardo (PDB)

The site of Playa don Bernando (PDB) is located on Pedro Gonzalez Island (14 ha) in the Pearl island archipelago (Figure 3.4). PDB is located in a tropical rain forest near the shoreline, and its midden deposits date between 4200 and 3600 cal BCE (Figure 3.7). It is the only Late Preceramic site —as far as we are aware of -- on the platform islands of Central America (Cooke et al., 2016; Martín et al., 2016).

Figure 3. 7. a. and b. Excavation at Playa don Bernardo 2015. Image: M.F. Martínez-Polanco, September 2015; c. Aerial photograph of Playa don Bernardo. Image: J.M. Martín, October 2015; d. dwarf deer antler 2015 excavation detail at Playa don Bernardo. Image: J.M. Martín, October 2015; e. Dwarf deer mandible 2008 excavation detail at Playa don Bernardo. Image: J.M Martín, August 2008; f. turtle shell 2015 excavation detail at Playa don Bernardo. Image: J.M. Martín, October 2015.

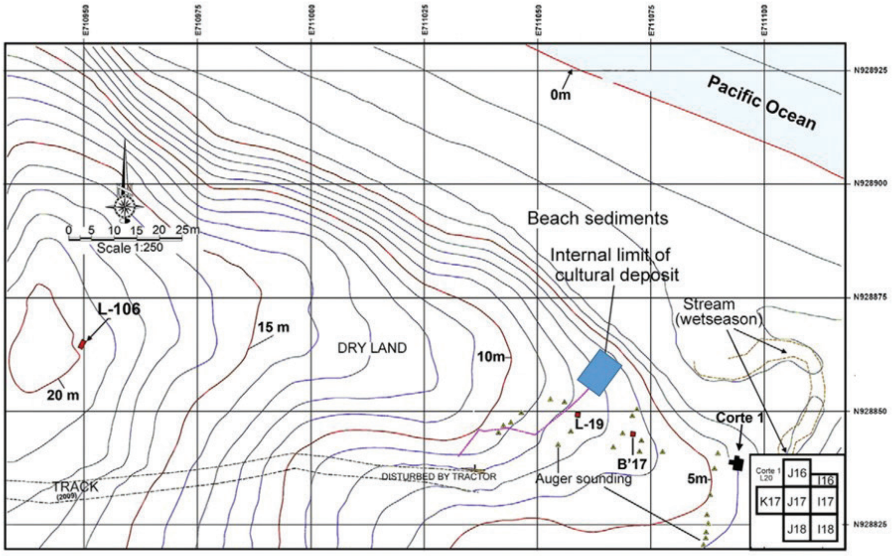


Figure 3. 8. Excavation plan at Playa don Bernardo, adapted to Cooke et al. 2016.

All prospection and excavation of the sampled archaeological sites in Pedro Gonzalez was directed by Martín between 2007-2009 and 2015. The excavations procedures consisted in test pits with varying depth between 1.2 and 4.1 m. The total area covered by these pits was 6.5 m² that represents less than 1% of the archaeological site (Cooke et al., 2016). In 2015, a new excavation was opened (Figure 3.8). The intervened area was 4x7 m and the total excavated area was 28 m² and the depth of this cut was 4.3 m. During both field seasons arbitrary levels of 10 cm were followed and faunal remains were recovered by using graded geological sieves with water (Cooke et al., 2016).

Cooke et al. (2016) proposed a vertical zonation of three Preceramic stratum groups or Macrostrata. Macrostratum I contains packed marine shells mixed with moderate amounts of vertebrate bone (5740-5600 Intercept cal BP); Macrostratum II is a more laminated and heterogeneous unit containing irregular patches of marine shell fragments (5920 Intercept cal BP); Macrostratum III is edaphically quite homogeneous (6000-5900 Intercept cal BP). It is characterized by sporadic marine shell and dense vertebrate bone in an excellent state of preservation (Figure 3.9).

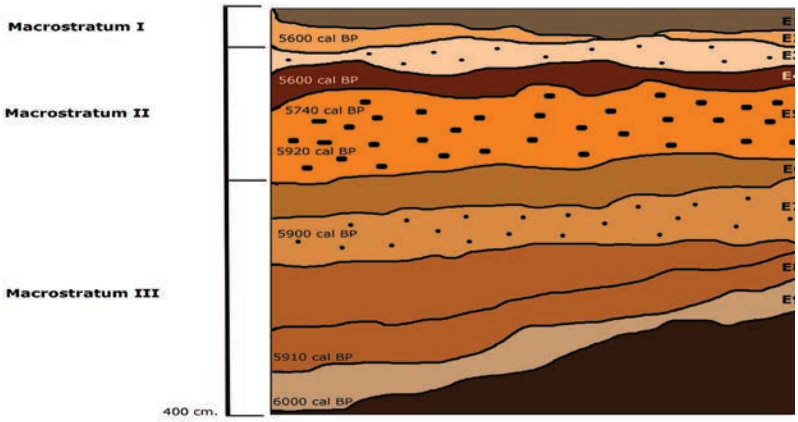


Figure 3. 9. Playa don Bernardo stratigraphy.

By the time the first human colonists arrived by sea, Pedro Gonzalez Island had approached its current configuration. These colonists occupied the island for four to six centuries. They cultivated maize and unidentified root crops and prepared them with small grinding stones where phytoliths were find (Martín et al. 2016). They fished in multiple inshore marine habitats (Cooke and Jimenez, 2009), drove or scavenged dolphins (*Delphinus delphis* and *Tursiops truncatus*) and hunted sea turtles (mostly *Eretmochelys imbricata*) and small land tortoises (*Kinosternon* spp.), iguanas (*Iguana iguana*), several genera of large snakes (*Boa constrictor* and *Colubridae* gen.), a few birds (mostly cormorants [*Phalacrocorax olivaceus*]) and a depauperate suite of terrestrial mammals including dwarf deer (Buckley et al., 2017), opossums (*Didelphis marsupialis*), agouti (*Dasyprocta punctata*), spiny rats (*Proechimys semispinosus*), furry spiny rats (*Diplomys labilis*), paca (*Cuniculus paca*), and monkeys (*Cebus* sp.) (Cooke et al., 2016; Martín et al., 2016). It is noteworthy to mention that some of the species found in the archaeological record that are no longer found in Pedro Gonzalez island. Such as, dwarf deer, opossum, spiny rats, paca, monkeys and turtles (Martín et al., 2016).

Dwarf deer (<10 kg) are the most abundant terrestrial mammal in the assemblage. The island's inhabitants consumed venison and used deer bones to make ornaments and tools (Martínez-Polanco et al., 2015; Buckley et al., 2017). While a ceramic period occupation existed, it was observed that the number of deer remains decrease across time, with none remaining by the ceramic occupations in the island (Martínez-Polanco et al., 2015; Martín et al., 2016).

The stone assembly recovered in PDB represents an opportunistic unifacial industry on flakes with a microlithic component. Within the lithic material that was analyzed, 63% of cores, nodules, flakes and discarded carvings made of agate were identified -a variety of quartz found in volcanic rocks-, 16% stone tools made of basalt and 13% of arcillolite (Martín et al., 2016).

Table 3. 2. Radiometric dates of Playa don Bernardo (Cooke et al., 2016).

Cont.	Material	Lab. ID	Measured date	Cal BP (2σ)	Intercept cal BP
L-19-I	*Argopecten circularis*	β-256752	4860 ± 50	5720–5560	5600
L-19-I	carbonised palm	β-256751	4900 ± 40	5660–5580	5600
L-19-I	*Argopecten circularis*	β-243898	4980 ± 40	5870–5650	5740
Corte 1-II	carbonised material	β-261219	5240 ± 50	6000–5890 & 5810–5760	5920
Corte1-II	carbonised material	β-261218	5140 ± 40	5840–5750 & 5840–5750	5900
Corte 1-III	carbonised material	β-261217	5150 ± 40	5840–5850 & 5840–5750	5900
B'17 39-III	carbonised Delphinus bone	β-304632	5350 ± 40	5990–5870	5910
B'17 41-III	carbonised material	β-278902	5330 ± 40	6190–5930	6000

3.2.2. Village Agriculture and Social Differentiation period (500 BCE-1520 CE)

This period witnessed increased settlement size and its nucleation, accompanied by social and ideological transformations signalled by the emergence of the Greater Coclé semiotic tradition by about 200 BCE (Cooke, 2005; 2011). This tradition represents a 1500-year continuum of tri- and polychrome painted ceramics. Locally produced fine goldwork accompanied ceramics after ca 400 BCE. Many motifs in both media were zoomorphic, and the tradition's most biologically realistic phase spanned 550-1400 CE (Labbe, 1995; Cooke et al., 2000).

Starting ca 200 BCE personal ornaments made of marine shells enter the cultural inventory. The five most favored genera and/or species were the Pacific giant conch (*Lobatus galeatus*), thorny oysters (*Spondylus* spp.), olive shells (*Oliva* spp.), Pacific giant conch (*Larkinia grandis*) and pearl oyster (*Pinctada mazatlanica*). Discrete refuse lenses with significant amounts of debris at Cerro Juan Díaz demonstrated production was specialized, probably at the household level (Mayo, 2004; Mayo and Cooke, 2005). After ca 700 CE, the most influential individuals and probable descent groups were capable of accumulating impressive quantities and varieties of fine pottery for lavish burials like the well-known cemeteries of Sitio Conte (Lothrop, 1937; Hearne and Sharer, 1992) and El Caño (Mayo and Mayo, 2013; Mayo and Carles, 2015) (Figure 3.10).

The Greater Coclé lithic inventory includes multiple functional tools appropriate for daily and seasonal activities of farming, hunting and fishing villages. Specialized quarries and workshops are scattered across the landscape and many of the cluster in the volcanic highlands. These localities provided basalts and andesites for multi-use polished tools, and lava-stones, tuffs and ignimbrites for fashioning grinding tools for maize. Field data point to established exchange routes interconnecting stone quarries, tools in early stages and finished artefacts in villages (Cooke, 1984).

Finally, at the ceremonial center of El Caño in seasonal swamp lands of Coclé province, a regional tradition of sculptures made mostly from hexagonal basalts developed (Mayo et al., 2010). The anthropomorphic and zoomorphic iconography is unique in Lower Central America and vouches for this site's being the primeval location of an ancient ethnic polity that subsequently fissioned.

In this thesis, two archaeological sites of this chronology were studied: Sitio Sierra (AG-3) and Cerro Juan Díaz (LS-3).

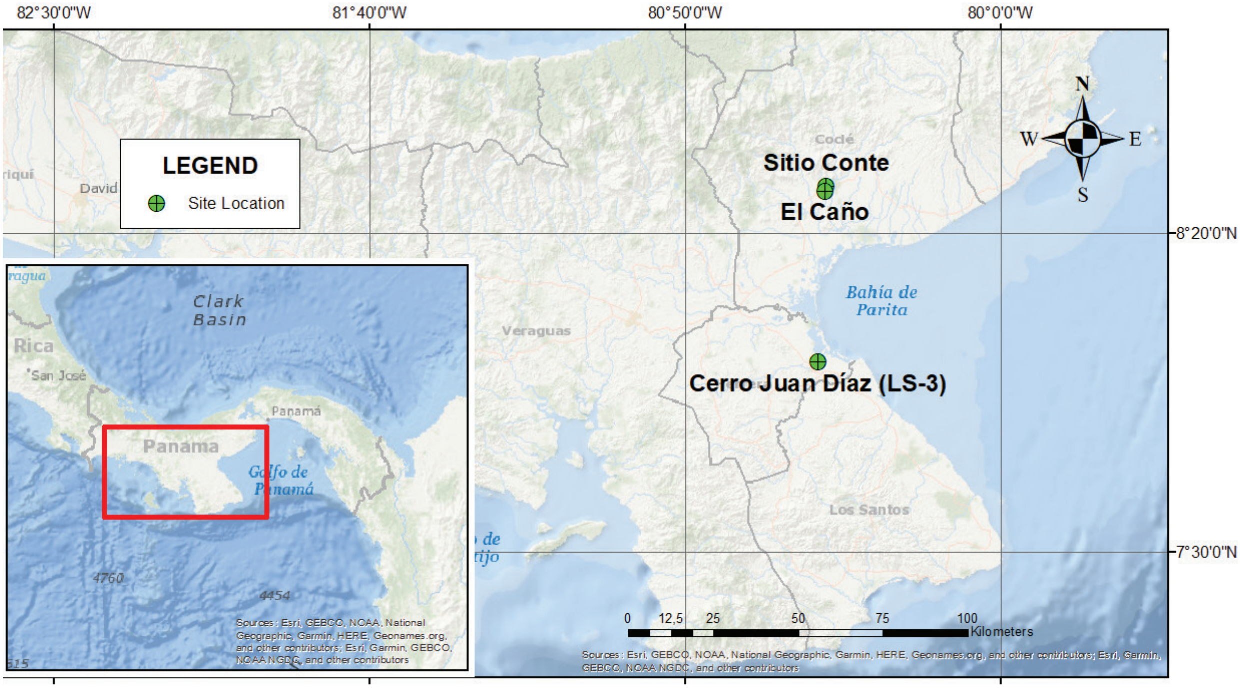


Figure 3. 10. Geographical location Greater Coclé semiotic tradition archaeological sites: Sitio Conte, El Caño and Cerro Juan Díaz (LS-3).

3.2.2.1. Sitio Sierra (AG-3)

A village was established at Sitio Sierra by the end of the second millennium BP, and there were people still living there at conquest (1515-1519 CE). There is no evidence that it was a high-ranked village. It is located 4 km south-east of La Loma village (Aguadulce District, Coclé Province, Panama) (Figure 3.4) on a slight rise adjacent to the Santa María river, and about one km north of its current channel. At this point – a straight-line distance of ~13 km from the marine shore of Parita Bay – the Santa María runs completely fresh today although slight tidal influence occurs here (Cooke and Tapia Rodríguez, 1994). Studies of paleo-channels have not been undertaken, however, and it is conceivable that oxbow lakes easily visible today just north of Sitio Sierra represent the major channel of the Santa María river during all or part of the village's occupation. In the 1970s, the vegetation was typical of dry wooded savannahs impacted by post-contact cattle grazing. Swampy areas had large stands of bucayo or gallito (*Erythrina fusca*), which has edible new buds and leaves (Cooke, 1972). The gallery forest along the Santa María was ecologically healthy, and included some tall trees (*e.g. Bombax barrigon* or barrigón and *Ficus maxmima* or higuerón) (Figure 3.2). The village appears to have been occupied continually based on ceramic sequences although the small quantities of pottery belonging to the Cubitá horizon (1500-1250 BP) (see: Cooke, 2011) may reflect a lull in occupation. Surface ploughing had altered the natural stratigraphy by 1970-1975 when the site was excavated, and domestic features dated after about 1300 BP were not found in a pristine state. The site has been a cane field belonging to the Ingenio Santa Rosa since 1975.

Figure 3. 11 a. Site vegetation wet season. Image: R. Cooke, 1975; b. Site vegetation at the late dry season. Image: R. Cooke, 1973; c. Profile B3 context. Image: R. Cooke, 1975; d. Deer remains in anatomical connection found at context A 2/1. Image: R. Cooke, 1975; e. Deer remains recovered at context B3. Image: R. Cooke, 1975; f. Deer remains found at context B3. Image: R. Cooke, 1975.

Archaeological remains are distributed over 45 ha., although it is not known whether the whole area was ever simultaneously occupied. Richard G. Cooke's (24 m^2) excavations between 1970 and 1971 (Cooke, 1972) employed only arbitrary levels of 10 cm. All pits were taken to bedrock. Small extensions to the initial pits were made in 1973 during a field course for Institute of Culture students, and in 1975, a considerably larger excavation was made during the entire dry season (December-May) using décapage techniques, which followed natural and cultural strata, and located several discrete features such as refuse lenses, structure floors with post molds, various kinds of pits, earth ovens, and two cemeteries (Cooke, 1979; 1984; Isaza Aizpurua, 1993; 2007) (Figure 3.11). In this campaign, 3.4 mm sieves lying flat were used to recover faunal remains, and small columns were kept back for sieving with water over 2 mm mesh. "Slit" trenches, 0.75 m wide, were used to determine the spatial extent, depth, and undulations of refuse lenses -- with considerable success.

In the 1975 excavations, two major areas were opened, and worked by décapage: Cut A and Cut B (Figure 3.12). Table 3 presents a list of the features employed for this study together with their inferred functions. In most cases, animal remains were found on structure floors, and in refuse lenses found adjacent to them or thrown over living floors.

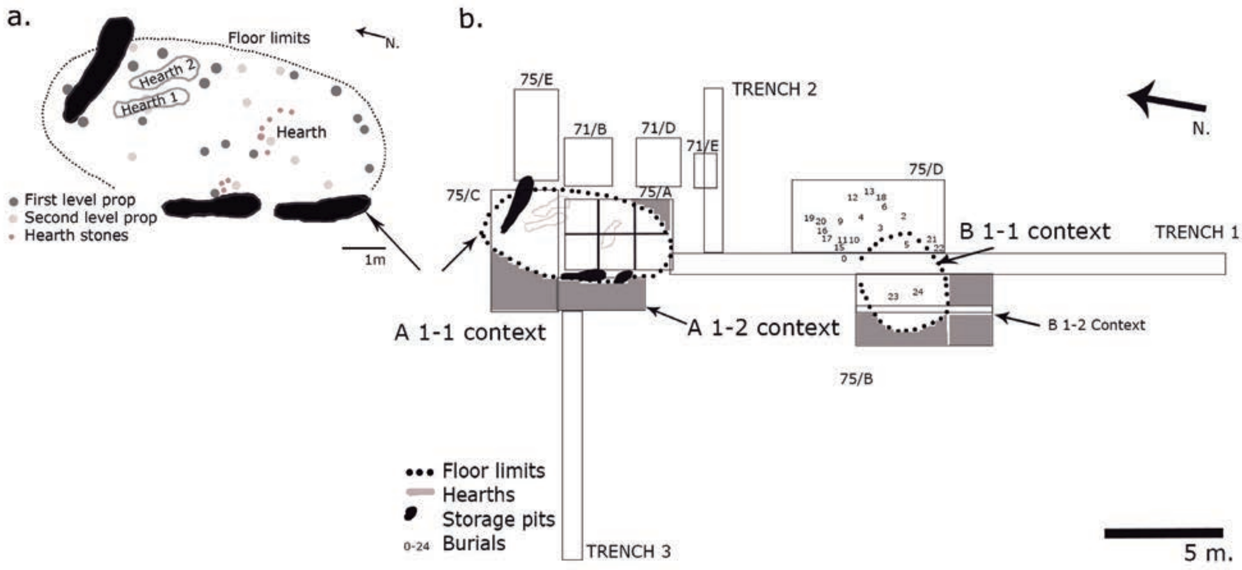


Figure 3. 12. Excavation plans and photographs Sitio Sierra (AG-3). a. A 1/1 context plan, there is an oval structure with hearths and storage pits. Modified from Cooke (1979:35) b. Excavations pits made between 1969 and 1975. Modified from Isaza Aizpurua (1993).

Table 3. 3 .Sitio Sierra (AG-3) context descriptions and dates. The Datations were taken of Isaza Aizpurua (2007) compilation.

[1]conventional C-14 age BP ± 1-sigma range.

[2]calibrated 2-sigma range BCE/CE.

Context	Description	Lab. #	DATE[1]	DATE CAL.[2]
A3	Kitchen refuse probably from a dwelling outside the pit limits			
A2-1 / A2-2	Kitchen refuse, dense accumulation	I-8556	1475 ± 110 BP	335 – 770 cal CE
404	Pit located at the base of A2-2			
A1-1 / A1-2	Oval domestic structure with a hearth and two hourglass-shaped pits	I-8613 CEI-9701	1715 ± 90 BP 1835 ± 90 BP	90 – 540 cal BCE 21 cal BCE – 395 cal CE
B4	Kitchen refuse accumulated gradually above B3			
B3	Kitchen refuse deposited rapidly over B2			
B2	Two superimposed structure floors alongside two hour-glass ovens			
B1	Floor of a circular structure	I-9702 I-9703	2015 ± 80 BP 1975 ± 80 BP	350 cal BCE – 209 cal CE 177 cal BCE – 224 cal CE

In Cut A, the lowest house floor was reconstructed as an oval about 8x4 m (Figure 3.10), and the position of post molds suggests multiple re-habilitation of the house in the same spot. A date of 1715 ± 90 BP (90 – 540 cal BP) was based on wood charcoal from a small hearth, but $\delta^{13}C$ (-25) was not calculated empirically at that time, and this omission could be a source of error. The typology of the pottery associated with the house (the early Aristides group) (Ladd, 1964; Cooke, 1972; 1976; Isaza Aizpurua, 1993) is consistent with this date. Two hourglass-shaped pits with burned stones in a central position for placing cooking pots, are inferred to be hornillas in local parlance: subterranean earth ovens, which are still in use in the region. A layer of soil with less cultural material suggests the abandonment of the lowest house A-1-1, which was followed by a later house (A-2-1) of which only the edge was recovered (Figure 3.12). Wasp nests in clay (*Sceliphron* sp.) had fallen into a shallow trough alongside the house floor of A-2-1, ostensibly made by water dripping from the palm frond roof. This inference was based on impressions of palm leaves on the back of some of the wasp nests. Others bore impressions of grasses (Poaceae), which allude to these nests having adhered to walls made cane (Cooke, 1979; 1984: 284). Another refuse lens (A-3) -- probably from an unidentified house -- was thrown over A-2, cutting deeply into the house floor (Figure 3.12).

In Cut B, a circular structure with post-molds was found above and alongside the lowest burial ground. It was associated with two charcoal dates with $\delta^{13}C$ inferred at -25: 2015±80BP (350 cal BCE – 209 cal CE), and 1975±80 BP (177 cal BCE – 224 cal CE). The dates are earlier than those for Cut A's house, and are consistent with the high proportion of La Mula group pottery in the house – the first bi- and tri-chrome style in Greater Coclé (Cooke, 1972; 1979; 1984; Isaza Aizpurua, 1993) (Figure 3.10). Feature B-3 – exclusively a refuse lens -- was deposited over the lowest structure (B-1), and an intermediate level of pits and trash heaps (B-2).

Carbonized macrobotanical remains were found in some quantity in houses and rubbish dumps at AG-3. Nearly 99% belong to maize, and many fragments of legged maize-grinding tables (*metates*) and grinding stones (*manos*) were deposited on structure floors, and in trash heaps. Spanish contact-period chronicles, however, vouch for the cultivation of manioc (*Manihot esculenta*), sweet potatoes (*Ipomoea batatas*), and squash (*Cucurbita* sp.) in the colluvium alongside rivers that enter Parita Bay. Maize and manioc complement themselves agriculturally and dietetically. Squash pollen and phytoliths were identified in domestic contexts at Sitio Sierra. Carbonized palm nuts of Attalea butyracea (*corozo gunzo* in regional Spanish) were probably collected in nearby fields where these palms are usually left standing today during de-vegetation for pastures and fields (Dickau, 2005).

The zooarchaeological record shows the consumption of marine shellfish (*i.e* grand ark, *Larkinia grandis*); single-banded moonsnail, *Natica unifasciata*); mangrove crabs (*i.e* mouthless crab, *Cardisoma crassum*); a wide variety of fish (70% marine/estuarine and 30% freshwater); frogs (*Leptodactylus insularum*) and toads (*Rhinella marina*); charred mud turtles (*Kinosternon scorpioides*); snakes (*Boa constrictor*) and iguanas (*Iguana iguana*); several species of birds, and open land and gallery forest mammals: white-tailed deer (*Odocoileus virginianus*), paca (*Cuniculus paca*), armadillo (*Dasypus novemcinctus*), and opossum (*Didelphis marsupialis*) (Cooke and Ranere, 1989; 1999; Cooke et al., 1996; 2007; 2008; 2013a). The frog and the toad, whose remains are common, can both be eaten by humans after diligent skinning, and toad may have served a ritual function as well a culinary one (Cooke, 1989).

3.2.2.2Cerro Juan Díaz (LS-3)

Cerro Juan Díaz is a large archaeological site (~150 ha), located near to Los Santos village, in the province with the same name (Figure 3.4; Figure 3.10). It is situated at an elevation of less than 42 meters of height, located 35 meters from La Villa river. Its location allows a quick access to the sea, from which is only 4 km away and into the region towards the highlands of Gran Coclé. During the period of occupation, it would have been 0.25-1 km closer to the coast (Cooke et al., 1998) (Figure 3.13).

Cerro Juan Díaz was an important village, where people with special occupations such as shamans were buried. The politic organization of this village was chiefdom. At spanish contact, Cerro Juan Díaz would have been within the territory of a chieftain whom the spanish named Parita. He had acquired prestige as a successful warrior beyond his territory (Lothrop, 1937; Cooke et al., 2003; Haller, 2004). A pueblo de indios called Cubitá had been established at Cerro Juan Díaz by 1575 CE.

The economy of this population was mixed: agriculture, fishing, hunting and gathering (Cooke and Sánchez Herrera, 1997; Cooke et al., 1998). Cerro Juan Díaz has a long and complex occupation history. The site was occupied between 200 CE until the middle of XVI century. Here, were identified a series of dumps that denote domestic activities between 250 CE and 1400 CE, but also mortuary sites 100 CE-1400 CE. Activity areas related to the manufacture of shell and bone artifacts were also identified (Mayo, 2004; Mayo and Cooke, 2005).

Figure 3. 13. a. and b. Operation 1B excavation preparation. Image: Cooke, R. 1994; c. Cerro Juan Díaz dry season. Image: R. Cooke, 1994; d. and e. Operation 1B excavation detail. Image: R. Cooke, 1994.

Many of these activities have been combined in the same period of time; others on the contrary have been developed or practiced only during a specific period of time. There is also evidence that ancient inhabitants slightly modified the hill´s topography, levelling the southern section (See: Platform, figure 3.12) where the majority of the burials were placed (Cooke et al., 1998; 2000; Díaz, 1999).

A multi-annual archaeological project (1992-2001) directed by Richard G. Cooke documented human occupation. The excavation strategy consisted in eleven field "operations" varied in size from 2 × 1 m test pits (ops-3a and 22) to op-31, which covered ~800 m² (Figure 3.14). Given that the site has been severely damaged by random illegal excavations, the excavations had to adapt to this problem. The features identified in the operations varied among them with regard to depth, complexity, and cultural and biological content. All the operations except op-2 showed evidence for some kind of mortuary activity (Sánchez, 1995; Cooke et al., 1998; 2000; Díaz, 1999; Cooke, 2001).

In this work we will focus on Operation 1B. This excavation was directed by Luis A. Sánchez and Adrian Badilla in 1992. They opened a 2 x 5 m area of excavation on a flat area of Cerro Juan Diaz 30 m from the La Villa River. They identified an ellipsoidal accumulation of sherds, lithics, shells and animal bones about 1.1 m on the longer axis, and about 0.2 m in depth (Feature 1) (figure 3.15). It seems to have formed quickly, the pottery found there could be partially restored, this is evidence that it did not alter much after deposition. In this feature were founded abundant vertebrate remains of fish, amphibians, reptiles, birds and mammals. The pottery belongs to the Cubita ceramic group, which dates between about 500 and 750 CE. Two years later, in 1994, Olman Solis expanded the original excavation to a 6 x 13 m area. In this excavation was observed that the Feature 1 formed part of a larger deposit (Stratum B), which formed in a slight depression on flat terrain. It would appear that it represented the refuse associated with a dwelling. Stratum B is consistently about 20 cm thick. The matrix is mostly fine silt and ash.

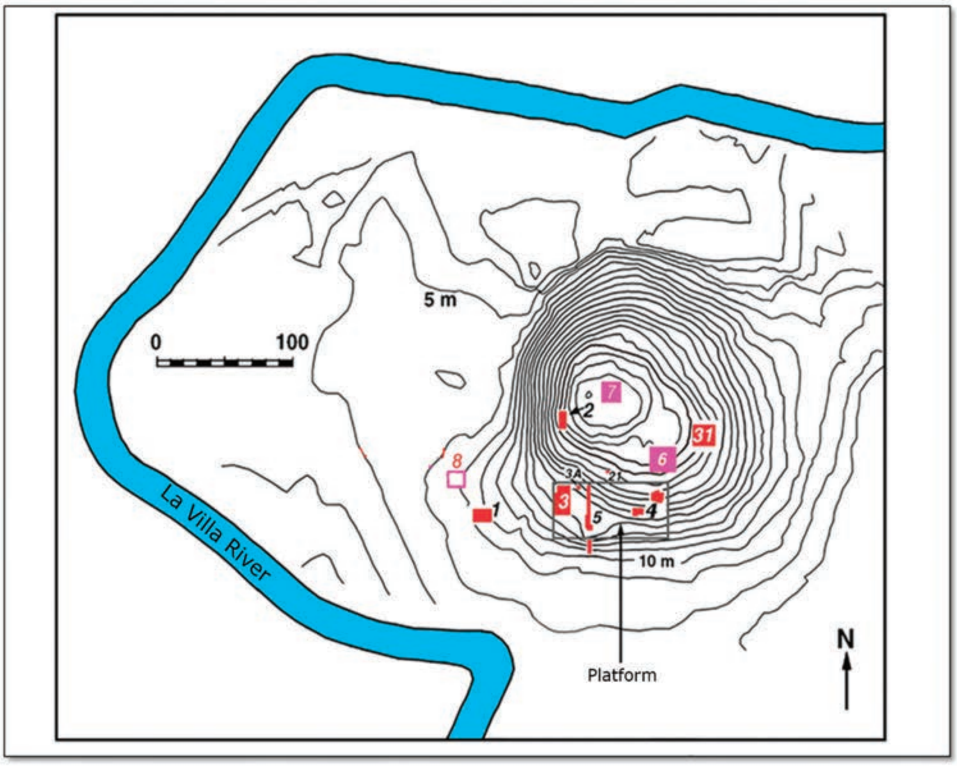
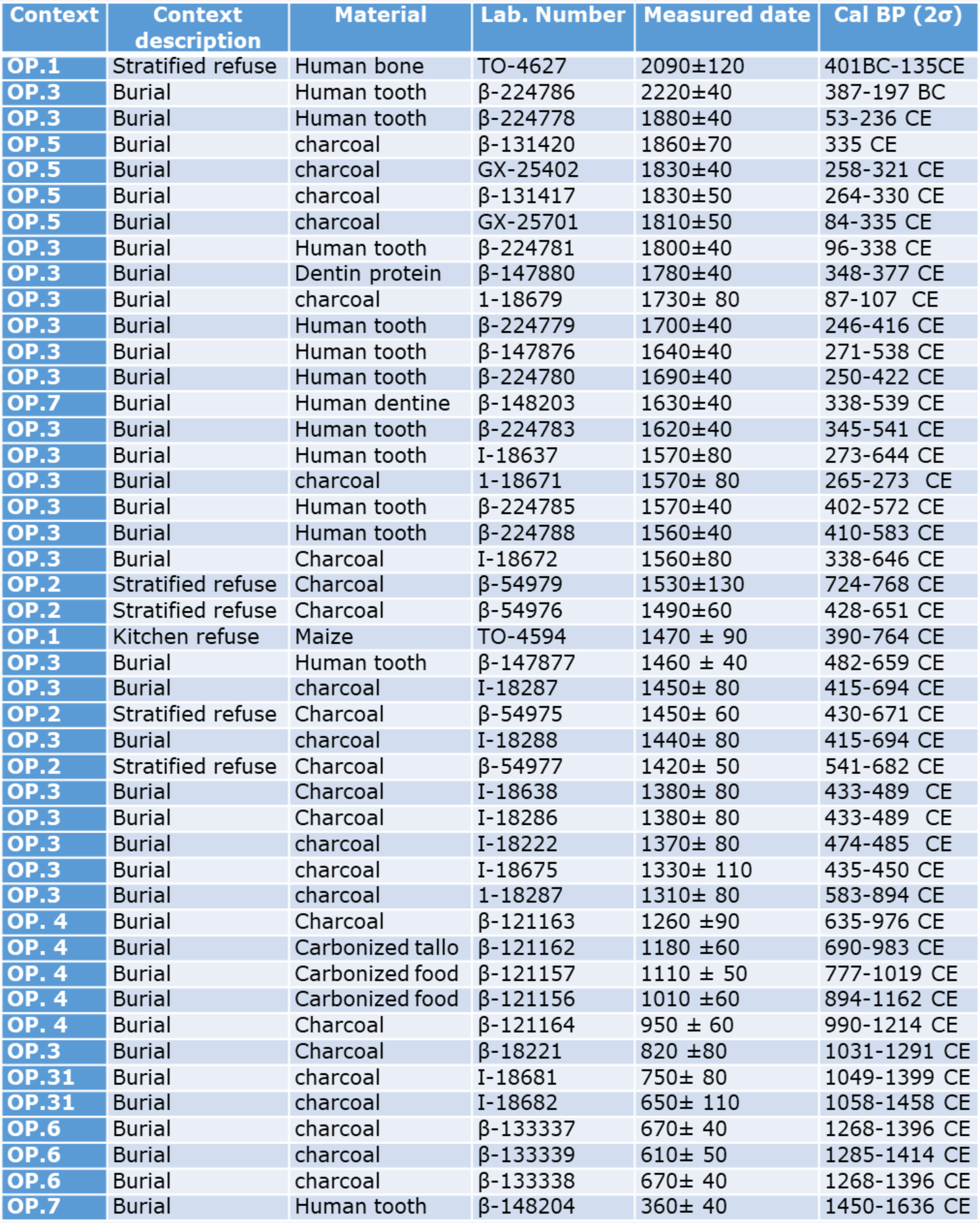


Figure 3. 14. Cerro Juan Díaz operation distributions. Modified from Cooke and Sánchez Herrera (1997).

Table 3. 4. Radiometric dates of Cerro Juan Díaz.



Context	Context description	Material	Lab. Number	Measured date	Cal BP (2σ)
OP.1	Stratified refuse	Human bone	TO-4627	2090±120	401BC-135CE
OP.3	Burial	Human tooth	β-224786	2220±40	387-197 BC
OP.3	Burial	Human tooth	β-224778	1880±40	53-236 CE
OP.5	Burial	charcoal	β-131420	1860±70	335 CE
OP.5	Burial	charcoal	GX-25402	1830±40	258-321 CE
OP.5	Burial	charcoal	β-131417	1830±50	264-330 CE
OP.5	Burial	charcoal	GX-25701	1810±50	84-335 CE
OP.3	Burial	Human tooth	β-224781	1800±40	96-338 CE
OP.3	Burial	Dentin protein	β-147880	1780±40	348-377 CE
OP.3	Burial	charcoal	1-18679	1730± 80	87-107 CE
OP.3	Burial	Human tooth	β-224779	1700±40	246-416 CE
OP.3	Burial	Human tooth	β-147876	1640±40	271-538 CE
OP.3	Burial	Human tooth	β-224780	1690±40	250-422 CE
OP.7	Burial	Human dentine	β-148203	1630±40	338-539 CE
OP.3	Burial	Human tooth	β-224783	1620±40	345-541 CE
OP.3	Burial	Human tooth	I-18637	1570±80	273-644 CE
OP.3	Burial	charcoal	1-18671	1570± 80	265-273 CE
OP.3	Burial	Human tooth	β-224785	1570±40	402-572 CE
OP.3	Burial	Human tooth	β-224788	1560±40	410-583 CE
OP.3	Burial	Charcoal	I-18672	1560±80	338-646 CE
OP.2	Stratified refuse	Charcoal	β-54979	1530±130	724-768 CE
OP.2	Stratified refuse	Charcoal	β-54976	1490±60	428-651 CE
OP.1	Kitchen refuse	Maize	TO-4594	1470 ± 90	390-764 CE
OP.3	Burial	Human tooth	β-147877	1460 ± 40	482-659 CE
OP.3	Burial	charcoal	I-18287	1450± 80	415-694 CE
OP.2	Stratified refuse	Charcoal	β-54975	1450± 60	430-671 CE
OP.3	Burial	charcoal	I-18288	1440± 80	415-694 CE
OP.2	Stratified refuse	Charcoal	β-54977	1420± 50	541-682 CE
OP.3	Burial	Charcoal	I-18638	1380± 80	433-489 CE
OP.3	Burial	Charcoal	I-18286	1380± 80	433-489 CE
OP.3	Burial	charcoal	I-18222	1370± 80	474-485 CE
OP.3	Burial	charcoal	I-18675	1330± 110	435-450 CE
OP.3	Burial	charcoal	1-18287	1310± 80	583-894 CE
OP. 4	Burial	Charcoal	β-121163	1260 ±90	635-976 CE
OP. 4	Burial	Carbonized tallo	β-121162	1180 ±60	690-983 CE
OP. 4	Burial	Carbonized food	β-121157	1110 ± 50	777-1019 CE
OP. 4	Burial	Carbonized food	β-121156	1010 ±60	894-1162 CE
OP. 4	Burial	Charcoal	β-121164	950 ± 60	990-1214 CE
OP.3	Burial	Charcoal	β-18221	820 ±80	1031-1291 CE
OP.31	Burial	charcoal	I-18681	750± 80	1049-1399 CE
OP.31	Burial	charcoal	I-18682	650± 110	1058-1458 CE
OP.6	Burial	charcoal	β-133337	670± 40	1268-1396 CE
OP.6	Burial	charcoal	β-133339	610± 50	1285-1414 CE
OP.6	Burial	charcoal	β-133338	670± 40	1268-1396 CE
OP.7	Burial	Human tooth	β-148204	360± 40	1450-1636 CE

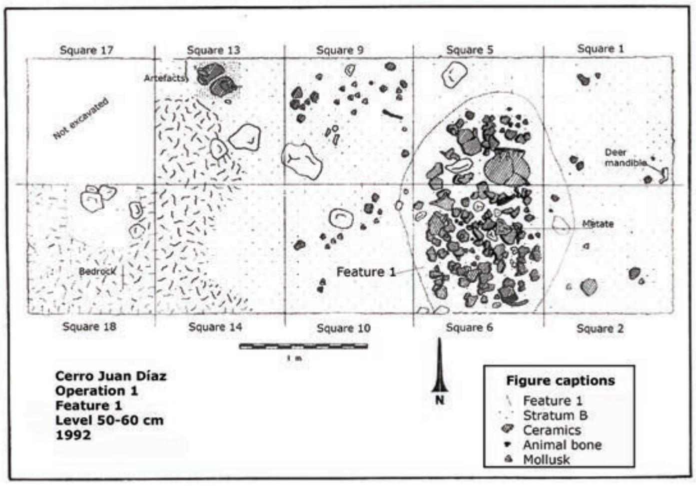


Figure 3. 15. Cerro Juan Díaz, Operation 1 feature 1.Image: R. Cooke personal archive.

3.3 New World cervids

Cervids were important to pre-Columbian communities in the ancient anthropogenic savannahs of central Panama, not only as a food resource, but also as symbols of standard cosmological spaces (Cooke, 2005). Nowadays, in Panama inhabits 3 cervid species: white-tailed deer (*Odocoileus virginianus* Zimmermann 1780), Central American red brocket (*Mazama temama* Kerr, 1792) and Amazonian brown brocket deer (*Mazama nemorivaga* Cuvier, 1817) (Buckley et al., 2017). White-tailed deer is the only deer reported from this seasonally dry area of Panama and the only one identified by zooarchaeological analysis at Parita Bay (i.e. Cooke, 2004; Cooke et al., 2008; Martínez-Polanco and Cooke, 2019). Meanwhile, in the Caribbean coast, *M. temama* is more frequent (i.e Linares, 1976), and at the Pearl Island archipelago, *M. nemorivaga* is the common species. In this section, will be presented the taxonomic relationship between these species, their ecology characteristics in order to have a referent. It is also includes red brocket (*Mazama americana* Erxleben, 1777) because inhabits lowland in Colombia near Panama.

Molecular dating suggests that the Cervidae originated and radiated in central Asia during the Late Miocene and that Odocoileini dispersed to North America around the Miocene–Pliocene boundary (Gallina, 2019). Cervids reached South America in the latest Pliocene about as soon the emergence of an isthmian land bridge permitted (Webb, 1998; 2000). Their success in South America may be attributed in part to the absence of any other ruminants (Eisenberg, 2000). Neotropical cervids underwent a rapid radiation after migration into South America. Most New World Cervidae descendent from the immigration of a single Odocoileine genus and extended widely in the neotropical region (Webb, 1998). The cervids began to radiate into the available habitats, and perhaps invaded in two phases. The first phase includes *Hippocamelus* and *Pudu* radiation and then *Mazama* (Eisenberg, 2000; Gilbert et al., 2006). The brockets and *Pudu*s evolved more recently as small-bodied forms descended from larger ancestors (Eisenberg, 2000). The origination of living cervids of South America was estimated to 200 kya for *Hippocamelus*, *Blastocerus*, *Ozotoceros*, 65 kya for *Mazama*, 48 kya for *Odocoileus*, and 16 kya for *Pudu* (Merino et al., 2005) (Figure 3.16).

The cervids in America are adapted to a wide range of habitats from dense forest to open environments (Emmons, 1999). Their adaptations include morphological, physiological and behavioral traits that maximize their efficient use of natural resources (Gallina, 2019). The phylogenetic inferences show that the evolution of secondary sexual characters (antlers, tusk-like upper canines, and body size) has been strongly influenced by changes in habitat and behavior (Merino and Vieira Rossi, 2010; Gallina, 2019).

Mazama is one of the more diverse genera among Neotropical deer with 10 recognized species. However, their phylogenetic relationship is very complex (Ruiz-García et al., 2007; Duarte et al., 2008; Escobedo-Morales et al., 2016; Gutiérrez et al., 2017; Heckeberg, 2020). The genus *Mazama* is polyphyletic (Gilbert et al., 2006; Duarte et al., 2008; Hassanin et al., 2012; Gutiérrez et al., 2017; Heckeberg, 2020) and *Mazama* genera represents separate radiations events with high levels of molecular and cytogenetic divergence (Gallina et al., 2019a). Traditional morphological traits such as unbranched antlers used to identify *Mazama* species are evolutionary convergent features, associated with adaptations to similar environments (González and Duarte, 2020). There is no consensus in the specific position of all *Mazama* species, the studies based on molecular data agree in pointing a close relationship of gray brocket deer *Mazama gouazoubira* and *M. Mazama nemorivaga* with South American genera *Blastocerus*, *Hippocamelus*, *Ozotoceros* and *Pudu*, recognized as the gray clade. *Mazama americana*, *Mazama temama*, *Mazama bororo*, *Mazama bricenii*, *Mazama nana* and *Mazama pandora* are grouped altogether with genus *Odocoileus* forming the red clade (Merino et al., 2005; Gilbert et al., 2006; Ruiz-García et al., 2007; Duarte et al., 2008; Merino and Vieira Rossi, 2010; Escobedo-Morales et al., 2016; Gutiérrez et al., 2017; Gallina et al., 2019a; Heckeberg, 2020) (Figure 3.16). This implies that the genus *Mazama* is paraphyletic (Gallina, 2019).

A completely resolved phylogeny of Neotropical deer is not available until now (Merino and Vieira Rossi, 2010; Gallina et al., 2019b; Heckeberg, 2020). After decades of research, the taxonomy and evolutionary history of South American cervids remains enigmatic, partly because of the scarce Plio- and Pleistocene fossil record (Webb, 2000). The use of complementary approaches such as ecological niche modeling, traditional and geometric morphometrics, cytogenetics and reproductive characters, new sequence techniques would provide more information about the evolutionary patterns of Neotropical deer (Gallina et al., 2020a; González and Duarte, 2020).

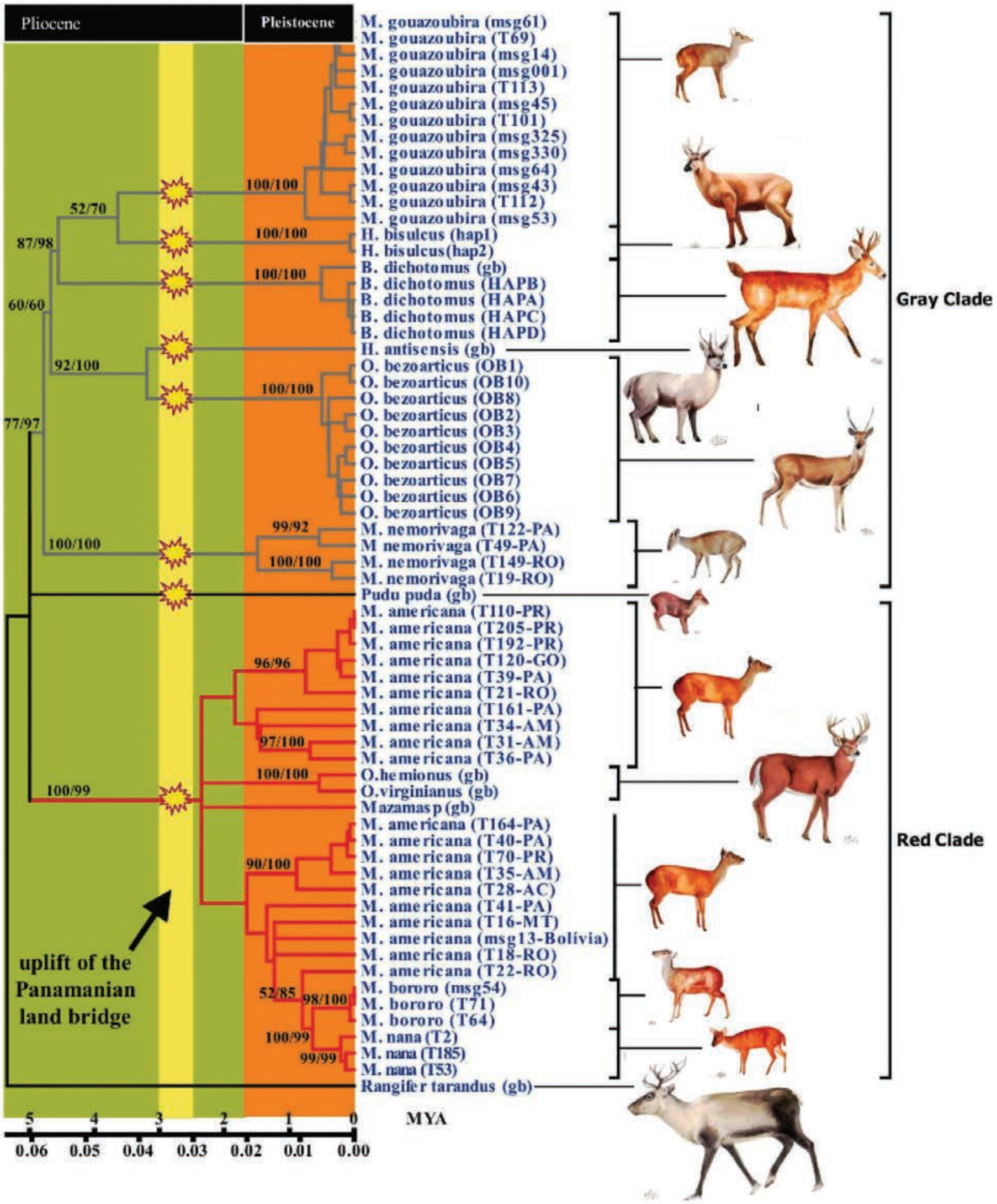


Figure 3. 16. Cervidae phylogenetic tree after: Barbanti Duarte et al. (2008).

3.3.1. White-tailed deer (*Odocoileus virginianus* Zimmermann 1780)

White-tailed deer (*Odocoileus virginianus* Zimmermann 1780) is distributed from southern Canada to Brazil (Eisenberg, 1989; Smith, 1991). It is a polytypic species that has become well adapted to a wide range of habitats from temperate to subtropical, and semi-arid environments to rainforest, and savannas (Eisenberg, 1989; Emmons, 1999). Thirty-eight subspecies have been described, of which 24 live in Latin America, where it is one of the largest extant mammals (Gallina et al., 2010; 2019b).

White-tailed deer differ in body size, coat color, and other physical features throughout its range (Eisenberg, 1989; Gallina et al., 2010; 2019b). The array of their measures is: total length: 104-240 cm, adult males in USA weight 90-135 kg and females 20-40% less (Gallina et al., 2010), but in the Neotropics the body size averages 50 kg, for males, and 35 kg for females (Gallina et al., 2010; 2019b). Adult males bear forked antlers with a variable number of tines Figure 3.17.a. The basic color is a light brown dorsum, with a white venter. The underside of the tile is white. The fawn is spotted at birth Figure 3.17.a. The pelage of whitetails found in the high Andes has a gray coat year-round Figure 3.17.a, while lowlands deer appears reddish-brown through year (Heffelfinger, 2011).

Habitat use by this deer species is predicated upon the quality, quantity, and heterogeneity of available forage and cover protection (Sánchez-Rojas et al., 1997; Gallina et al., 2010; Ramírez Lozano, 2012). Diet varies among regions and seasons due to discontinuities in the availability of food, cover, and water (Sánchez-Rojas et al., 1997). In high rainfall periods, a large quantity of foodstuffs becomes available to the deer although, paradoxically, dietary diversity may be diminished at the beginning of the rains when the deer become more selective, choosing young leaves of trees, shrubs, and vines (Sánchez-Rojas et al., 1997; Bello et al., 2001; 2004; Arceo et al., 2005). Dry seasons are critical periods during which the deer orientate their foraging towards the most nutritious fruits, and leaves trees, shrubs and herbs available in that moment (Sánchez-Rojas et al., 1997; Bello et al., 2001; 2004; White-tailed deer is crepuscular, their movements could be related to different ecological, environmental and behavioral variables. Hunger, reproduction, physiological condition, habitat, predator and human activity are the behavioral variables to which deer could respond (Gallina et al., 2010; 2019b). The amount of precipitation is a key factor in deer reproduction (Gallina et al., 2019b). Deer occur in small social groups. The most common association is mother and the nearly grown offspring or a courting male and female, but in some cases large aggregations could be observed in open areas (Eisenberg, 1989; Gallina et al., 2010; 2019b). White-tailed deer are strong swimmers and will readily cross sizable streams within their home range (Marchinton and Hirth, 1984).

Figure 3. 17. a. white-tailed deer young male. June 2016, PNN Chingaza, Colombia; b. white-tailed deer male with velvet antlers. September 2007, PNN Chingaza, Colombia a. white-tailed deer male. October 2017, Cali, Colombia; d. white-tailed deer male. September 2013, Paz de Ariporo, Colombia; b. white-tailed deer females. October 2017, Cali, Colombia; f. white-tailed deer female. June 2016, PNN Chingaza, Colombia . white-tailed deer females. July 2008, Panama City; h. white-tailed Deer calf. April 2006, Villavicencio, Colombia; c. white-tailed deer calf. August 2013, Tauramena, Colombia; j. white-tailed deer calf. September 2013, Paz de Ariporo. Images: M.F. Martínez-Polanco.

To sum up, white-tailed deer is 1. ecologically protean residing in deserts, savannahs, prairies, mountains, and deciduous and tropical forests 2. able to adapt well to agricultural landscapes, 3. trophically plastic, 4. an opportunistic feeder and 5. selective feeder (Eisenberg, 1989; Smith, 1991; Teer, 1994; Gallina et al., 2010). It chooses relatively nutritious and highly digestible plants and plant parts, such as young leaves (Eisenberg, 1989; Smith, 1991; Teer, 1994; Arceo et al., 2005; Gallina et al., 2010; 2019b). However, it also feeds on grasses, sedges, nuts, fungi, fruits, and fallen flowers (Eisenberg, 1989; Smith, 1991; Gallina et al., 2010; 2019b; Ramírez Lozano, 2012).

3.3.1.1. Whitetails populations in islands

Whitetails also are found in islands, on the coast of Georgia and South Carolina, USA (Blackbeard/Sapelo, Hilton Head, Hunting and Bull islands). These are not discrete and completely isolated islands but simply coastal areas separated from the mainland by a river or marshy area. Deer on these islands are smaller than the mainland deer. It seems that deer are able to swim between the mainland and some of these barrier island (Heffelfinger, 2011).

Key deer, smallest of the North-American white-tailed deer, occupy islands south Miami (Florida, USA) from Little Pine Key to Sugarloaf Key. This population is geographically, phenotypically and genetically differentiated from mainland deer populations. The islands size ranges between 8 to 2400 ha. The distance between Big Pine (the biggest island) to adjacent islands varies from 0.1 to 6.4 km, and all shows deer activity (Hardin et al., 1984). The body size of does averages 30 kg and 40 kg for bucks (Heffelfinger, 2011).

In Panama whitetails are native to the 673 km² island of Coiba situated 24 km off the Pacific coast of Panama. This deer is smaller than other central American whitetails, their weight is 22.5 kg. In Contadora Island at Pearl Island archipelago, 48 km of Panama Pacific coast, inhabits a deer population that is result of escapes or liberations from a captive herd brought from the mainland (Heffelfinger, 2011).

In South America, there are two island deer populations that are isolated from the mainland. Deer on Isla de Margarita (40 km approx.) off the Venezuelan Caribbean coast and Curaçao Island population (60 km) off Venezuela's northwest coast. The Margarita populations were isolated long time ago and show morphological differentiation -smaller body sizes, and distinctive cranial and peculiar mandible traits- from the mainland populations. The weight of males average 31 kg and females 27 kg (Molinari, 2007). In the case of Curaçao Island, the archaeological record of the island shows that there are no evidences of deer from archaic period (500 AC), deer remains are presents before this period when the Caquetios migrants arrived to the island. It seems that Caquetios transported live deer in wooden canoes across 60 km of ocean. This evidence represents the earliest known deer translocation in America (Heffelfinger, 2011). In other island of the Caribbean such as Aruba, Islas Los Roques, Trinidad and Tobago are also archaeological evidence the deer translocation. In Carriacou and Grenada are reported after 1500 cal yr BP (Fitzpatrick, 2015).

3.3.2. Central American red brocket (*Mazama temama* Kerr, 1792)

This species is distributed in Central America to Northwest of south America - Mexico, Belize, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama and Colombia) (Eisenberg, 1989; Bello-Gutiérrez et al., 2010; Gallina et al., 2019a). Red brocket prefers well preserved forest sites, perennial and sub perennial forest, cloud forest, low-dry forest and low-flooded forest. It also lives in transformed forest, secondary forest and croplands (Bello-Gutiérrez et al., 2010; Gallina et al., 2019a), through in some conservation areas it avoided deforested sites and agricultural fields. For this reason, it is considered habitat specialist (Gallina et al., 2019a).

The measures range are: total length 90-120 cm; 12-32 kg weight. Their colour is reddish and the ventral area is white. The males wear a simply spikes without ramifications (Gallina et al., 2019a) (Figure 3.18).

Figure 3. 18 a. Central American red brocket calf. Image: https://bioweb.bio/galeria/Foto/Mazama%20zamora/Registros%20fotogr%C3%A1ficos/431895; b. Central American red brocket male. Image: http://venadosrbtc.blogspot.com/p/los-ungulados-de-la-rbtc.html. c. Central American red brocket female. Image: https://www.biolib.cz/en/image/id360429/.

Red brocket is generally seen alone or in pairs, it forages early in the morning and during the evening (Eisenberg, 1989; Bello-Gutiérrez et al., 2010). Their diet is specialized, consuming less than 10 classes of plants during the dry seasons and 10 to 15 during the wet season (Bello-Gutiérrez et al., 2010; Gallina et al., 2019a). Fruit is preferred when it is available (Eisenberg, 1989). In the Calakmul Biosphere Reserve (Mexico), red brocket is a forest specialist species because it consumes 20 species of forest plants and its diet is composed by fruits (80%), leaves and flowers (20%) (Weber, 2005).

3.3.3. Amazonian Brown Brocket deer (*Mazama nemorivaga* Cuvier, 1817)

This species is distributed in Central and South America - Panama (San Jose Island), Colombia, Venezuela, French Guiana, Guyana, Surinam, Brazil, Peru and Ecuador- (Eisenberg, 1989; Rossi et al., 2010; Gallina et al., 2019a). This species inhabits tropical and subtropical broadleaf moist forest biome and most of them are related to the Amazon region. Amazon red brocket exhibit some selectivity for pulpy fruits with hard exocarp (Eisenberg, 1989).

Their morphometric range is: total length: 76-102 cm and their average weight 15 kg (Gallina et al., 2019a). Their colour is dark brown and the ventral fur is yellowish or whitish. The males wear a simply spikes without ramifications (Eisenberg, 1989; Rossi et al., 2010; Gallina et al., 2019a). The Amazonian brown brocket is solitary and active all day. This species presents territorial behaviour (Eisenberg, 1989; Rossi et al., 2010) (Figure 3.19).

The presence of brocket deer species along their distribution has been considered as indicator of well-preserved tropical forest. They live in forest habitats (Gallina et al., 2019a).

Figure 3. 19 a. Amazonian Brown Brocket deer female. Image: https://www.mammalwatching.com/2019/06/11/primarily-peruvian-primates-owlet-lodge-and-los-amigos-research-station-trip-report/2019-50-amazonian-brown-brocket-mazama-nemorivaga-2/. b. Amazonian Brown Brocket deer male. Image: https://www.naturalista.mx/taxa/74553-Mazama-nemorivaga

3.3.4. Red Brocket deer (*Mazama americana* Erxleben, 1777)

The red brocket deer (*Mazama americana*) is a medium-sized artiodactyl, weighing between 20 and 30 kg at maturity. Their total length varies between 90 to 145 cm (Varela et al., 2010). *M. Americana* is the largest species in the genus *Mazama* (Gallina et al., 2019a). Their body color is reddish-brown, the neck and face are grey, the hind limbs, tail and part or their face are white. Males wear antlers, that are short and straight spikes turned backwards without ramifications (Figure 3.20).

This species is one of the most abundant and widely distributed cervids in Neotropical forest. Its distribution ranges from Colombia, Venezuela, through Argentina and Brazil (Emmons, 1999). This species is found in all main forest biomes of South

America and overlaps its ranges with *M. guazoubira*, M. *nemorivaga, M. nana and M. bororo* and show strong morphological and life style convergent features, but currently occupies different habitats. Red brockets inhabit a variety of ecosystems such as montane forest, lowland dry forest, rainforest, savannas near to forest edges. The species elevation ranges reach an altitude of up to 2000 m a.s.l. (Varela et al., 2010). However, other authors report higher elevation ranges. For example in Colombia at Sierra Nevada de Santa Marta even up to 4000 m a.s.l. (Alberico et al., 2000).

The diet of Amazonia red brocket populations indicates a fruit and seed-eating dominated diet, while leaves, flowers and fungi are consumed in less quantity. The diet composition changes seasonally and geographically (Varela et al., 2010). This species is shy and wary. They are also solitary but it can be observed in pairs during the mating season (Varela et al., 2010; Gallina et al., 2019a). They frequently visit mineral licks and trees with fruits. They are exceptional swimmers and frequently use small streams for their movements as an anti-predatory strategy (Varela et al., 2010).

Figure 3.20. a. Red brocket deer male. Image: https://pt.wikipedia.org/wiki/Ficheiro:Red_Brocket_(Mazama_americana)_male_(28091090800).jpg . b Red brocket deer female. Image: https://panama.inaturalist.org/observations/10470099. c. Red brocket deer calf. Image: https://www.anywhere.com/flora-fauna/mammal/corzuela-colorada

3.4. White-tailed deer in pre-Columbian times

The white-tailed deer played an important role in pre-Columbian intellectual systems. The Maya linked this species to agriculture, the sun, rain, the cyclical nature of time, and, fecundity and prosperity (Brown, 2001; Pohl, 1981). The Maya managed deer populations in order to ensure an adequate meat supply for feasting. They achieved this by preferentially hunting young adults, in order to guarantee reproductive success (Carr, 1996; Masson, 1999). Another kind of Maya management entailed the elite control of forests that were frequented by deer as a conservation strategy. It is known, as well, that the Maya kept deer in captivity, taming and corn-feeding them (Carr, 1996; Masson, 1999; Masson and Peraza Lope, 2008; Montero-Lopez, 2012, 2009; Thornton, 2011). In the Andean world, white-tailed deer also played an important role in the symbolic sphere. For instance, in Moche pottery are represented hunting deer scenes, as ritual hunts to obtain victims for sacrifice (Bourget, 2001). The purpose of deer hunting was not to obtain food but to capture deer for ritual sacrifice (Bourget, 2001). Probably the hunt itself was seen as an offering to the deities (Rusell, 2012).

The white-tailed deer was important to pre-Columbian communities in the ancient anthropogenic savannahs of central Panama, not only as a food resource, but also as symbols of standard cosmological spaces (Cooke, 2005). Deer antlers and bones were commonly employed for making artefacts and ornaments (Cooke, 2004a). Male deer with branched antlers are frequently represented on polychrome ceramics and occasionally on cast-gold pendants after about 2300 cal yr BP (Cooke, 2004; 2011; Cooke and Jiménez, 2010) (Figure 3.20). Cooke and Ranere (1989) and Cooke (1992a) inferred -- on the basis of early sixteenth century CE chronicles -- that deer hunting in the lowlands bordering Parita Bay was socially controlled, being proscribed periodically for prestigious members of the community (perhaps warriors) in order to protect deer stocks, and thus ensure sufficient carcasses for periodic feasts. Large quantities of dried and salted deer carcasses (*venado en cecina* is the Spanish-language term) were deposited in special store-houses in the village of Natá in the chiefdom controlled by a descent group of the same name.

Figure 3. 21. Ceramic Deer representation from Gran Coclé semiotic tradition. Images: Cooke, R.G.

4. OBJECTIVES

4.1. General objective

To understand deer hunting as a subsistence strategy in Pre-Columbian times in Panama, through multiproxy study of deer samples from pre-ceramic groups to complex politicized societies located in continental areas (Cerro Mangote, Sitio Sierra and Cerro Juan Díaz sites) and in islands (Playa don Bernardo site) in order to better understand human and deer relation across time and space.

4.2 Particular objectives

· To study deer diet as a proxy to reconstruct paleoenvironments through a combined analysis of microwear, mesowear and stable isotopes.

· To determine the hunting seasonality patterns based on changes in deer diet along the year.

· To perform a comparison between insular and continental deer populations through a geometric morphometric study.

· To determine the purpose of cervid accumulations in different Panamanian archaeological sites through a taphonomical study.

· To compare deer hunting across time and space and to evaluate management strategies through a zooarchaeological study.

· To contribute to the knowledge of the Pre Columbian subsistence strategies in Panama.

5. Materials and Methods

5.1. Materials

The sampling of the materials for this thesis varies between site, the research question and the methods selected. In table 5.1 it will be find the sample size arranged by site and methodology and in the next paragraphs a description of the sample by method.

Table 5. 1. Sample size by archaeological site and method. Abbreviations: n/a: not analyzed.

Site	Zooarchaeology and Taphonomy	Mesowear	Microwear	Isotope analysis	Geometric morphometrics
Playa don Bernardo (PdB)	2502	85	40	41	30
Cerro Mangote (AG-1)	2082	34	27	38	n/a
Sitio Sierra (AG-3)	2973	20	18	11	n/a
Cerro Juan Díaz (LS-3)	4225	70	57	55	n/a
TOTAL	11782	209	142	145	30

5.1.1. Zooarchaeology and Taphonomy

- Cerro Mangote (AG-1): The remains coming from two different excavations were organized by occupations periods: the red zone (n=270) and brown zone (n=1812). In total, 2082 white-tailed deer remains were studied (Table 5.1).

- Sitio Sierra (AG-3): For this study the materials were organized by excavation unit and context. Unit A, contexts: A3; A2-1 / A2-2; 404 (a pit); A1-1 / A 1-2. Unit B, Contexts: B4; B3; B2; B1. In total, 2973 white-tailed deer remains were analyzed (Table 5.1).

- Cerro Juan Díaz (LS-3): The sample is composed by 4225 white-tailed deer remains from operation 1B (Table 5.1).

- In the case of Playa don Bernardo the zooarchaeological and taphonomical analysis were already performed and one part of them were published (Martínez-Polanco et al. 2015) and the other one will be presented in this thesis. The number of remains analyzed was 2502 (Table 5.1). To determine size changes at PDB the sample was composed by 30 teeth, MS-II=7 and MS-III=23. We do not count with any teeth from MS-I.

5.1.2. Mesowear and Microwear

All available deer dental material from Playa don Bernardo, Cerro Mangote, Sitio Sierra and Cerro Juan Díaz were selected. For mesowear analysis, 209 teeth were selected (Cerro Juan Díaz n=70; Sitio Sierra n=20; Cerro Mangote n=34; Playa don Bernardo n=85). In order to perform microwear analysis, 142 teeth were employed (Cerro Juan Díaz, n=57; Sitio Sierra, n=18; Cerro Mangote, n=27; Playa don Bernardo, n=57) (Table 5.1). In both cases, we selected only adults, taking into account the degree of wear of the teeth, not including the most worn ones, and also the unworn teeth. In the case of Cerro Juan Díaz, we selected teeth from operations 1, 3, 4, 5 and 31. We sampled all contexts at Sitio Sierra (A3, A2-1 / A2-2, A1-1 / A1-2, B4, B3, and B2). At Cerro Mangote, we focused our sample on the brown zone, which represents the more intense occupation in the site. In the case of Playa don Bernardo samples from all the macrostratums were selected.

Scores of extant cervids collection from the American Museum of Natural History in New York (AMNH) and Smithsonian National Museum of Natural History in Washington D.C. (NMNH) were calculated to compare with the archaeological ones from Playa don Bernando. Extant white-tailed deer (*Odocoileus virginianus*) from Coiba Island and Florida Keys (n=18); Amazonian brown brocket deer (*Mazama nemorivaga*) from Colombia, Venezuela, British Guiana, Brazil and Peru (n=20); Central American red brocket (*Mazama temama*) from Mexico, Guatemala, Nicaragua, Costa Rica and Panama (n=42); red brocket (*Mazama americana*) from Colombia, Venezuela, Ecuador, Bolivia and Brazil (n=55).

5.1.3. Stable isotope analysis

For this analysis were selected bone and teeth of deer archaeological samples from Playa don Bernardo (n= 41), Cerro Mangote (n=38), Sitio Sierra (n=11) and Cerro Juan Díaz (n=55) (Table 5.1). Consistent element and side was obtained to avoid mistakenly re-sampling the same individual twice in cases where samples were from the same stratigraphic layer. Where bone, dentine, and enamel were available from the same individual, all three were sampled to reconstruct early (enamel) versus later (bone and dentine) isotope results.

5.1.4. Geometric morphometrics

30 archaeological teeth from Playa don Bernardo and 205 modern teeth from the collection of Museum national d'histoire naturelle (MNHN), American Museum of Natural History in New York (AMNH) and Smithsonian National Museum of Natural History in Washington D.C. (NMNH) were studied (Table 5.1). Lower third molars were selected for this study and only the left mandibles and teeth were used in the modern collections in the case of the archaeological site we used both sides (17 left and 13 right) but all pictures of right mandibles were mirrored left.

5.2. Methods

5.2.1. Zooarchaeological analysis

Zooarchaeology studies the animal remains found in archaeological contexts. These findings are product of human complex behavior related to the environmental context and cultural choices. The purpose of zooarchaeology is to understand human and animal relationships in the past (S. Davis 1989; Chaix and Meniel 2005; Reitz and Wing 2008; Hesse and Wapnish 1985).

In order to explain cultural change or continuity in the past by using faunal remains, it is important to distinguish different uses or patterns that could affect the formation of the zooarchaeological record. Taphonomy plays an important role in the study of animals in the past. Zooarchaeology implies interdisciplinarity, because uses concepts, methods and techniques of the other disciplines such as: biology, ecology, geology, paleontology, anthropology among others (S. Davis 1989; Chaix and Meniel 2005; Reitz and Wing 2008).

At the same time, there are other approaches that could be useful to the zooarchaeological analysis. For example, etnoarchaeological research, spatial analysis, isotopic chemistry, geometric morphometrics or experimentation. This kind of information could be used to better understand post-depositional aspects, temporal and spatial factors, and also socio-economical characteristics of the assemblage studied (Chaix and Meniel 2005; S. Davis 1989; Reitz and Wing 2008).

5.2.1.1. Anatomical representation

Cervid remains were analyzed and identified by using a modern reference collection housed at Smithsonian Tropical Research Institute (STRI) Archaeology Laboratory in Panama. At the same time, classical manuals were used as reference (Barone 1976; Schmid 1972) and manuals written about zones near the study area (i.e. Peña and Pinto 1996; Broughton and Miller 2016; France 2009; Hillson 1999).

In many occasions the anatomic identification level is limited by the remains fragmentation and many elements are classified as unidentified, to avoid the loss of information from these remains in this thesis it was used the classification suggested by Rosell (2001) in three main categories:

- Long bone: They are formed by a cylindrical diaphysis with two epiphyses that are located at their ends. There are the animal extremities, except for the carpals and tarsals.

•Flat bone: There are characterized by an irregular and flattened morphology means that practically no medullary cavity is present. They are the ones that make up the cranial, axial skeletons and the girdles (pectoral and pelvic) of the animals.

•Articular bone: These bones do not have a medullary cavity and inside they are formed by spongy tissue very dense and compact. There are the carpal and tarsals.

The zooarchaeological analysis employed several units of quantification, in this thesis were used the following ones, summarized by: Reitz and Wing, (2008), Chaix (2005) and Klein and Cruz-Uribe (1984).

•Number of Remains (NR): This refers to the total number of remains that make up the zooarchaeological assemblage, without taking into account the degree of taxonomical and anatomical identification that precision that was attained.

•Number of Identified Specimens (NISP): This index takes into account only the bone remains that were identified taxonomically. This index usually is lower than the NR.

•Minimum Number of Elements (MNE): This index quantifies the elements belonging to an individual, whether they are whole or fragmented. For this quantification, it is necessary to take into account different variables of each identified bone fragment, such as the area of the bone, the face, its position in the skeleton, the number of times that appears in the skeleton and its age. Each bone is divided into concrete portions, numbered from the nearest to the mouth to the furthest (Figure 5.1). Each bone is, in turn, composed of four faces, which together make up the anatomical element and allow its identification with a higher level of precision 1. Anterior, cranial or dorsal; 2. Posterior, caudal or palmar / plantar; 3. Exterior or lateral; 4. Interior or medial (Schmid 1972).

Figure 5. 1. Scheme of portions in long and flat bones of white-tailed deer.

•Minimum Number of Individuals (MNI): This index defines the minimal number of animals that could be present in the assemblage. This index does not reflect the real abundance of the animals, and is only a guide to the minimum number of individuals present in the assemblage. In addition, this index does not imply that the animals were complete when the accumulation was formed. This index is calculated by summing the most frequent element taking into account laterality, age and size.

5.2.1.2. Age and sex

In zooarchaeology, the study of age allows to understand human behaviors such as sedentism, mobility and storage, because multiple physiological events correspond to a seasonal periodicity that are reflected in the increase of bone tissues. The growth rate of these tissues is related to factors such as metabolic rates, reproductive cycles, migration patterns, nutrition and climate cycles, which may give indications of the relationship of men with animals in the past (S. Davis 1989; Chaix and Meniel 2005; Reitz and Wing 2008).

The age at death of white-tailed deer was established by reference to epiphyseal fusion, tooth eruption sequence, and tooth wear. Based on Purdue (1983) data presented in the table 5.2, it was established three grades of fusion: without fusion, in the cases where the epiphysis was separated of the diaphysis (Figure 5.2, c. b.); Evident fusion, when the epiphysis was united to the diaphysis but a line it is observed; and complete fusion, in the cases where the diaphysis was complete linked to the epiphysis and the union line is not observed (Figure 5.2, a.).

Figure 5. 2. Fusion degrees observed in white-tailed deer radius. a. without fusion b. without fusion c. fused.

Table 5. 2. Long bone fusion sequence after Purdue (1983). In parentheses initial fusion month.

Element	Initial fusion		Half-fused		Complete	
	Female	Male	Female	Male	Female	Male
Radius (px)	2	5	2	5	5	8
Humerus (di)	2	5	2	8	20	12
2nd Phalanx	5	8	5	8	11(8)	17
1st Phalanx	11(8)	11	11(8)	11	20	17
Tibia (di)	17(14)	17(14)	17(14)	17	20	23
Calcaneum	17(14)	20	20	20	29(26)	29(26)
Ulna (px)	20	20	20	20	29(26)	A(38)
Femur (px)	20	20	20	20	32	A(38)
Metacarpal	20	23	20	23	29(26)	29(26)
Metatarsal	20	17	20	23	29(26)	29(26)
Radius (di)	20	29(26)	20	29(26)	29(26)	A(38)
Femur (di)	23	29(26)	23	29(26)	29(26)	A(38)
Tibia (px)	23	29(26)	23	29(26)	29(26)	A(38)
Ulna (di)	23	29(26)	29(26)	29(26)	29(26)	35(32)
Humerus (px)	29(26)	A(38)	29(26)	A(38)	A	A(38)
Cervical vert. (ce)	2	2	2	2	5	5
Thoracic vert. (ce)	2	2	2	2	5	5
Lumbar vert. (ce)	2	2	2	2	5	5
Acetabullum	5	8	5	8	11(8)	11
Atlas (do)	11(8)	8	11(8)	8	17(14)	20
Sacrum	17(14)	11	17(14)	17	A	
Lumbar vert. (po)	23	17	23	20	35	A(38)
Lumbar vert. (an)	20	17	29(26)	20	35	A(38)
Thoracic vert (po)	29(26)		29(26)		A	
Thoracic vert (an)	23	29(26)	29(26)	29(26)	A	
Cervical vert. (an)	29(26)	35(32)	29(26)	35(32)	A	A(38)
Cervical vert. (po)	29(26)	A(38)	29(26)	A(38)	A	A(38)
Pubis symphysis	23	A(38)	29(26)	A(38)	A	A(38)

Tooth eruption and attrition sequences are criteria used to determine the relative age of herbivorous mammals, because the eruption of the teeth and their replacement follows a chronological sequence. However, animal diet, geographic location and individual variability could influence dentition (S. Davis 1989; Hillson 1996, 1999; Mariezkurrena 1983). From tooth eruption and tooth wear it is possible to establish relative age classes not an exact age (Reitz & Wing 2008). Tooth crown height is reduced by attrition and surface crown changes could be used to determine relative ages (Reitz & Wing 2008).

In the case of the white-tailed deer age is estimated based on the classical research of Severinghaus (1949), who made a detailed description of the process of eruption and dental wear of this species. He used modern wild population sample from New York (United States), he proposed a series of age classes and subclasses. However, the exact determination of the age is challenging when one deals with archaeological samples. Specially in the case of Neotropical white-tailed deer because there are differences between populations in tooth chronology and tooth wear due to differences in habitat quality and environmental characteristics (Ojasti, 2000). In order to fine-tune age classes, data from contemporary animals are needed from which relationships can be established with the archaeofaunal samples. This is all very well in theory, but as far as we know, there are no such studies of Neotropical deer for making direct comparisons. For these reason was selected two broader categories: juveniles and adults. Also, because they have a meaning in the dynamics of the populations.

•Juveniles: This relative age classes are compound by individual minors to 18 months. This age class is characterized by deciduous or replacement teeth, the eruption of the third molar, and the absence of dental wear, if there is very slight.

•Adults: Individuals older than 18 months correspond to this age group because individuals have complete adult teeth, the third molar is fully active and there are slight to moderate wear in the premolars and molars. Individuals older than 6 years have permanent teeth with high and very high wear.

The white-tailed deer is a species that present a marked sexual dimorphism, the males are bigger than females and also present branched antlers (Figure 5.3). By using this trait distinguishing males from females is straightforward. However, these differences are evident after a year and a half of age when the deer have reached reproductive age (Gallina et al. 2010; Verme and Ullrey 1984; Galindo-Leal and Weber 1998). An important characteristic is that given the presence of the antlers in the skull of the males, the front being stronger while that of the females is more gracile (Reitz and Wing 2008).

Size changes: In order to study size changes in PDB deer, it was calculated the crown area of m3. It was employed the software Fiji to take the maximum length and width measures in mm and then the area was calculated and standardized by log10 function.

5.2.1.3. Skeletal representation profiles

In zooarchaeology the skeletal representation profiles are used to understand the final composition of the archaeological sites. This composition could be influenced by two aspects: 1. Differential transport and 2. Differential conservation process (Binford 1981; Klein 1989). Differential transport models start from the assumption that the prey skeleton is distributed along a path that starts at the kill site and finish to the place of final consumption (Metcalfe and Jones 1988). Metcalfe and Jones (1988) proposed the followings selective transport strategies: 1. Bulk strategy, where large quantities of anatomical parts of high, medium and low quality are selected, being more abundant those of lower quality; 2. Gourmet strategy, in which the high utility parts are the most frequent and the parts of moderate utility are not included; 3. Unbiased strategy, in which the parts appear proportionally according to their quality; 4. Reverse utility strategy, the lower quality parts are very abundant in contrast with the parts of greater quality that are almost not represented.

Figure 5. 3. a. Male white-tailed deer; b. female white-tailed deer.

To perform skeletal differential distribution analysis, the bone elements were grouped by parts: head (skull, mandible, maxilla, molars and premolars); axial skeleton (vertebrae and ribs); forequarter (scapula, humerus, radius and ulna); hindquarters (pelvic waist, femur, patella and tibia); forefoot (metacarpal and carpal); hindfoot (metatarsal and tarsal) and foot (metapodia and phalanges). From these bone elements the NR was quantified by body part and then the archaeological bone frequencies with the expected frequencies if the deer skeleton were complete, applying the following equation:

$$d=(LnX)-(LnY)$$

Where X is the percentage of each skeletal portion (% NISP) and Y is the percentage of the same portion in a complete skeleton. Both values were naturally log-transformed to give linearity back to the variables. Positive values show that the skeletal portion is more abundant compared to the standard and negative values that the skeletal portions are underrepresented (Reitz and Wing 2008). The skeletal portions were organized as a follows: Head (cranium, mandible, maxilar); Axial (Atlas, axis, lumbar vertebrae, thoracic vertebrae, cervical vertebrae, sacral vertebrae, sternum, ribs); Forequarter (scapula, humerus, ulna, radius); Forefoot (acetabulum, ileum, ischium, femur, tibia); Hindquarter (scaphoid, trapezium, uncinated, lunate, metacarpal. Rudimental metacarpal); Hindfoot (Patella, metatarsal, astragalus, calcaneus, cuboid, cuneiform, intern cuneiform) and foot (metapods, phalanx proximal, phalanx medial, phalanx distal, phalanx) (Reitz and Wing 2008).

To carry out the selective transport analysis, the abundance index of skeletal parts or MAU (Minimal Animal Units) was obtained (Lyman 2008). The MAU is obtained by dividing the number of elements identified by the number of anatomical units present in a complete skeleton. MAU% is the relativized scale obtained by dividing between the standard (greater MAU) and multiplying by 100. Subsequently, the MAU% was compared against the utility index proposed for the white-tailed deer by Madrigal and Holt (2002) modification of the index proposed by Binford (1984) and the simplified index of Metcalfe and Jones (1988). For this purpose, the MAU of the long bones was obtained by dividing by two, the phalanges dividing into eight, the cervical vertebrae dividing into five (excluding the atlas and the axis), the thoracic vertebrae dividing into twelve and the lumbar vertebrae into seven (Madrigal and Holt 2002; Sauer 1984).

Bone differential destruction may be influenced by its own characteristics, such as its density and also for the interaction and intensity of the external forces that acting on the bone (Lyman 1994). To study the differential conservation in relation to bone density (VD) were used Lyman (1994) values averaged following Reitz and Wing (2008), and it were plotted volume density (VD) against NISP, and calculate a correlation coefficient (Pearson's r) between these variables.

5.2.2. Taphonomical analysis

The taphonomical analysis focused on bone breakage and surface alteration. Surface alterations were identified macroscopically and microscopically. All skeletal specimens were examined using a stereomicroscope (Leica Wild M10, up to 120). The Atlas of taphonomic identifications were used as reference (Fernández-Jalvo and Andrews 2016).

5.2.2.1. Bone breakage: Fragmentation and fracture

The remains found in archaeological sites are characterized by the high degree of fragmentation, which could be caused by different taphonomical agents such as biological agents and/or physical process. Two different words could be used to distinguish this causes, fragmentation when the cause is a physical process and fracture when a biological agent is the responsible (Fernández-Jalvo and Andrews 2016).

The inherent characteristics of the bone produce different break patterns when the bone is green or dry (Bunn 1983; Villa and Mahieu 1991). Green bones have a high degree of plasticity, but they could break when the pressure is greater than their strength. In these cases, the fracture follows the natural lines of the bone. The fractures are produced by biological agents when the bone is green, because their intention is to obtain the nutrients that are inside the bones (Bunn 1983; Villa and Mahieu 1991).

The opposite case is the fragmentation of the dry bone, because the physical characteristics of the bone changed, now the bone lost its moisture and its organic properties, the bone is fragile and brittle. At this moment the bone reacts different in front of pressure, forming perpendicular cracks. This kind of fragmentation is produced by physical process without any intentionality (Bunn 1983; Villa and Mahieu 1991).

To study long bone representation, the anatomical zone (proximal, medial, distal, whole) of the long bones (humerus, radius, femur, tibia, and metatarsal) were recorded. In order to evaluate bone breakage, it was distinguished colour changes in the outlines and also fracture angle in order to discriminate an old breakage (occurring at or near the time of deposition) from a new breakage (occurring during or after the excavation) (Steadman, Plourde, and Burley 2002).

Villa and Mahieu (1991) proposed a methodology to study breakage bone patterns. They studied the fracture plan, by observing 3 aspects: 1. Fracture angle; 2. Delineation and 3. Fracture surface. The fracture angle is established in relation to the cortical bone and could be: straight, oblique or mixed (Figure 5.4). The delineation is studied with respect to longitudinal bone axis and could be: transversal, curved and longitudinal (Figure 5.4). The aspect of the fracture surface which could be: smooth or irregular (Figure 5.4). By studying this characteristics Villa and Mahieu (1991) observed that the fractures are curved with oblique angles and smooth surfaces. While, fragmentation is transversal with straight angles and smooth or irregular edges.

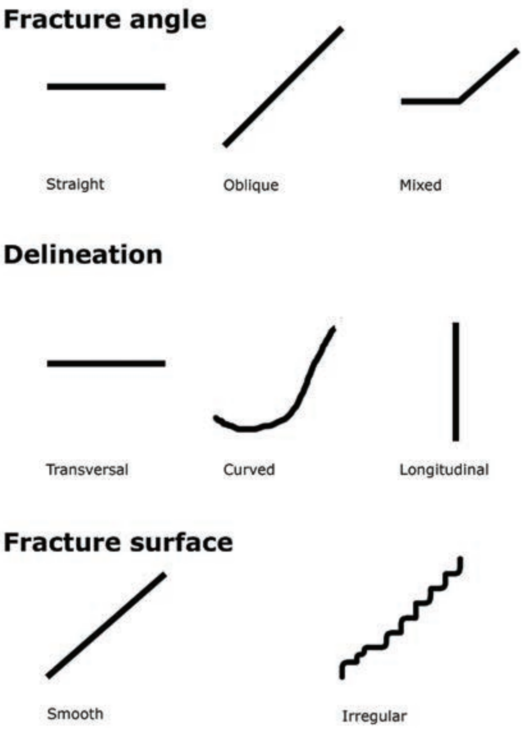


Figure 5. 4. Bone fracture and fragmentation characteristics.

5.2.2.2. Butchering

Lyman (1987) defines butchering as the human reduction and modification of an animal carcass into a consumable part. In this definitions consumable refers, to all forms of use of carcass products including but not restricted to consumption of products as food. Human behaviors could be studied through butchering process and evidenced by the butchery pattern as determined from an assemblage of faunal remains. It is assumed that prehistoric butchers utilized the most pragmatic butchering process and evidence of butchering could be interpreted as reflecting efficient human activity (Lyman, 1994).

Butchering consists of a set or series of sets of human activities directed towards the extraction of consumable resources from a carcass (Lyman 1994). Preparing carcasses for consumption involves a series of activities that includes the extraction of external nutrients (skin, meat, and tendons) to obtaining internal resources (fat and marrow) (Binford, 1981). Butchery marks can be identified in the archaeological record; they are known as cut marks. According to Binford (1981), cut marks can result from three activities: 1) skinning; 2) disarticulation and 3) filleting (Binford, 1981). Skinning is the activity that refers to the extraction of the animal's skin, separating it from the rest of the body. This type of cut marks are produced in areas with little muscle mass, these will tend to be transverse marks, of variable intensity, and mainly located on the skull (frontal and parietal), mandible, in the distal radius and tibia, and in the metatarsals, although there may be some variability (Binford, 1981). In the case of deer, it is expected to find cut marks of this type located near the antlers.

The disarticulation consists of dismembering the animal into quarters. This type of activity is carried out to facilitate the transport of the animal and is done following the anatomy of the animal. In this way, the axial, cranial, and coxal skeleton are isolated from the appendicular skeleton. In this process, the scapula is held together with the humerus, while the femur is separated from the coxal by the acetabular zone. The disarticulation marks are located at very specific points, in articular surfaces of the ends of long bones on the surfaces of vertebrae or pelvic parts. The separation of the forelimb can be observed in incisions located on the caudal aspect of the scapula and the external face of some ribs. In the case of the posterior limb, the cut marks are found in the proximal area of the femur and the acetabulum (Binford, 1981).

Defleshing is the extraction activity of meat, which is attached to the bones. This process is one that leaves the greatest number of marks, although there may be variability depending on the type of consumption made of the animal. The marks that can be observed on the bone surface are incisions and scrapes, which are generally longitudinal and/or oblique, that present variable longitudes but on many occasions are long. Although they can be found on all the skeletal parts of the animal, more frequently in the parts with less muscle mass. They are very frequent in the diaphysis of the long bones, but also in the metaphyses of the bones, particularly in areas of muscle insertions. In flat bones are also observed this kind of marks (Binford, 1981). Once the extraction of the skin and meat is finished, the bones keep some nutrients inside. the periosteum, which can also be consumed or removed to facilitate bone fracture, this activity leaves very fine incision-like cut marks in groups and parallel to the longitudinal axis of the bone (Binford, 1981; Blumenschine and Selvaggio, 1988). The marrow and fat contained mainly in the epiphyses of the long bones. To obtain the marrow, the bones need to be breakage. During this process, it is recurrent that the joints are affected, even disappearing. This has to do with crushing them to access the internal content of the bone (Binford, 1981).

5.2.2.3. Surface alterations

The changes observed on the bone surfaces could provide information on aspects related to the agents and their degree of participation in the process of site formation. The physical, mechanical and chemical processes through which some alterations occurred remain unchanged over time. For this reason, experimental and actualistic perspectives can be used to understand it (Shipman 1981).

5.2.2.3.1. Anthropic modifications

Attention was focus on four anthropic modifications: cut marks, fracture, thermal damage and tooth marks. Then, they will be described.

•Cut Marks: They are linear grooves, with a variable longitude and width. The transversal section of a cut mark has a “V” shape, and their walls and the bottom presents microestriae. Sometimes, associated to a cut mark it is found barbs or small striae, at the end or the start of the principal mark. Other traits that could be identified are shoulder effect, when the prominent sector of the edge touches the cortical bone. Basically are identified four types of cut marks: 1. Incisions or slicing marks (slight grooves with a variable longitude and width); 2. Scrape marks (shallow, wide striae that run along the bone lengthwise); 3. Chop marks (cuts of small length deep and wide) and 4. Saw marks (Deep, short and concentrate incisions). The type of mark depends on the instrument used and also on how the instrument has been used. The presence of cut marks is incidental. However, the position and the type are common used to described the butchering process. The analysis of cut marks took into account the number of striations, location on the anatomical element, distribution over the surface (isolated, clustered and crossed), orientation with respect to the longitudinal axis of the bone (oblique, longitudinal and transverse) and delineation (straight, sinous or curved) (Binford 1981; Potts and Shipman 1981; Shipman and Rose 1983; Fernández-Jalvo and Andrews 2016) (Figure 5.5). The cut marks were also measured under the microscope.

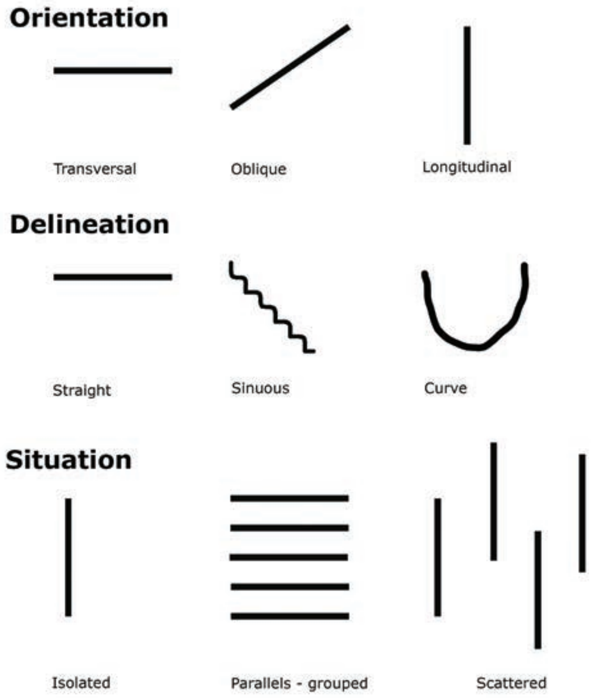


Figure 5. 5. Cut marks characteristics.

•Fracture: Humans break bones with some intention, nutritional or technological (to manufacture artifacts or tools). To fracture green bone, the technique more common is direct percussion, against a rock (anvil) using a chopping tool (hammerstone). Other strategy is to change surface bone temperature (hot and cold) (Cáceres et al. 2002; Outram 2001). In the archaeological remains could be identified the next traits: Percussion stigmas (circular or oval depressions produced by bone compaction when there is an impact that does not have sufficient force to break the bone); 2. Percussion impacts (Depressions in the cortical bone in which the maximum intensity is produced when the bone is broken); 3. Percussion cones (Small extractions of bone tissue that are detached in the percussion impact zone); 4. Cortical flakes (small detachments of cortical tissue resulting from percussion impact which in turn leave a negative in the cortical section of the element); 6. Parasitic splinters (percussion cones which did not fully detach). 7. Counter-strokes (cuneiform fractures located on the face opposite the point of impact) (Binford 1981; Johnson 1985; Blumenschine and Selvaggio 1988; Blumenschine 1995; Pickering and Egeland 2006; Fernández-Jalvo and Andrews 2016).

Another type of human fracture is known as peeling, this is a flexion fracture. This kind of fracture is usually found in ribs, flat bones and vertebrae apophysys. To break the bone one part is in the mouth and another in the hand and the pressure origins this kind of fracture. This type of fracture is identified by bent fracture edges and cortical flakes that leave the trabecular tissue exposed (Pickering et al. 2013; Fernández-Jalvo and Andrews 2016).

•Burning damage: The study of burning changes into the bone surfaces could bring us information about animal consumption and processing. The colour changes observed macroscopically is the most common way to study this aspect. In this thesis, six degrees of thermal damage were identified [from 0 (unburned) to 5 (calcined) and 6 when 2 burning colours were observed] using Stiner et al. (1995) criteria. Grade 0: no apparent alteration; Grade 1: bone surface with small scattered spots of brown color, conserving part of its collagen; Grade 2: the bone presents a homogeneous brown color; Grade 3: the bone is charred, acquiring a black color. The collagen has been completely lost in this phase; Grade 4: gray and / or bluish coloration of the bone; Grade 5: the bone is completely calcined, white. In figure 5.6 could be observed some examples of this stages.

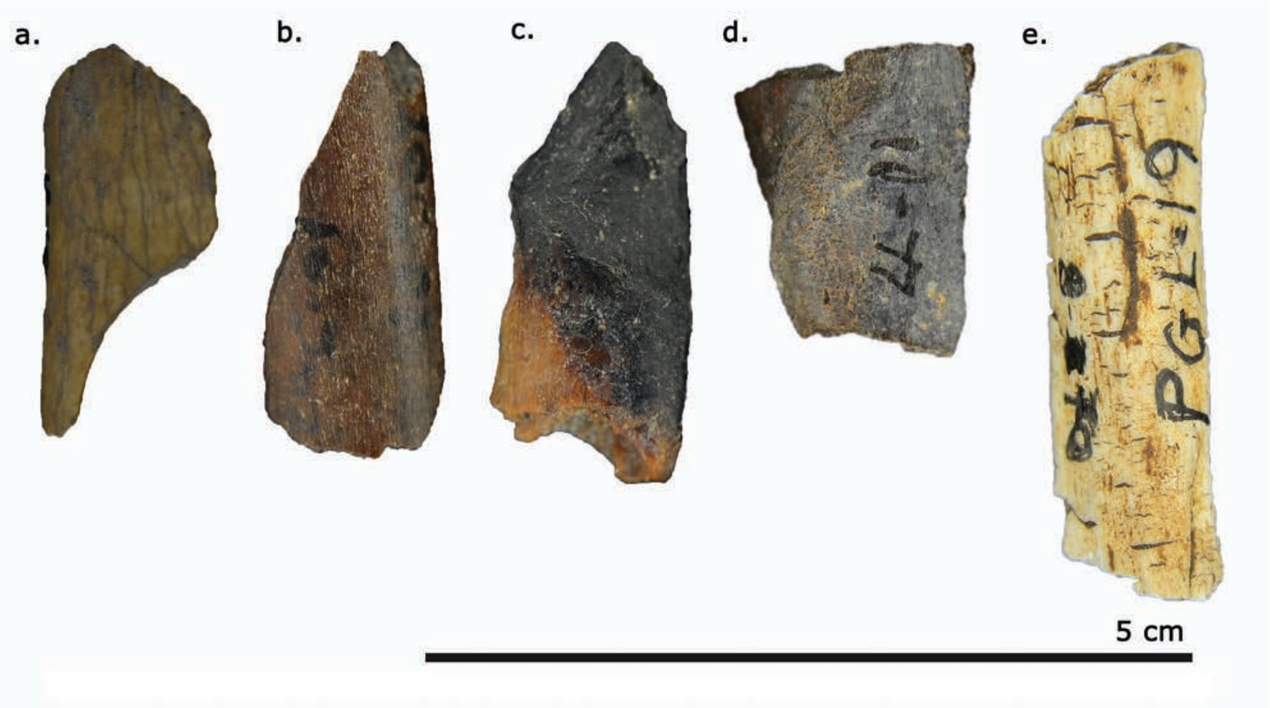


Figure 5. 6. Burning damage coloration changes.

Human tooth marks: Human tooth marks were classified by following their morphology and their position into the bone, as 1. pits (ovoid shape and shallowness), or 2. scores (elongated shape and internal crushing) (Fernández-Jalvo and Andrews 2011; Landt 2007; Pickering et al. 2013; Fernández-Jalvo and Andrews 2016). Their distribution, orientation and dimensions were taken into account.

5.2.2.3.2. Non-anthropic modifications

Humans are not the lone responsible to produce faunal accumulations, other agents as carnivores and rodents could do this or at least modified it (Brain 1981; Fernández-Jalvo and Andrews 2016).

- Carnivores: carnivores can produce changes on the bone surface as a consequence of the extraction of soft tissues and by the action of fracturing the bones to consume the marrow. By definition carnivore tooth mark are sinuous striations with a U-shaped cross-section with a flat or irregular background. Their morphology, length and width are variable and sometimes they have rounded edges (Binford 1981; Bunn 1983; Shipman 1981). The basic types of bite that can be identified are: 1. Scores, tooth scratches, or striations (can be short, parallel and linear. Sometimes they can have a U-section or a V-section); 2. pits (they are oval or circular and sometimes the cortical tissue is preserved within the depression); 3. Digestion (the action of saliva or gastric juices makes the elements appear rounded or even polished); 4. Punctures or perforations (they are deep depressions left by a molar or by a dental series on the surface of the bone); 5. Furrowing (loss of bone tissue by pitting); 6. Notches (semicircular marks in the fracture edge) (Binford 1981; Maguire, Pemberton, and Collet 1980; Selvaggio 1994; Fernández-Jalvo and Andrews 2016).

- Rodents: Rodents can modify bone remains when are exposed to the open air. These animals use the bones to wear their continuously growing dentures or to obtain some minerals needed for their diets. Rodent bites have a particular morphology that is characterized by the presence of wide grooves of variable length with flat and parallel bottoms or in the shape of a fan (Maguire, Pemberton, and Collet 1980; Brain 1981; Fernández-Jalvo and Andrews 2016). The fact that the rodents had access to the bones means that the bones lost their fresh condition before being covered by sediment which would indicate a relatively long period of exposure of the sediments to weathering phenomena (Maguire, Pemberton, and Collet 1980; Brain 1981).

5.2.2.4 Bone artefacts manufacture

Manufacture is the process of transforming the raw material into an artifact, going through different stages such as extraction, elaboration, and decoration. This process leaves different anthropogenic evidences (Pérez Róldan 2005; Pérez Roldán 2013). The materials that provide the most information on manufacturing traces are elements such as the core, debris, and blanks/preform, which help to reconstruct the entire manufacturing process of each analyzed artifact (Pérez Róldan 2005; Pérez Roldán 2013; Nagy 1990; Wells 2012). The core refers to that fragmented or complete bone or to the horn that presents transversal or longitudinal cuts or percussions, which are determined as part of the extraction technique. Cores exhibit evidence of this process as cutting, hacking and wedging marks, but there are no signs of additional working such as scraping, grinding or polishing which would indicate the intention to create a finished tool. The purpose of this activity is to produce blanks or performs. This has not been anatomically modified and sometimes combines extraction marks with others, such as cut marks (Pérez Róldan 2005; Pérez Roldán 2013; Nagy 1990; Wells 2012). Blanks are portions of osseous material cut from cores that will be further reduced into tools. One or more proposed tools may be conceived at the time of removal, but the type is not always apparent. Blanks generally retain evidence of the ways in which they were removed such as grooving and snapping (incisions, notches, fractures) (Pérez Róldan 2005; Pérez Roldán 2013; Nagy 1990; Wells 2012). Debris is defined as fragmented pieces of osseous material too small to be reduced into tools and displaying a single cut edge and no other modification such as grinding or polishing. These pieces represent discard in the process of reducing material to a blank or preform and can be difficult to distinguish from highly fragmented cores. Into this group are the articular ends that have been cut in order to expose useable segments. This area usually conserves wear due to cutting or transverse sawing or in some cases, percussion (Pérez Róldan 2005; Pérez Roldán 2013; Nagy 1990; Wells 2012). The artifact is the finished product (Pérez Róldan 2005; Pérez Roldán 2013; Nagy 1990; Wells 2012).

A series of activities involves the manufacture process. Abrading is the reduction of the surface material using a grinding implement such as a sandstone abrader. Abrasion used in the manufacture of tools results in striations, a series of thin, parallel lines. Chopping is a percussive action where a relatively heavy tool cuts into the raw material resulting in a series of notches in the chopped surface. Cutting is produced with sharp tools which are pushed and pulled over the surface leaving incisions in the form of small channels. Grooves are generally larger, deeper versions of incisions. Incising and grooving are two actions that are performed during the cutting of the raw material. Scraping is an action aiming at reducing and shaping the surface of the raw material by pulling and pushing a scraping tool over the surface while applying pressure. The resulting debris is often dust-like pieces of material. Finally, polishing is an action which adds lustre to the surface of osseous tools, achieved through abrasion with a very fine stone and often soft materials such as hide (Nagy 1990; Pérez Róldan 2005; Pérez Roldán 2013).

5.2.2.5. Post-depositional modifications

Moisture can produce changes in the surface of bone remains, which may be the presence of manganese stains, concretions or root affectations.

- Manganese stains: manganese stains are black and could be isolated or concentrated in one point of the bone. They are produced by bacteries who lives in humid and aerobics environments with a neutral pH or close to neutral (Fernández-Jalvo and Andrews 2016). The manganese stains could tell us about the presence of puddles of water or low intensity flows (López-González, Grandal-d'Anglade, and Vidal-Romaní 2006).

- Concretions: The presence of concretions are related to humidity changes in the substrate where the bone is. These changes give rise to a dilatation and a compaction of the sediments together with their humidification and drying (Courty, Goldberg, and Macphail 1989).

- Root damage: The signs produced by the presence of roots on the surface of the bones are are defined as sinuous, wide, elongated, superficial grooves and with a U-shaped section, which appear in a detritic way and that can affect a part or all of the remains (Binford 1981; Hesse and Wapnish 1985; Lyman 1994; Fernández-Jalvo and Andrews 2016). There can be two mechanisms of variation, a dissolution of the bone surface that is in direct contact with the roots through the segregated acids during the absorption of nutrients that allow their growth (Johnson 1985). The second, by the action of fungi and bacteria during the process of plant decomposition (Grayson 1988).

5.2.3. Mesowear and Microwear analysis

5.2.3.1.The teeth

The tooth is a hard structure consisting of a dentine and enamel. Cementum is a softer material than bone that protects the roots of the tooth and makes it stay in place. Also in some herbivores cementum is found on the labial and lingual surfaces of some teeth. Infundibulum is found in the premolars and molars of some ungulates (i.e. camelids, cervids, bovids, equids). It is a tunnel-shaped structure found in the body of the crown of the premolars and/or molars where it is wider than on the occlusal surface (Hillson 1996, 1999; Reitz and Wing 2008).

The main function of teeth is to capture and process food. Animals that have different types or rather shapes of teeth are known as heterodonts, such as mammals. Each type of tooth has a function, so that the incisors are responsible for cutting or holding, the canines to drill or grab, the premolars and molars to process food, grind and / or crush (Hillson 1999, 1996; Reitz and Wing 2008).

In general, the teeth of mammals are made up of: 2. incisors, they have a crown and a simple root; Canines also have a simple root and punctuated crowns; 3. Premolars, which may have one or more roots and simple or complex crowns; and 4. Molars, which have several roots and complex crowns (Hillson 1996, 1999; Reitz and Wing 2008).

The denture of the cervids is selenodont, which is characterized by a triangular shape of the cusps. The occlusal surface of the molars and premolars is not covered with enamel. The layers of enamel, dentine and cement are rather exposed. Cement in the center, surrounded by a layer of enamel, then a layer of dentin, all wrapped in a second outer layer of enamel. These characteristics, the triangular shape and the exposure of the layers, together with the lateral movement of the maxilla and the mandible allow the animals that have this type of denture to chew in a very efficient way very hard vegetal material; because when the upper and lower molars and premolars cross, they cut and grind what they are consuming (Hillson 1996).

Deer teeth are brachydont or mesodont because they feed on fibrous vegetation. This type of dentition is characterized by having teeth and are covered by enamel that covers a little more than the gum line which allows them to have a reserve of material that is worn out with time to go consuming hard plant materials (Hillson 1996).

The white-tailed deer dentition consists of 3 molars and 3 premolars on each side of the jaw; 3 molars and 3 premolars on each side of the jaw and has only 3 incisors and 1 canine on the jaw for a total of 28 teeth (Severinghaus 1949). The whitetails dental formulae is:

$$\frac{(0\ \ 0\ \ 3\ \ 3)}{(3\ \ 1\ \ 3\ \ 3)}$$

The mesowear an microwear analysis were performed at Molecular Laboratory at Institut Català de Paleoecologia Humana i Evolució Social (IPHES) in Tarragona.

5.3.2.2. Mesowear analysis

Fortelius and Solounias (2000) proposed a method known as mesowear in order to identify the diet of a particular species from a particular location in space and time. They used the three main dietary categories of browser, grazer, and mixed feeder as defined by Hofmann and Stewart (1972). They were looking for a method to quickly analyze large amount of samples of extinct taxa placed in museums in order to better understand ungulate paleocommunities. Mesowear is result of the attrition and abrasion over long period and it reflects the annual diet of an animal (Amano et al. 2016; Rivals, Rindel, and Belardi 2013; Rivals et al. 2017; Fortelius and Solounias 2000).

Mesowear analysis involves the observation of cusp morphology, by describing the sharpness and the relief of molar tooth cusps. Mesowear is scored macroscopically from the buccal side of upper molars, preferably the paracone of M2. The relative contribution of attrition and abrasion to the total wear should be considered to understand this method, sharp cusps mean that attrition (tooth on tooth) predominates strongly, and blunt cusps are product of abrasion (food on tooth). Leaf browsing herbivorous had an attritive wear patterns (sharp molar cusp) and grazing animals with high abrasion diets results an abrasive wear patterns (blunt molar cusp) (Fortelius and Solounias 2000).

According to Fortelius and Solounias (2000), mesowear analysis is applicable only if factors related to diet have a significantly stronger influence on wear patterns than factors related to structure or wear stage. This authors found that wear in ungulates tends to be stable during life, except for the earliest and latest stages. For this reason, it is recommended to select only adult individuals. Sample size is also relevant, they observed that mesowear pattern stabilizes after about 20 or 30 individuals, and usually gives a reasonable approximation after about 10.

Besides, Rivals, Mihlbachler, and Solounias (2007) study of mesowear and crown height measurements of a large sample of one brachydont, one mesodont and one hypsodont species conclude that: mesowear is not stable throughout the lifespan of an individual; and mesowear stability is related to initial crown height. For this reason, it is recommended to select individuals showing intermediate degrees of dental wear when mesowear is more related to diet and not with age. Also, it is suggested not include in mesowear analyses unworn (and marginally worn) teeth, extremely worn teeth, and those with broken or damaged cusp apices.

Mihlbachler et al. (2011) proposed a standardized method "mesowear ruler". It consists in a cast of six stages of modern horse cusps ranging in shape from high and sharp (stage 0) to completely blunt with no relief (stage 6) according to the degree of facet development. Mesowear is scored on each specimen and then averaged for each sample, "mesowear score" This ruler-shaped platform could be placed near the fossil for comparison, even though it is created to horses it could be used in other species. In this thesis were used the "mesowear ruler" developed for sika deer (Rivals and Takatsuki 2015) and adapted to deer by us (Figure 5.7).

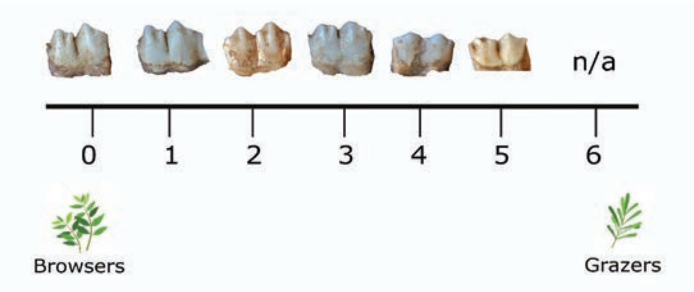


Figure 5. 7. Mesowear score example from Pedro González samples.

It is important, to keep in mind that the high levels of abrasion could be produced also from the soil or dust particle ingestion. In order to test how this affected the mesowear score Kaiser et al. (2011) performed an analysis of ungulates and they found that mesowear is more related to the effect of eat grazes than dust or soil. Other researchers show the same pattern in different species (Kubo and Yamada 2014; Saarinen and Lister 2016).

5.3.2.3. Microwear analysis

Microwear analysis allows to distinguish browsers, grazers and mixed feeders by studying microscopic features on the tooth enamel (Solounias and Semprebon 2002). The abrasion of food particles over the tooth enamel produce a microwear pattern. There is a great variability in the hardness and abrasiveness of plants, and also in the parts and the age of the plant, all of these characteristics will produce different patterns on the tooth enamel (Solounias and Semprebon 2002). Two basic features appear on the enamel surface during the mastication process: scratches and pits. This pattern is quickly produced and continuously overwritten and thus indicates the diet of the last days or weeks before death (Grine 1986). It brings insights about the paleonvironmental conditions weeks or even days within the time of the animal death. It responds to animal food preferences and their dietary ecology (DeSantis 2016; Xafis, Nagel, and Bastl 2017; M. Davis and Pineda Munoz 2016; Solounias and Semprebon 2002).

Microwear has been used to differentiate among browsers, grazers, and mixed feeders in extant ungulates and in the fossil record. Solounias and Semprebon (2002) proposed to observe the patterns of microwear by using low magnification microscopes (35x), so far the studies have been conducted with high magnification microscopes.

Solounias and Semprebon (2002) and Semprebon et al. (2004) developed a detailed protocol for the study of microwear and involves several steps. First, the occlusal surface of each tooth was cleaned with ethanol 96%. Second, the occlusal surface was molded using a high-resolution silicone dental impression material (i.e., polyvinyl siloxane). Third, the positive cast was created by using transparent epoxy resin. When the cast was made, they are ready to be examined under the stereomicroscope. Initially, Solounias and Semprebon (2002) proposed to performed microwear analysis on the second enamel band of the paracone of upper M2. However, it is observed that the microwear can be distinguish in the other molars and also premolar 4. Therefore, if the sample is not large, other molars or even premolar 4 could be used. The upper and lower teeth can also be used, and other parts of the tooth can also be considered too (Figure 5.8) (Xafis, Nagel, and Bastl 2017; Rivals, Julien, et al. 2015).

The cast is observed under the stereomicroscope. A Zeiss Stemi 2000C stereomicroscope at 35× magnification were used to observe microwear features (pits and scratches) on the enamel bands, are quantified by using an ocular reticile 0.4 x 0.4 mm area. Solounias and Semprebon (2002) observed that microwear could be variable on a single tooth, to avoid this, they propose to count in two different enamel locations. Then the two counts per cast were averaged to obtain a mean number of pits and scratches. Sometimes, cast represents badly preserved *enael* or taphonomic defects (features with unusual morphology and size, or fresh features made during the collecting process or during storage). In this occasions, it is suggested by King, Andrews, and Boz (1999) to remove them from the analysis.

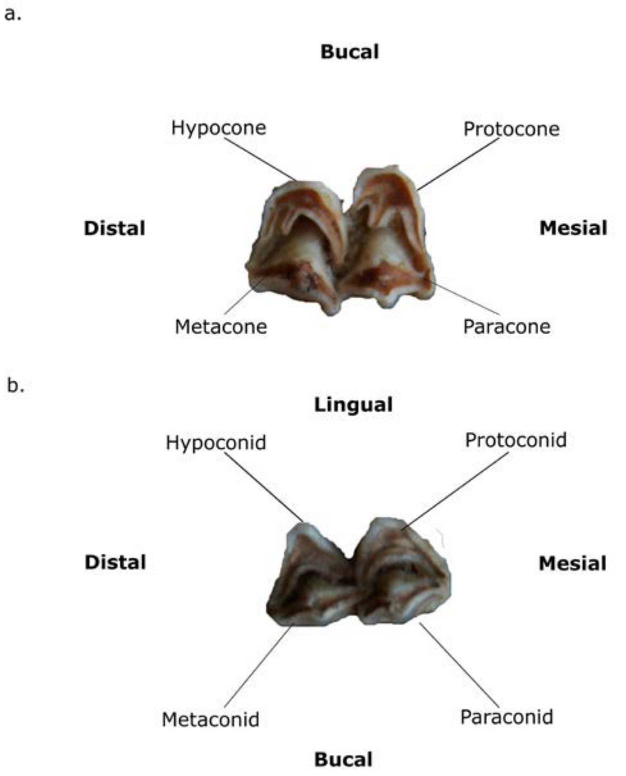


Figure 5. 8. Nomenclature of the tooth cusps on (a) lower and (b) upper molars.

Starting from pits and scratches means, they constructed bivariate plots of the extant ungulates. In this way, they organized all taxa by dietary category and they obtain a value and ranges for browsing, grazing, and mixed feeding ungulates. So, the scratches counting allows distinguish three dietary categories: browsers (0-17), grazers (17.5-29.5) and mixed feeders which presents some overlapping values (Solounias and Semprebon 2002). In this thesis, it was used the R code proposed by Rivals (2019) to create the bivariate plots.

As stated above the principal microwear traits are pits and scratches, however Solounias and Semprebon (2002) mention others, thereupon are explained:

- Pits: Pits shape is circular or sub-circular and had similar widths and lengths. Could be: small, large (deeper and less refractive, and their size is almost the diameter of small pits) or punctures.(Figure 5.9 a. and c.).

- Scratches: Scratches are elongated microfeatures that are not merely longer than they are wide but have straight, parallel sides. Scratch texture was assessed as being either fine (i.e., narrow scratches that appear relatively shallow and have low refractivity), coarse (i.e. wide scratches that are also relatively deep but have high refractivity, relatively shiny) (Figure 5.9 a. b. c.).

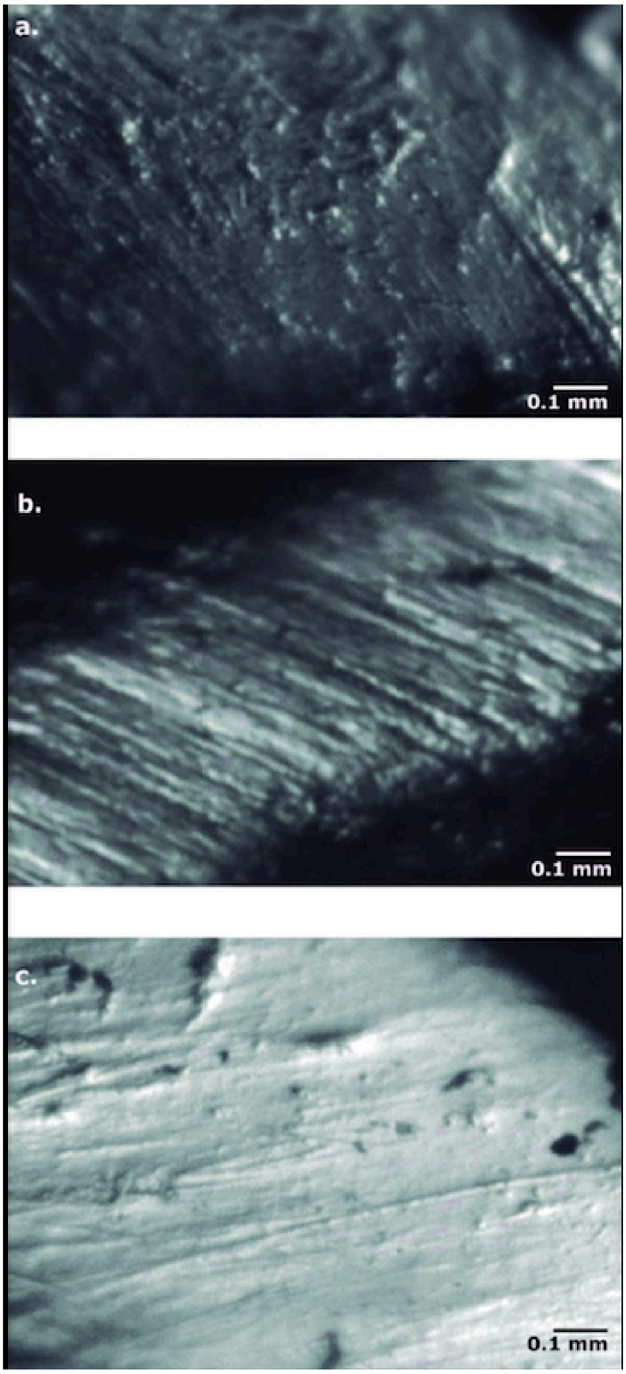


Figure 5.9. Examples of microwear features on the enamel bands of the occlusal surface of white-tailed deer teeth. a. Small pits and fine scratches on a m1 from Cerro Juan Díaz (specimen CJD-OP5-145); b. Fine and coarse scratches on a m2 from Cerro Mangote (specimen CM-CO40-169); c. Fine and coarse scratches and small and large pits on a m2 from Cerro Juan Díaz (specimen CJD-SP-160).

- Gouges: This features have ragged, irregular edges and are much larger (approximately 2–3 times as large) and deeper than large pits.

- Cross scratches: Cross scratches are oriented somewhat perpendicularly to the majority of scratches observed on tooth enamel.

The microwear pattern is sensitive to seasonal, local and individual variations in diet (Semprebon et al. 2016). The variability of the microwear pattern is correlated with the duration of the accumulation of an assemblage (Rivals, Schulz, and Kaiser 2009) for that reason it allows an estimation of the duration of the human occupation in a specific location and in a precise period –seasonality- (Sánchez-Hernández et al. 2014; Rivals and Semprebon 2011; Rivals and Takatsuki 2015). Also it allows to identify if the archaeological assemblages are result of a single or multiple death events. Taking into account that the scratches are sensitive to seasonal variations and each season could be associated with specific food it is expected that each season produce a specific microwear signal. If the mortality events took place across seasons more diverse will be the range of food and the microwear signal (Rodríguez-Hidalgo et al. 2016; Rivals, Solounias, and Schaller 2011).

Rivals et al. (2015) proposed a methodology to study the scratches variation, by using the standard deviation and the coefficient of variation, that allows to distinguish 3 types of human occupations: 1. Seasonal or Shorter events; 2. Events longer than a season events; 3. Separated events, according to their position in the heat map of the scratches coefficient of variation (X axis) and the scratches standard variation (Y axis).

5.2.4. Stable isotope analysis

The isotopic geochemistry is another tool to study prehistoric subsistence patterns and their transformation over time; the local, seasonal climate patterns in the past; and the reconstruction of human environment interactions (Reitz and Wing 2008). This approach is also helpful to study the origin and complexity of agriculture and it provide important insights into the food combinations which form diets providing understandings into prehistoric foodways that, when coupled with other zooarchaeological information, have further implications for the socioeconomic organization of cultures in the past (i.e. Allitt, Stewart, and Messner 2008; Balasse, Bocherens, and Mariotti 1999; Emery, Wright, and Schwarcz 2000; Sharpe et al. 2018; Kwak and Zedler 1997; White et al. 2001).

Stable isotopes show a trophic level effect in which the relative proportions of one isotope to another change in a systematic way between the consumer and its food source. Fractionation depletes or enriches isotopes measured as a ratio of the heavier isotope to the lighter one. The deviation from the standard is expressed on differential units delta relative to a standard and measured in parts per thousand or per mil. Isotope values are reported in standard delta notation:

$$\delta=[(\text{Rsample} - \text{Rstandard})/(\text{Rstandard})]^{*}1000$$

R = $^{13}C/^{12}C$, $^{15}N/^{14}N$ or $^{18}O/^{16}O$ (McKinney et al. 1950). The standards are V-PDB (Pee Dee Belemnite) for carbon; atmospheric nitrogen (Ambient Inhalable Reservo ir AIR) for nitrogen and, V-SMOW (Vienna Standard Mean Ocean Water) for oxygen (Coplen 1996, 2011; Mariotti 1983).

The carbon, nitrogen, and oxygen isotopic ratios are obtained from organic (collagen) and mineral (carbonate) components of teeth and bone. Carbon isotopes should be studied from both the organic (collagen) and inorganic (hydroxyapatite) portions of bone and teeth to interpret dietary combinations. The organic component reflects protein sources in the diet and the inorganic component a whole diet (Ambrose and Norr 1993; Kellner and Schoeninger 2007).

Carbon isotopes are the most common of the isotopes studied for dietary information. The stable carbon isotope composition of animals tends to reflect the isotopic composition of the plant basis of their diet (Deniro and Epstein 1978; van der Merwe 1982). Plants incorporate various numbers of carbon atoms through the photosynthesis pathway which converts carbon dioxide into more complex molecules; therefore, a distinction of plants is made on the number of carbon atoms they incorporate, plants in C_3, in C_4 and crassulacean acid metabolism (CAM). C_3 plants include wheat (*Triticum aestivum*), rice (*Oryza sativa*), all root crops, legumes, vegetables, nuts, honey and most fruits. Algae and phytoplankton are also C_3 plants. C_4 plants include millet (*Panicum miliaceum*), maize (*Zea mays*), sorghum (*Sorghum vulgare*), amaranths (*Amaranthus* spp.), chenopods (*Chenopodium* spp.), sugarcane (*Saccharum* spp.), tropical pasture grasses, and saltmarsh grasses. CAM plants fix carbon dioxide by either C_3 or C_4 pathways depending the environmental conditions such as salinity, day length, night temperature, and water stress. Their ratios are intermediate. Cacti (Cactaceae) euphorbs (Euphorbiaceae), agaves (Agavaceae), bromeliads (Bromeliaceae) and orchids are examples of CAM. Generally, are found in hot environments. The study of carbon isotopes in herbivores can be used to detect variation in the availability of C_4 plants across time and landscape (Harrison and Katzenberg 2003; Krueguer and Sullivan 1984).

The use of bone apatite carbonate for dietary reconstruction is polemic because problems with bone diagenesis. However, the possibility to recover biogenic isotopic signals from apatite offers the opportunity to extend paleodietrary research recovering dietary information from skeletal remains from which collagen has long disappeared (Quade et al. 1992). Bone carbonate is derived from the total dietary pool of carbon ingested (Ambrose and Norr 1993; Tieszen and Fagre 1993).

Nitrogen isotopic values varies in terrestrial plants. Legumes obtain nitrogen from atmosphere and soil while non-legumes obtain it only from the soil. ^{15}N values become more positive as nitrogen is transferred along the way from plants to herbivores and carnivores. This information with the carbon allow to distinguish the trophic level of the consumer and also the amount of marine/lacustrine contributions to the organism's diet (Deniro and Epstein 1978; Schoeninger, Deniro, and Tauber 1983).

Isotopic oxygen values reflect the composition of the water that the individual consumed throughout his life, also reflecting the climate and geography of the area where he lived (Hobson 1999; Knudson and Price 2007; Luz, Cormie, and Schwarcz 1990). The values of $\delta^{18}O$ are also influenced by some characteristics of the individual, such as body size, habits of water consumption, domestic ranges among others.

5.2.4.1. Laboratory Protocol

Bone and dental fragments were sampled either because they were already isolated or were extracted using a diamond-tip drill. Collagen extraction protocol for bone and/or dentine followed standard methodology per Longin (1971) and modified per France, Owsley, and Hayek (2014). None of the sampled fragments bore signs of glue or other consolidants. Solid fragments (~200-800 mg) were sonicated in ultrapure water, then placed into centrifuge tubes and weighted to establish the initial weight of the sample. Samples were demineralized with 0.6M hydrochloric acid (HCl) in 4°C conditions, rotating the solution every 24 hours until reactions ceased. After neutralizing the samples in ultrapure water, humic acids were removed through submersion in a 0.125 M sodium hydroxide (NaOH) solution for 24 hours at room temperature. The remaining organic materials in the neutralized solution were solubilized by soaking in 0.03 M HCl at 95°C overnight. Purified collagen was extracted through isolating the soluble phases and lyophilizing it. Samples weighed into tin cups were combusted in a Costech 4010 Elemental Analyzer coupled to a Thermo Delta V Advantage mass spectrometer. The $\delta^{13}C_{collagen}$, $\delta^{15}N_{collagen}$ values are calibrated against an internal acetanilide and urea_UIN3 reference materials, as well as USGS40 and USGS41 (Schimmelmann et al. 2009). Error has consistently been recorded at ±0.2‰ (1σ) for both carbon and nitrogen values.

Structural carbonate from bone, dentine, and enamel was extracted according to modified methods of Bryant et al. (1996). Fine bone/dental powder ground by agate mortar and pestle was soaked in 2-3% sodium hypochlorite (NaClO) solution overnight to remove organic components. Neutralized samples were soaked for four hours in 1 M acetic acid solution buffered with 1 M calcium acetate (pH~4.5) to remove secondary carbonate phases (Garvie-Lok, Varney, and Katzenberg 2004; Pelletier et al. 2016). Desiccated, neutralized samples were weighed into Exetainer vials, reacted with concentrated (SG >1.92) phosphoric acid (H_3PO_4), and analyzed on a Thermo Gas Bench II connected to a Thermo Delta V Advantage mass spectrometer. The $\delta^{13}C_{carbonate}$ and $\delta^{18}O_{carbonate}$ values were calibrated against NBS-19 and LSVEC carbonate reference materials and have an error of ±0.2‰ (1σ).

All carbonate samples were analyzed with the Fourier-Transform Infrared Spectrometer with the attenuated total reflectance attachment (FTIR-ATR). Following pertinent literature, samples with IR-SF (mineral crystallinity index values) above 4.0 and C/P ratios (indicating the mineral carbonate phosphate) less than 0.1 were omitted from our analysis (Smith et al. 2007; Wright and Schwarcz 1996).

Bone and teeth extraction were performed at the Molecular Laboratory at Institut Català de Paleoecologia Humana i Evolució Social (IPHES). Sample preparation was carried out the Archaeology Laboratory at George Masson University and were analyzed at the Smithsonian Museum Conservation Institute Stable Isotope Mass Spectrometry Laboratory. The carbonate samples were analyzed with the FTIR-ATR at the Smithsonian Institution Museum Conservation Institute.

5.2.5. Geometric morphometrics

Geometric morphometric (GM) analysis is the statistical study of shape and size and their covariations with other variables. In zooarchaeology GM have been used to explore domestication and population variation (Bopp-Ito et al. 2018; Cucchi et al. 2011, 2017, 2019; Drake, Coquerelle, and Colombeau 2015; Duval et al. 2015; Haruda et al. 2019; Larson et al. 2007; Owen et al. 2014; Seetah et al. 2014).

There are some concepts that must be defined to better understand GM. The first one is shape, it could be defined as: "All the geometric information that remains when location, scale and rotational effects are filtered out from an object" (Kendall 1977). Another one is centroid size, it is the one measure of size that is mathematically independent of shape. Finally, landmarks, that are discrete anatomical loci that can be recognized as homologous in all specimens in the study. In GM a datum is the set of all individual landmarks. The assumptions behind landmarks in GM are that the landmarks are consistent in their relative position from one specimen to another, and they cover adequately the overall form of the biological structure, can be located and relocated without error, and finally share the same planarity (Bookstein 1996; Zelditch, Swiderski, and Sheets 2012).

Bookstein (1996) proposed a classification of landmarks: type I corresponds to discrete juxtaposition of tissues, or sufficiently small features to be defined by a single point; type II landmark corresponds to maximum of curvature; it may correspond to similar developmental features; type III landmark is an extremal point that can correspond to an end-points of diameters, a centroid, or an intersection between interlandmark segments and it is constructed geometrically. Ideally landmarks are homologous anatomical loci that provide adequate coverage of the morphology and can be found repeatedly and reliably.

Measurement error is defined as "the variability of repeated measurements of a particular character taken on the same individual, relative to its variability among individuals …" (Bailey and Byrnes 1990). Measurement errors could be systematic or random. The systematic ones are consistent biases in a measurement meaning that all measures are incorrect to a consistent degree. These errors could interact with a biological factor for this reason are the worst. The random errors are not frequent but they are modeled by a statistical distribution (normal) (Zelditch, Swiderski, and Sheets 2012). The sources of systematic errors are multiple and could be: 1. individual (the biological variation among members of the population), 2. imaging technology and 3. Measurement (Zelditch, Swiderski, and Sheets 2012). Others source of error are: User-based sources of error (*i.e.* experience among researchers, inherent researcher tendencies for precision and accuracy, and comprehension of instructions), and data collection-based sources of error (repeatability of landmark protocols) (Shearer et al. 2017; Muñoz-Muñoz and Perpiñán 2010). Here, every single measurement was made by the same person to avoid any inter-individual error. By decomposing the error into its sources and treating each potential source of error as a factor by performing a Procrustes ANOVA or a MANOVA the error could be avoided (Zelditch, Swiderski, and Sheets 2012). A way to reduce intra-individual measurement error is to average the repeated measures of the same specimens, in this way it could be quantify measurement error.

GM compared the shape configurations of several specimens using Generalized Procrustes Analysis (GPA); minimizing the sum of squared distances between homologous landmarks by translating, rotating and scaling them to best fit (Rohlf and Slice 1990). This procedure aligns the coordinates with a least squared approach to remove the originals scale, position and orientation allowing the comparisons.

In this thesis, a 2 dimensions' model of the lower third molar was proposed. In order to construct it, only the left mandibles and teeth were selected in the modern collections. In the case of the archaeological site both sides were used but all pictures of right mandibles were mirrored left. A picture of each specimen occlusal surface was taken oriented parallel to the camera focal plane. A Canon T3i with Canon macro lens EF-S 60mm was used. A landmark protocol was proposed, 13 points were selected in order to describe m3 shape, most of them are type I and II (Figure 5.10). Landmarks were digitized from images with a TPSdig2 v. 2.17 (Rohlf 2005). The GPA was performed by using R Geomorph package (Adams and Otárola-Castillo 2013) and MorphoJ (Klingenberg 2011). To assess variation in user accuracy and precision 13 landmarks were placed on 10 replicates of the same tooth picture and 10 replicates of different teeth pictures. A t test was performed to compare the two samples by using the new set of Procrustes coordinates (or shape coordinates) product of the GPA.

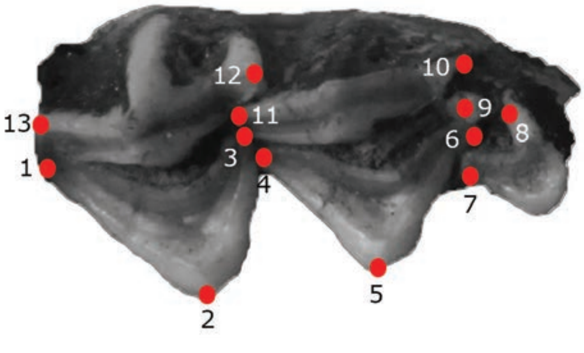


Figure 5. 10. Type I and II Landmarks examples used to describe the shape of m3.

6. RESULTS

6.1. Behind white-tailed deer teeth: A micro- and mesowear analysis from three Panamanian pre-Cololumbian archaeological sites

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Behind white-tailed deer teeth: A micro- and mesowear analysis from three Panamanian pre-Columbian archaeological sites

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ABSTRACT

The white tailed-deer (*Odocoileus virginianus* Zimmermann 1780) is one of the largest mammals in Holocene America. It was a primary resource for pre-Columbian communities in the wooded savannas of Panama for several millennia. The oldest remains yet found refer to the Late Preceramic period (6000-4500 cal yr BP), when people were already farming (i.e. at Cerro Mangote). Deer bones, antlers, and inferentially, sinews and skins, were used for tools, ornaments, musical instruments, and furniture. A prominent role in regional (i.e., Greater Coclé) symbolism is evidenced by the frequent representation of these cervids on ceramic, gold, and bone art objects at hierarchized villages and burial grounds during the period 2300-500 cal yr BP. We infer the duration and seasonality of human-deer interactions across a region characterized climatically by ~4 month intense dry seasons, and ~8 month unpredictable wet seasons. We combine microwear and mesowear analyses of deer teeth at three pre-Columbian sites with different time spans –Cerro Mangote (AG-1) (5900-3020 cal yr BP), Sitio Sierra (AG-3) (2300-500 cal yr BP), and Cerro Juan Díaz (LS-3) (2300-400 cal yr BP)–. The two dental wear methods indicate that the white-tailed deer was a browser at these sites. The microwear results, based on the degree of variability in the numbers of microwear traits such as scratches and pits, show that white-tailed deer hunting was restricted to wet seasons at Cerro Mangote and Cerro Juan Díaz while, at Sitio Sierra, different kinds of occupational events involving white-tailed deer occurred throughout the year.

1. Introduction

1.1. The white-tailed deer

The white-tailed deer (*Odocoileus virginianus* Zimmermann 1780) is one of the largest extant mammals in tropical America whose body mass averages 50 kg for males, and 30 kg for females (Emmons, 1999). This species is notably protean in its choice of habitat, being able to adapt to vegetated deserts, savannas, prairies, mountains, and both temperate deciduous, and tropical dry and evergreen forests (Smith, 1991). Generally, the white-tailed deer avoids densely wooded biomes. Behaviorally, it is plastic, and trophically, it is opportunistic especially in regard to its consumption of human food crops. It chooses relatively nutritious and highly digestible plants and plant parts, such as young leaves (Eisenberg, 1989; Smith, 1991; Teer, 1994; Arceo et al., 2005; Gallina et al., 2010). However, it also feeds on grasses, sedges, nuts, fungi, fruits, and fallen flowers (Eisenberg, 1989; Smith, 1991; Gallina et al., 2010; Ramírez Lozano, 2012).

Habitat use by this deer species is predicated upon the quality, quantity, and heterogeneity of available forage (Sánchez-Rojas et al., 1997; Gallina et al., 2010; Ramírez Lozano, 2012). Diet varies among seasons due to discontinuities in the availability of food, cover, and water (Sánchez-Rojas et al., 1997). In high rainfall periods, a large quantity of food resources becomes available to the deer although, paradoxically, dietary diversity may be diminished at the beginning of the rains when the deer become more selective, choosing young leaves of trees, shrubs, and vines (Sánchez-Rojas et al., 1997; Bello et al., 2001, 2004; Arceo et al., 2005). Dry seasons are critical periods during which the deer orientate their foraging towards the most nutritious fruits, and leaves trees, shrubs and herbs that are then available (Sánchez-Rojas et al., 1997; Bello et al., 2001, 2004; Arceo et al., 2005).

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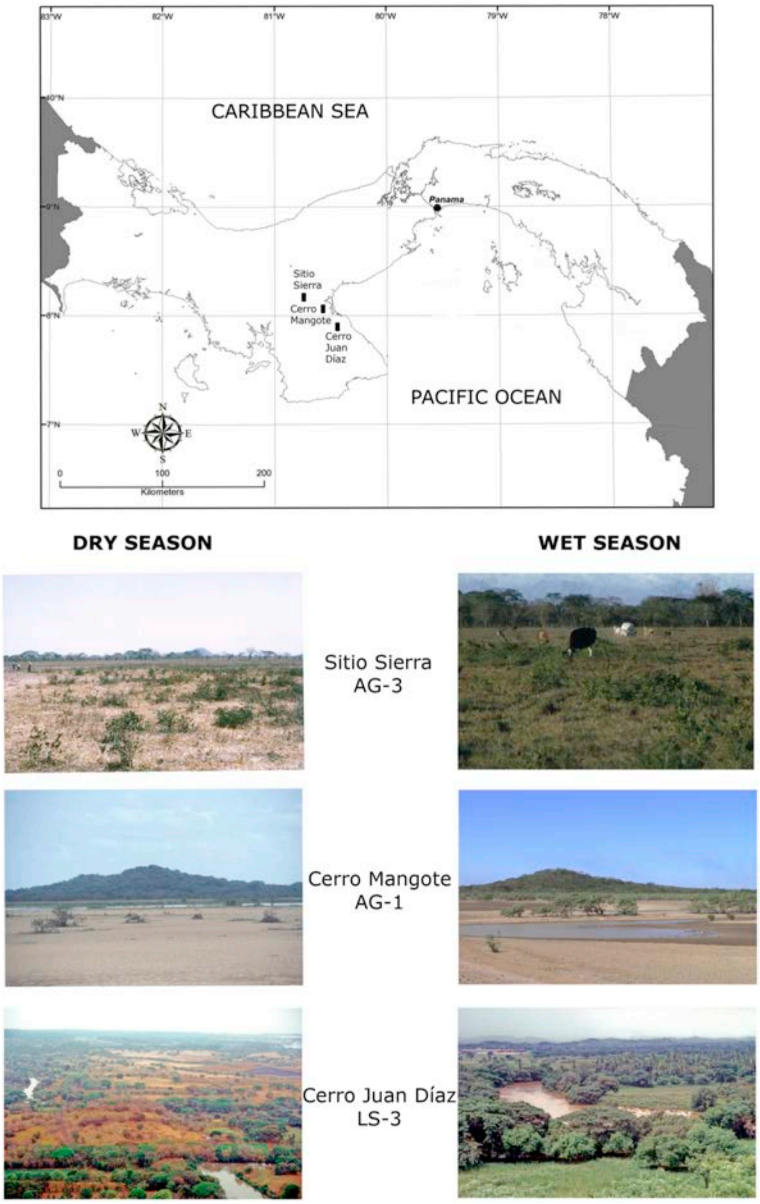

Fig. 1. Geographical location of Cerro Mangote (AG-1), Sito Sierra (AG-3) and Cerro Juan Díaz (LS-3) and pictures of the areas during the wet and dry seasons. Images Cooke's personal archive.

1.2. *Pre-Columbian targeting of white-tailed deer on the Pacific watershed of Panama*

Zooarchaeological data show that the white-tailed deer was a targeted mammal species across the ancient anthropogenic savannas of central Pacific Panama for at least 8000 cal years (Cooke et al., 2007, 2008). It merits the term “apex species,” not only for its primary role in human dietary well-being and in social feasting events (Martínez-Polanco and Cooke, 2019), but also for affording a ready supply of raw material for making tools and personal ornaments. In addition, after about 2300 cal yr BP, adult male white-tailed deer became prominent actors in the symbolic realm of the Greater Coclé culture area being often depicted in diverse ways on painted and modelled ceramic art and on goldwork (Cooke, 2004b, 2011; Cooke and Jiménez-Acosta, 2010).

This paper concentrates on three pre-Columbian sites located within 15 km of the active Pacific coast of Parita Bay – Cerro Mangote (AG-1), Sitio Sierra (AG-3), and Cerro Juan Díaz (LS-3) (Fig. 1), which is the most north-westerly extension of the much more extensive Panama Bay. Politically, Parita Bay belongs today to the provinces of Herrera and Coclé, and, geographically, it represents the north-eastern corner of the Azuero Peninsula. Known in popular parlance as the dry crescent (*Arco Seco*), its eponym (Parita) refers to the paramount chieftain who held sway over several chiefdoms that abutted onto Panama Bay during the immediately pre-Conquest years (1515 and 1522) (Haller, 2004; Isaza Aizpurua, 2007, 2013; Cooke et al., 2008). The term dry crescent refers to the fact that strong north-south trade winds accentuate desiccation during the usually 4–5 month dry season in this region (Cooke et al., 2008). All over the isthmus, wet season precipitation is heavily influenced by orography, and, in the vicinity of Parita Bay, convectional uplift, and electric storms are less pronounced than elsewhere. During the wet season (May–December), the landscape is green and lush, and seasonal swamps form in low-lying areas. Fresh water is provided by rivers, which rise in the central mountain range (Cordillera Central), or down the north-south hilly spine of the Azuero Peninsula. During the sunny dry season (strongest in January–April) the water table falls dramatically and evapo-transpiration is very rapid. Some streams (but not the largest rivers) dry out, and vegetation cut for clearing fields burns quickly (Cooke et al., 2008). By April, the landscape has become brown and parched (Cooke et al., 2008). Vegetation history has documented an early Holocene onset of fire-induced forest removal in the central Pacific lowlands and foothills, except for gallery forests included some tall trees (e.g. *barrigón* (*Bombax barrigon*) and *higuerón* (*Ficus* spp.)), which remain lush and tall along stretches of major rivers, such as the Santa María, Parita and La Villa, in whose watersheds the referred three sites are located (Piperno, 2011b) (See Fig. 2 a. and f.). Surviving wooded patches contain many fire-tolerant taxa that have xeromorphic characteristics (i.e. microphyllous leaves, thorns, leaves, and thick bark) as well as drought-adapted tree species, such as *chumico* (*Curatella americana)*, and *nance (Byrsonima crassifoloia)*, which often occur in large stands (Linares, 1977: Fig. 3). This was the kind of anthropogenic environment that nurtured human-white-tailed deer symbiosis during most of the Pre-Columbian Era.

Our objective in this article is to use microwear and mesowear analysis of teeth in order to infer the duration and seasonality (wet versus dry season) of human interactions with white-tailed deer at three Panamanian archaeological sites with different chronologies and unequal population size and density – Cerro Mangote (AG-1), Sitio Sierra (AG-3), and Cerro Juan Díaz (LS-3).

2. Regional setting

Cerro Mangote (AG-1), Sitio Sierra (AG-3), and Cerro Juan Díaz (LS-3) are now located respectively eight, 13 and four km inland from the active coastline of Parita Bay in central Pacific Panama (provinces of Coclé and Herrera) (Fig. 1). The Pre-Columbian landscape in the vicinity of the three sites would not have been identical, but would have comprised variable combinations of wooded savanna (with extensive open and/or grassy areas), dry forest remnants especially on hills, tidal flats, mangroves, freshwater seasonal swamps, and mature gallery forest along larger rivers (Cooke et al., 2008). Since about 6000 cal years ago, the deltas of the Santa María and Parita rivers have been prograding seawards. Delta formation is particularly rapid at the outlet of the Santa María because of its particularly large sediment load due to its length of 145 km from its source in the central cordillera to Parita Bay (Clary et al., 1984; Weiland, 1984; Cooke and Ranere, 1999; Isaza Aizpurua, 2007, 2013).

Cerro Mangote (AG-1): is today located in Aguadulce District, Coclé Province, Panama at the edge of Parita Bay, and just landward of a zone of high tidal flats (Clary et al., 1984; Cooke and Ranere, 1999). It is situated on the flattish summit (~48 m a.s.l) of a small hill located on the north bank of the Santa María River (Fig. 1). The active marine shore would have been only 2 km away at the time people stopped living there on a regular basis (Cooke, 1984; Cooke and Ranere, 1999). Excavations were conducted by McGimsey in 1955 and by Ranere in 1979 (McGimsey, 1956, 1958; Ranere, 1979; McGimsey et al., 1986; Cooke and Ranere, 1992c). It is a small site (ca. 2250 m^2) that was used exclusively as a dwelling for a maximum of 2880 years (5900-3020 cal yr BP) (Table 1). The shell-bearing kitchen middens spread across the hill's summit are assigned exclusively to the Late Preceramic in the regional cultural sequence (McGimsey, 1956, 1958; Ranere, 1979; McGimsey et al., 1986; Cooke and Ranere, 1992c). Burial activities, however, continued long after the abandonment of the dwelling site, by which time pottery was in use (4425-2010 cal yr BP) (Smith-Guzmán, personal information, August 2019). Isotope proportions (C and N) calculated from human bone collagen infer a predominantly terrestrial diet that included significant amounts of C$_3$ plants, but with input from C$_4$ plants, whose source is likely to have been maize (Norr, 1995; Cooke et al., 1996). Cerro Mangote had a small catchment area, over which the mammals most frequently hunted were white-tailed deer and raccoon (*Procyon lotor*) (whose isthmian subspecies is known to prefer mangroves), green and black iguanas (*Iguana iguana* and *Ctenosaura similis),* and several bird species from marine edge, mangrove, dry forest, and riverine biomes (Cooke et al., 2013a). Aquatic foods comprised inshore molluscs and crabs, and almost exclusively marine fish with a clear bias towards the capture of oligohaline marine catfish (Ariidae), snook (*Centropomus* spp.), and toadfish (*Batrachoides* spp.), as well as smaller sleepers (*Dormitator latifrons*) from inshore pools. Non-fish vertebrates provided as much dietary meat as fish (Cooke and Ranere, 1989, 1992a; Cooke, 1992; Mayo and Cooke, 2005).

Ranere (1979) interpretation of the stratigraphy at Cerro Mangote is that there are only two major culture-bearing zones, which he named the “Red Zone” and the “Brown Zone”. During the red zone occupation, which is estimated to have lasted from ca 5900 cal yr B.P. to ca 5500 cal yr B.P., the intensity of human settlement was not sufficient to modify the natural (red clay) character of the soil development with organic matter. The more intense brown zone occupation apparently added much larger amounts of organic matter, and built up from ca 5500 B.P. to ca 4500 cal yr B.P. or whenever the first Monagrillo complex pottery entered the record (Willey and McGimsey, 1954; Ranere, 1979; Cooke and Ranere, 1992c). Table 1 presents radiocarbon data for the site and a description of each occupation zone.

Sitio Sierra (AG-3): is located 4 km south-east of La Loma village (Aguadulce District, Coclé Province, Panama), on the north bank of the River Santa María, and 12.5 km straight line distance from its current marine outlet (Fig. 1). This site was excavated by Richard Cooke from 1971 to 1975 (Cooke, 1979, 1984; Isaza Aizpurua, 1993, 2007). This village was established by the end of the second millennium BP, and people were still living there at the time of the conquest (1515–1519 CE). It appears to have been occupied continually based on the unbroken ceramic sequences (Cooke, 2011). There is no evidence that it was a high-ranked village in a chiefdom known to be under the aegis of Escoria at Spanish contact (Cooke et al., 2003; Cooke, 2011). The subsistence pattern of this population at about 1500 cal yr BP comprised fishing (30% freshwater and 70% marine fish) and hunting mostly deer, iguanas, and freshwater turtles (Cooke and Ranere, 1989, 1999; Cooke et al., 1996, 2007, 2008; 2013a). Carbonized macrobotanical remains were found in some quantity in houses and rubbish dumps at AG-3. Nearly 99% belong to maize, and many fragments of legged maize-grinding tables (*metates)* and grinding stones (*manos)* were deposited on structure floors, and in trash heaps. Squash (*Cucurbita* sp.) pollen and phytoliths were identified in domestic contexts. Carbonized palm nuts (*Attalea butyracea)* were probably collected in nearby fields where these palms are usually left standing today during de-vegetation for pastures and fields (Dickau, 2005, 2010) (see Fig. 2 c.).

In the 1975 excavations, two major areas were opened, and worked by *décapage*: Cut A and Cut B. Table 1 presents a list of the features

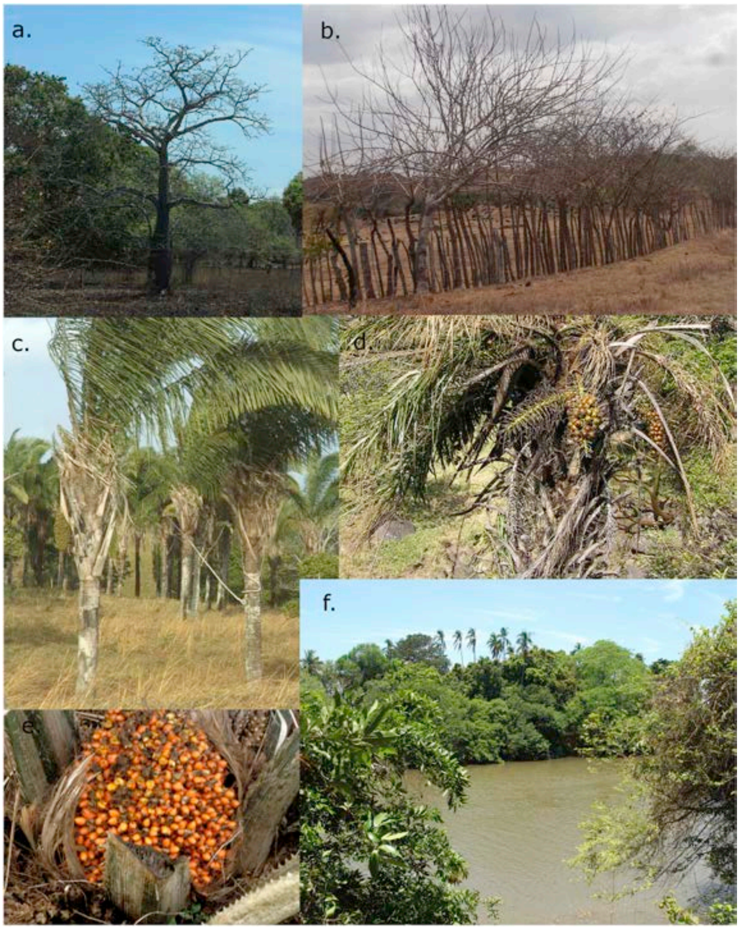

Fig. 2. Some examples of typical plant species of the dry crescent of the central Pacific lowlands of the isthmus of Panama.
a. Barrigon (*Bombax barrigon),* a tall deciduous *tree* of the remnant gallery forest along the Santa María river near Sitio Sierra (AG-3). Image: Martínez-Polanco, M.F. April, 2015, Cocle province.
b. Ciruelo (*Spondias purpurea*), a cultivated deciduous tree, which produces an edible fruit (hog-plum in English). Stakes of this species are planted to make living fences between pastures, usually reinforced with barbed wire fences. The juicy fruits are eaten by birds, cows, horses and humans. Image: Martínez-Polanco, M.F. April 2014, Cocle province.
c. Corozo gunzo (*Attalea butyracea*). This palm species was planted around pre-Columbian settlements, and is still protected in pastures, which have been cleared for homogenizing forage. The fronds are much appreciated for roof- and wall-thatching. Image: Cooke, R. 1975, Cocle province.
d. Wine palms (*Acrocomia aculeata*). Image: Dickau, R. 2005. Ancón, Panama City.
e. American oil palm (*Elaeis oleifera*). Image: Dickau, R. 2005. Casita de Piedra, Chiriquí,
f. Gallery woods along Santa Maria River in the late dry season. The tall palms are coconuts (*Cocos nucifera*) which were observed by the Spanish around Parita Bay in the early sixteenth century CE and appear to have been in the process of colonizing the Pacific coast of Panama. Image: Martínez-Polanco, M.F. April 2015, Cocle province.

employed for this study together with their inferred functions. In most cases, animal remains were found in pit fills, and in refuse lenses found adjacent to houses or thrown over their living floors (Cooke, 1979:35).

***Cerro Juan Díaz* (LS-3):** is located on the coastal plain bordering Parita Bay and on both banks of the tidal valley of the Parita River. The site is dominated by a 42 m-high hill located in Los Santos Province (Fig. 1). Today, Cerro Juan Díaz is 4.3 km inland from the active marine shore although, when the settlement was thriving, it would have been 0.25–1 km closer to the coast (Cooke et al., 1998). Fieldwork was carried out by an international team under Cooke's supervision from 1992 to 2001. Eleven field "operations" were performed here, each one with different dimensions ranging from 2 × 1 m test pits to an 800 m^2 *décapage* excavation (Cooke et al., 1998, 2000). Cerro Juan Díaz is a residential-cum-mortuary site (2300-400 cal yr BP), where dwelling floors, kitchen middens, and trash pits, alternate with graves, many of which have multiple burials with individuals treated for death in different ways (Díaz, 1999; Cooke et al., 2000). Residential areas, shell and bone artifact workshops (Mayo, 2004; Mayo and Cooke, 2005), and several ritual zones including burials and associated features, such as stone-walled ovens, were located. Also, there is evidence for low-level modification of the hill's topography by the ancient inhabitants of the site who, for example, leveled the southern section of the hill where some of the burials were placed, and which probably functioned as a social or ritual space used for gatherings (Cooke et al., 1998, 2000). Some grave units at Cerro Juan Díaz contained individuals buried with special artifacts, such as hammered gold plaques, carefully crafted marine shell necklaces and other personal ornaments made of marine shells, including thorny oyster (*Spondylus* spp.), and preforated teeth of carnivores including jaguar (*Panthera onca*), puma (*Puma concolor*), and ocelot (*Leopardus pardalis*) (Sánchez, 1995; Cooke et al., 1998; Díaz, 1999). The subsistence economy of this population was mixed: marine shellfish gathering; fishing in inshore waters and tidal rivers; agriculture heavily biased towards maize; hunting emphasizing iguanas, birds, white-tailed deer, and smaller terrestrial mammals (Jiménez-Acosta and Cooke, 2001; Cooke et al., 2007, 2013a; Isaza Aizpurua, 2007; Cooke and Jiménez-Acosta, 2008).

In sum, Cerro Juan Díaz presents a complex stratigraphy produced by multiple activities carried out in the same settlement over at least 1900 years (i.e., burials and associated activities, dwellings, kitchen refuse, workshops, and social and residential areas). In Table 1, we present the radiocarbon dates and a brief description of the operations.

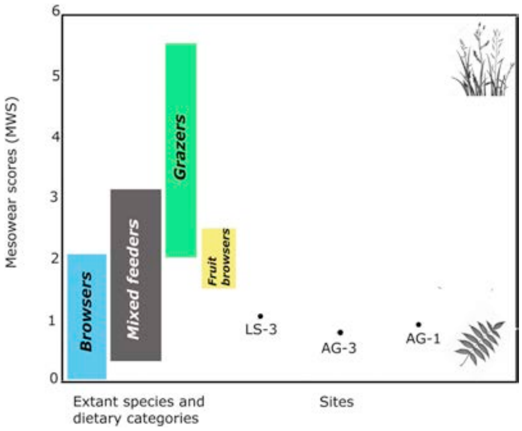

Fig. 3. Mesowear results for the archaeological white-tailed deer (*Odocoileus virginianus*) from Cerro Mangote (AG-1), Sitio Sierra (AG-3) and Cerro Juan Díaz (LS-3). Data on modern ungulates from Fortelius and Solounias (2000) and Rivals et al. (2013, 2017).

3. Materials and methods

3.1. Materials

We selected all available white-tailed deer dental material from the three sites. For mesowear analysis, we sampled 124 teeth (Cerro Juan Díaz n = 70; Sitio Sierra n = 20; Cerro Mangote n = 34). In order to perform microwear analysis, 102 teeth were employed (Cerro Juan Díaz, n = 57; Sitio Sierra, n = 18; Cerro Mangote, n = 27). In both cases, we selected only adults, taking into account the degree of wear of the teeth, not including the most worn ones, and also the teeth without wear. In the case of Cerro Juan Díaz, we selected teeth from operations 1, 3, 4, 5 and 31. We sampled all contexts at Sitio Sierra (A3, A2-1/A2-2, A1-1/A1-2, B4, B3, and B2). At Cerro Mangote, we focused our sample on the brown zone, which represents the more intense occupation in the site.

3.2. Methods

3.2.1. Microwear and mesowear

Analyses of microwear and mesowear allow different kinds of dietary inferences. Broadly speaking, microwear distinguishes among browsers, grazers, and mixed feeders (Solounias and Semprebon, 2002). Since plant species, and their component parts, vary with regard to hardness and abrasiveness, distinct patterns are etched into the tooth enamel in the form of microscopic pits and scratches (Solounias and Semprebon, 2002). Patterns are produced quickly, and are continuously overwritten. Consequently, they indicate the type of diet during the last days or weeks before an individual's death (Grine, 1986). In addition, paleoenvironmental conditions, food preferences, and dietary ecology can be inferred weeks, or even days, before an animal dies (Solounias and Semprebon, 2002; Davis and Pineda Munoz, 2016; DeSantis, 2016; Xafis et al., 2017).

Microwear patterns are also sensitive to seasonal, local and individual variations in diet (Semprebon et al., 2016). This variability depends to a degree upon how long it took a death assemblage to accumulate (Rivals et al., 2009) and, by inference, how long, or at which season of the year, people lived in a given locality (Rivals and Semprebon, 2011; Sánchez-Hernández et al., 2014; Rivals and Takatsuki, 2015). In addition, microwear is capable of identifying whether archaeological assemblages are the result of a short death event, or of multiple ones over longer periods of time (Rivals et al., 2015). Taking into account that, firstly, scratches in the enamel are

Table 1
Cerro Mangote (AG-1), Sitio Sierra (AG-3) and Cerro Juan Díaz (LS-3) context descriptions and dates. The dates were calibrated by using INTCAL13.

Site code	Context	Context description	Method	Material	Lab. Number	Measured date[a]	Cal BP (2σ)[b]
AG-1	Above red clay	Preceramic dump site	Radiometric	charcoal	Y-458d	6810 ± 110	5974-5531 BCE
AG-1	Red zone	Preceramic dump site	Radiometric	charcoal	β-1219	6670 ± 215	6014-5215 BCE
AG-1	Red zone	Preceramic dump site	Radiometric	Protothaca	TEM-206/Beta-1703	6330 ± 170	5617-4859 BCE
AG-1	Red zone	Preceramic dump site	Radiometric	Crassostrea	TEM-174	5990 ± 180	5317-4488 BCE
AG-1	Red zone	Preceramic dump site	Radiometric	Crassostrea	TEM-176	5440 ± 130	4532-3982 BCE
AG-1	Red zone	Preceramic dump site	Radiometric	Crassostrea	TEM-175	5140 ± 120	4241-3666 BCE
AG-1	Red zone	Preceramic dump site	Radiometric	Crassostrea	TEM-207,/Beta-1702	4630 ± 150	3661-2926 BCE
AG-1	Brown zone	Preceramic dump site	Radiometric	Crassostrea	TEM-208/Beta-1704	3980 ± 160	2901-2039 BCE
AG-1	Brown zone	Preceramic dump site	Radiometric	charcoal	β-1218	3555 ± 100	2196-1641 BCE
AG-3	A2-1/A2-2	Kitchen refuse	Radiometric	charcoal	I-8556	1475 ± 110	335–770 CE
AG-3	B1	Floor of a circularstructure	Radiometric	charcoal	I-9702	2015 ± 80	350 BCE – 209 CE
AG-3	B1	Floor of a circularstructure	Radiometric	charcoal	I-9703	1975 ± 80	177 BCE – 224 CE
AG-3	A1-1/A1-2	Oval domestic structure	Radiometric	charcoal	CEI-9701	1835 ± 90	21 BCE – 395 CE
AG-3	A1-1/A1-2	Oval domestic structure	Radiometric	charcoal	I-8613	1715 ± 90	90–540 BCE
LS-3	OP.1	Kitchen refuse	AMS	Maize	TO-4594	1470 ± 90	390-764 CE
LS-3	OP.3	Kitchen refuse	Radiometric	charcoal	1–18679	1730 ± 80	87-107 CE
LS-3	OP.3	Kitchen refuse	Radiometric	charcoal	1–18222	1370 ± 80	474-485 CE
LS-3	OP.3	Kitchen refuse	Radiometric	charcoal	1–18287	1310 ± 80	583-894 CE
LS-3	OP.3	Kitchen refuse	Radiometric	charcoal	1–18288	1450 ± 80	415-694 CE
LS-3	OP.3	Kitchen refuse	Radiometric	charcoal	1–18675	1330 ± 110	435-450 CE
LS-3	OP.3	Kitchen refuse	Radiometric	charcoal	1–18672	1380 ± 80	433-489 CE
LS-3	OP.3	Kitchen refuse	Radiometric	charcoal	1–18671	1570 ± 80	265-273 CE
LS-3	OP. 4	Kitchen refuse	Radiometric	Charcoal	β-121163	1260 ± 90	635-976 CE
LS-3	OP. 4	Kitchen refuse	Radiometric	Carbonized tallo	β-121162	1180 ± 60	690-983 CE
LS-3	OP. 4	Kitchen refuse	Radiometric	Carbonized food	β-121157	1110 ± 50	777-1019 CE
LS-3	OP. 4	Kitchen refuse	Radiometric	Carbonized food	β-121156	1010 ± 60	894-1162 CE
LS-3	OP. 4	Kitchen refuse	Radiometric	Charcoal	β-121164	950 ± 60	990-1214 CE
LS-3	OP.31	Kitchen refuse	Radiometric	charcoal	1–18681	750 ± 80	1049-1399 CE
LS-3	OP.31	Kitchen refuse	Radiometric	charcoal	1–18682	650 ± 110	1058-1458 CE

[a] conventional C-14 age BP ± 1-sigma range.
[b] calibrated 2-sigma range BCE/CE.

sensitive to seasonal variation, and, secondly, that each season may be associated with specific foods, it stands to reason that each season produces a specific microwear signal. The more seasonal are the mortality events, the more diverse will be the range of food and the microwear signal (Rivals et al., 2011; Rodríguez-Hidalgo et al., 2016). By using the standard deviation and the coefficient of variation, analysis of scratch variability permits distinguishing short or long mortality events (Rivals et al., 2015).

On the other hand, mesowear reflects the physical characteristics of the plants that the animals consume, which are visible on the occlusal relief and overall shape of the molar cusps (Fortelius and Solounias, 2000). For example, browser diets show little abrasion and molars are characterized by sharp buccal cusp apices. Conversely, grazers have abrasive diets and they ingest grit. Thus, their molars have more rounded and blunt apices. To sum up, mesowear results from attrition and abrasion over a long period of time, and reflects the annual diet of an animal (Fortelius and Solounias, 2000; Rivals et al., 2013, 2017; Amano et al., 2016).

Tooth mesowear: Mesowear analysis involves the observation of cusp morphology, and proceeds by describing the sharpness and the relief of molar tooth cusps (Fortelius and Solounias, 2000). These attributes are scaled from 0 (more sharp) to 6 (more blunt); mesowear is scored on each specimen and then averaged for each sample (Mihlbachler et al., 2011; Rivals et al., 2013, 2017).

Tooth microwear: We follow the method proposed by Solounias and Semprebon (2002) and Semprebon et al. (2004). Microwear analysis comprises several steps: 1) selecting teeth, 2) making a mould of the occlusal surface using a material appropriate for dental impressions, such as polyvinylsiloxane, 3) making a cast using transparent epoxy. In order to observe the epoxy casts under incident light, we used a Zeiss Stemi 2000C stereomicroscope at 35× magnification. The microwear features (pits and scratches) were quantified on the enamel bands, and on the mesiobuccal cusp of the second molar within a standard (0.4 × 0.4 mm) area by using an ocular reticle. Counting the scratches allows distinguishing three dietary categories: browsers (numbers of scratches in the range of 0–17), grazers (numbers of scratches in the range of 17.5–29.5), and mixed feeders which present some overlapping values (Solounias and Semprebon, 2002). In order to compare the variability of the scratches and the pits, we performed a two-way variance analysis (ANOVA) without replication when the data meet the assumptions to carry out the test, while, in the opposite case, we performed a Kruskal-Wallis test and a Mann-Whitney pairwise test in order to identify differences between groups. In this article, the R code proposed by Rivals (2019) was used to create the bivariate plots.

Scratch variability: We also quantified the variability of the number of scratches, in order to estimate the relative duration of the occupation of the sites by following Rivals et al. (2015). This tool allows to distinguish among three types of human occupations (a. Seasonal or shorter events; b. Longer-than- a-season events; c. Two separated events) according to their position on the heat map of the scratches' coefficient of variation (X-axis) and the scratches' standard variation (Y-axis).

4. Results

Tooth mesowear: In Table 2 we present the results of the mesowear analysis. Mesowear analysis shows very low values indicating that white-tailed deer diet at the archaeological sites was low in abrasiveness – a situation that is similar to that of present-day typical browsers or browse-dominated mixed feeders. It is likely that Cerro Mangote deer were heavier browsers than those hunted at the other sites, although the difference is not statistically significant (Fig. 3). However, the Kruskal-Wallis test shows that there are no significant differences between the three sites ($H = 0.06$; $p = 0.96$).

Table 2
Summary of mesowear and microwear data for the archaeological white-tailed deer (*Odocoileus virginianus*) from Cerro Mangote (AG-1), Sitio Sierra (AG-3) and Cerro Juan Díaz (LS-3). Abbreviations: n: sample size; MWS: Mesowear score; NS: Number of scratches; NP: Number of pits; M: mean; SD: Standard deviation; CV: coefficient of variation.

SITE		Mesowear		Microwear		
		n	MWS	n	NS	NP
LS-3	M	70	1.17	57	11.59	7.5
	SD		1.31		2.52	4.52
	CV		1.12		0.21	0.6
AG3	M	20	0.95	18	10.75	9.61
	SD		0.82		3.12	4.11
	CV		0.86		0.29	0.42
AG-1	M	34	1.02	27	10.92	7.25
	SD		1.02		1.89	3.86
	CV		1.02		0.17	0.53

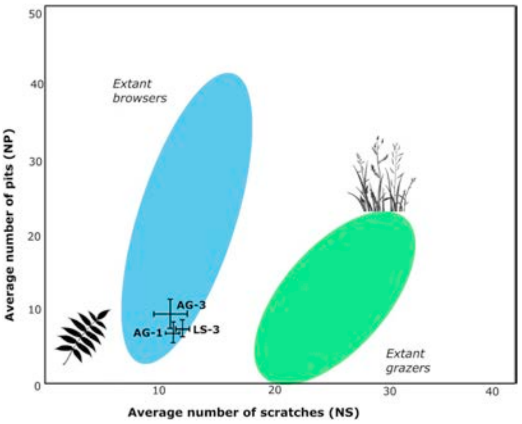

Fig. 4. Bivariate plot of the average numbers of pits and scratches in the archaeological white-tailed deer (*Odocoileus virginianus*) from Cerro Mangote (AG-1), Sitio Sierra (AG-3) and Cerro Juan Díaz (LS-3). Error bars correspond to standard error of the mean (± 1 SEM). Ellipses correspond to the Gaussian confidence ellipses ($p = 0.95$) on the centroid for the extant leaf browsers and grazers from Solounias and Semprebon (2002).

Tooth microwear: The number of scratches and pits is low in the three cases (Table 2), locating their values in the lower part of the 95% confidence ellipse in comparison to the modern browsers (Fig. 4). Microwear analysis indicates that deer were typical browsers at the time of death. There is no significant difference in the number of scratches among the three sites ($F = 1.82$; $gl = 2$; $p = 0.16$). However, there are significant differences in pits among the three sites (Table 1). The number of pits is highest at Sitio Sierra ($H = 6.06$; $p = 0.04$). Table 3 summarizes graphically the differences in pit variation among the samples from Sitio Sierra, Cerro Mangote and Cerro Juan Díaz, and shows that there no differences in the case of Cerro Mangote and Cerro Juan Díaz.

Scratch variability: Scratch variability at Cerro Mangote is low (see Fig. 5) falling in area a. on the heat map, and thus corresponding to seasonal or shorter events. In the case of Cerro Juan Díaz, it is not

Table 3
Mann-Whitney pairwise pit comparison between Cerro Mangote (AG-1), Sitio Sierra (AG-3) and Cerro Juan Díaz (LS-3).

	Sito Sierra (AG-3)	Cerro Juan Díaz (LS-3)
Cerro Juan Díaz (LS-3)	*0.02*	-
Cerro Mangote (AG-1)	*0.01*	0.94

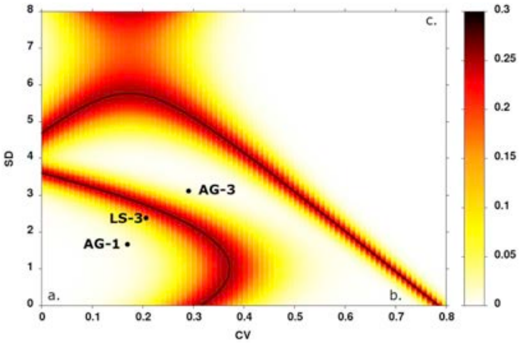

Fig. 5. Heat map (boundary lines of the three regions with the error probability) and the fossil samples from Cerro Mangote (AG-1), Sitio Sierra (AG-3) and Cerro Juan Díaz (LS-3). a. Seasonal or shorter events; b. Longer than a season events; c. Separated events (data from Rivals et al., 2015).

possible clearly to distinguish scratch variability because it falls on the boundary between areas a. and b. On the other hand, scratch variation at Sitio Sierra is notably higher than at the other sites, falling in area b. of the heat map, and thus indicating several events at different time of the year or events distributed over one or several years (Fig. 5).

5. Discussion

This study presents mesowear and microwear analyses of white tailed deer teeth from three Panamanian pre-Columbian sites located in the so-called dry crescent of the central Pacific lowlands of the isthmus. The low scratch and pit variation in the samples from Cerro Mangote and Cerro Juan Díaz suggests that white-tailed deer were more likely to have been hunted at these sites during the rainy season (May-December) when the deer were more selective about their diet, and focused on the young leaves of particular shrub and vine taxa (Sánchez-Rojas et al., 1997; Bello et al., 2001, 2004; Arceo et al., 2005). On the other hand, at Sitio Sierra, deer were likely hunted mostly during the dry season since pits and pit variation have a higher frequency in these samples than in those from Cerro Mangote and Cerro Juan Diaz. A wide diversity of available plant species and plant parts (e.g. fruits, seeds, leaves and woody forage) from several taxa of shrubs and trees, are conducive to a more variable white-tailed deer diet during the dry months (Sánchez-Rojas et al., 1997; Bello et al., 2001, 2004; Arceo et al., 2005).

Martínez-Polanco and Cooke (2019) presented a detailed zooarchaeological and taphonomical study of the white-tailed deer at Sitio Sierra. They describe a communal feasting event at which deer meat was consumed in large quantity. Socially, holding communal feasts of this nature would have been more practical and appealing between late December and late April, than during the rainy and stormy months. Dry season is the time of year when the communities of the Pacific-side Ngäbe (formerly Western Guaymí) held their stick-throwing competitions – the *krun* (Ngäbere) or *balsería* (Spanish) -, which were attended by many people from dispersed hamlets scattered over the landscape, and which offered great prestige to the individual or kin group that had been able to accrue sufficient food and fermented maize beverages - known as *do kwaga* in Ngäbere and *chicha fuerte* in Panamanian Spanish - for feeding a throng of guests (Young, 1976).

The Maya, whose realms were situated further north on the Central American isthmus, linked the white-tailed deer to agriculture, the sun, rain, and the cyclical nature of time - features that they believed were the supernatural correlates of fecundity and prosperity (Pohl, 1981; Brown, 2001). According to Pohl (1981) the Maya still hold feasts in mid-December in the hope of a good harvest the following year, and no harvest ceremony can be held until the agricultural cycle has been formally concluded. The Maya situation described by Pohl lends support to the hypothesis that the feasting event identified at Sitio Sierra was timed for the early dry season when cobs are harvested rapidly in order to diminish weevil (Curculionidae: *Sitophilus zeamais*) and avian attacks (e.g., in Panama's case, parrots and parakeets [*Amazona*, *Aratinga,* and *Pionus* spp.] (Cooke et al., 2013a)).

Cerro Mangote is a considerably older dwelling-site than Cerro Juan Diaz and Sitio Sierra (likely maximum span, 7800-5500 cal yr BP), and, covering 2250 m^2 (McGimsey, 1956), its lifestyle and subsistence were understandably quite different from that of the Sitio Sierra nucleated village. The earliest Late Preceramic inhabitants of this hill-top settlement consumed maize according to microbotanical data (Piperno, 2011b) – an issue discussed in greater detail below –, and two coeval rock-shelters did so also. At one of these – the Aguadulce Shelter (AG-13) –, located ca 18 km inland from the Parita Bay shoreline in a narrow coastal plain (Ranere and Hansell, 1978; Piperno et al., 2000). At this site, Late Preceramic cultigens included, in addition to maize, squash (*Cucurbita moschata)*, *lerén* (*Calathea allouia*), bottle gourd (*Lagenaria siceraria*), arrowroot (*Maranta arundinacea),* manioc *(Manihot esculenta*), and, possibly, an American yam (*Dioscorea sp.*) (Piperno, 2011a). These domesticates would have needed rain to germinate and sprout.

The multi-cultigen Late Preceramic agriculture in the lands bordering Parita Bay was enhanced by palms, such as the American oil palm (*Elaeis oleifera*), whose easily-collected and bunched orange-red fruits provide an oil, which would have afforded an important source of calories (see Fig. 2 e.). Carbonized remains of the American oil palm have only been identified at the Aguadulce Shelter among the Parita Bay sites, and they dominated the macrobotanical assemblage here during all periods, including the Late Preceramic (Dickau, 2010) – meriting the consideration that the intensive exploitation and processing of this palm's fruits was a major wet season activity at the Aguadulce Shelter (Cooke and Ranere, 1992b). Ecologically, this makes sense since the American oil palm forms large stands in poorly drained soils, which leave the palms under water during the rainiest periods. Such habitats surround the Aguadulce Shelter today. Carbonized parts of the fruits of *coyol* or wine palm (*Acrocomia aculeata*), whose fruits have an edible mesocarp, a hard oily kernel, edible hearts, and a sap used today for making palm wine (See Fig. 2 d.). Carbonized seeds of the fruits of the fire-resistant *nance* tree (*Byrsonima crassifolia*), which today is made into drinks and flavoured desserts, and would have provided an important source of vitamins in the past, were found under the shelter, too. Lastly, phytolith and pollen evidence shows that maize was used at the Cueva de los Ladrones rockshelter (LP-1) from the very bottom of its Late Preceramic occupation (7800–7630 cal yr BP) (Piperno et al., 1985; Piperno, 2011b). At this early stage of maize's evolution, of course, it would not have been as productive as varieties used at the later villages (Cooke, 1984: 283–286; Dickau, 2010: Table 2). At such an early stage of development, of course, maize would have been far less productive than varieties used at Panamanian villages until about 2300 cal yr BP (Galinat, 1980; Cooke, 1984:283–286). The discovery at El Gigante rockshelter, in Honduras, of robustly domesticated productive staple grain landraces with 10–14 rows, which were directly AMS-dated between 4340 and 4020 cal yr BP (Kennett et al., 2017), suggests that the timing of the appearance in the regional diet of productive staple maize landraces has not yet been identified on the isthmus of Panama.

Archaeologists who work in Panama have discussed whether Cerro Mangote was occupied preferentially during the dry season, and whether its temporary residents participated in a seasonal round, moving from site to site and changing subsistence activities as the optimality of resources varied seasonally (Piperno and Pearsall, 1998: 293; Cooke, 2005: 142). The question is whether the denizens of coastal sites such as late Preceramic Cerro Mangote (7800-5500 cal yr BP) and the Early Ceramic Monagrillo site (4500-3200 cal yr BP) would have preferentially fished during the dry months when this activity was purportedly more practical. But, there are multiple issues with this supposition. Artisanal fishing practiced today around Parita Bay does not offer a perfect analogy with pre-Spanish fishing practices since it relies mostly on dug-out and gunwaled canoes with outboard motors. Before the recent globalization of fishing practices in Panama, however, modern fisherfolk often preferred to stay in port during the dry season because of the strength of on-shore winds and the real dangers of capsizing. Falling into shallow waters in Parita Bay would have been dangerous in ancient times because of the threat caused by large in-shore sharks, such as hammerheads (*Sphyrna* spp.), tiger-shark (*Galeocerdo cuvier*) and bull-shark (*Carcharhinus leucas*) (Cooke et al., 2016). Estuary-loving American crocodiles (*Crocodylus acutus*) would have represented another genuine threat to life in those pre-firearm days. It is understandable why these afore-named marine animals were so prominent in the painted and modelled ceramic art of the Greater Coclé semiotic tradition, which materialized in the last five centuries BCE (Cooke, 2011), because, on a cognitive level, these animals would have required supernatural appeasement mediated by shamans (Cooke, 2004a; Cooke and Jiménez-Acosta, 2010).

At the time of the shell-bearing middens, in which our deer samples were laid down at Cerro Mangote, between 8000 and 5500 cal yr BP, fishing was bimodal, comprising a focus on fish taxa whose body masses averaged 0.7 kg weight, and were likely taken in mangrove channels and tidal rivers close by the site, and a second strategy concentrating on smaller fish, such as fat sleepers (Eleotridae: *Dormitator latifrons*), which became entrapped in desiccating *albina* pools when the rains stopped, when they could be easily have been caught by hand or with scoops (Cooke and Ranere, 1999). Fishing strategies around Parita Bay had changed, however, by 4500 cal yr BP (Cooke, 1992): thereafter, human consumption focused on small fish under about 200 g live weight, which move into estuarine waters in large shoals, and are most economically trapped with inter-tidal barrier tidal traps that do not require complex technology (Cooke and Tapia, 1994; Zohar and Cooke, 1997, 2019). Until the last decade, when globalization caused great changes in traditional fishing in Panama, a sizable proportion of catches around Parita Bay was salted and wind-and-sun dried, and then exported or carried to inland communities. In pre-Columbian times, salt would have been most economically obtained by scraping the salt-laden dried out surface of the *albinas* during dry periods, and then boiled down in clay vessels. Arguments have been made that the coast to interior movement of fish was prevalent in pre-Conquest times (Carvajal-Contreras et al., 2008) and it is substantiated by finds of the bones of small thread-herrings (Clupeidae: *Opisthonema libertate*), long-fin herrings (Pristigasteridae: *Ilisha fuerthii)* and croakers (Sciaenidae: *Ophioscion typicus*) in the Early Ceramic middens at the Cueva de los Ladrones rock-shelter, located 20 km inland (Cooke, 2001; Carvajal-Contreras et al., 2008).

Dry seasons at Cerro Mangote, then, would have *facilitated* both drying and salting fish, and collecting sleepers in *albina* pools, but that does not mean that fishing was ignored during the wet months. A dry season occupation of Cerro Mangote may also have coincided temporally with trapping over-wintering shore birds, e.g., whimbrel (*Numenius phaeopus*), willet (*Catoptrophorus semipalmatus*), and small calidrid sandpipers, as well as iguana-hunting by night in the mangroves (Cooke, personal observation in mangroves near Cerro Mangote). All these taxa were reported in the middens at Cerro Mangote (Cooke et al., 2007; Cooke et al., 2013b). But, there again, arguing for rigid seasonality in this case is counter-intuitive: exploiting birds and iguanas could have been practiced by people who stayed year-round at the site. In sum, dry and wet seasons favoured different subsistence activities at Cerro Mangote, and wet season occupation is substantiated by the mass collection of the mangrove crab (Gecarcinidae: *Cardisoma crassum*) (Ranere, 1979; McGimsey et al., 1986). This crab species is very abundant at the beginning of the wet season (late April–June), when vast numbers congregate at the landward edges of mangroves, where they can be trapped using collective methods (Bright, 1966).

Even though the maize planted at Cerro Mangote (Norr, 1995; Dickau, 2010; Piperno, 2011a) would not have yet attained the foliage density and kernel-size of later varieties, the large number of grinding implements in the kitchen midden (some with maize phytoliths incrusted on them) is consistent with constant maize use, and the existence of nearby fields (McGimsey, 1956; Ranere, 1979; Piperno, 2011a). It is well known that crops planted in fields or garden plots increase the deer population because deer prefer second-growth vegetation, and would thus have benefitted from the disturbance of primary forest cover for opening garden plots and fields (Smith, 1991; Teer, 1994; Geist, 2000; Gallina et al., 2010; Cherry et al., 2018). It is interesting to pointed out that even the palm fruit availability in the area our results do not evidence that deer consumed it.

Lastly, as an addendum, the fact that isotope data for intensive maize consumption at Cerro Mangote (Norr, 1995; Cooke et al., 1996: 114 Fig. 5), which is very similar to Sitio Sierra's, would appear to be at odds with the early maize that, we argue, would have been sown in Cerro Mangote's fields or garden plots, on-going evaluation of the burials at this site by Smith-Guzmán (personal communication, August 2019) is confirming that their calibrated [INTCAL 13] ^{14}C age spans the time period between 2475 BCE and 230 CE. Therefore, Norr's published isotope estimates for high maize consumption at Cerro Mangote should correspond temporally, not to the shell-bearing middens there, but to a time-span during when large-kernelled and multi-rowed productive races were likely being consumed.

At Cerro Juan Díaz, seasonality for deer hunting could not be evidenced from the microwear analysis. Two alternatives stand out: firstly, Cerro Juan Díaz represents a village occupied all year round, and secondly, inferring only wet season hunting is a sampling issue because we used samples from different excavation units or "operations," which could belong to dissimilar occupational events. This may explain their location on the boundary between area a. and b. on the heat map (Fig. 5). But the discovery at Cerro Juan Diaz of several funerary precincts spanning at least 1800 calendar years, some of which show evidence for discrete burial groups with connotations of kinship relationships and ancestor-worship (Cooke and Sánchez Herrera, 1997; Cooke et al., 1998, 2000; Díaz, 1999), argues strongly for long-term sedentary occupation.

6. Conclusion

Microwear and mesowear analyses address the issue of the times of year when deer hunting was practiced at three sites bordering Parita Bay in the strongly seasonal dry crescent of Pacific Panama: Cerro Mangote (AG-1), Cerro Juan Díaz (LS-3), and Sitio Sierra (AG-3). At two sites located in two different watersheds with markedly different calibrated radiocarbon ages, and very different population sizes – Cerro Mangote and Cerro Juan Díaz –, the tooth wear data infer that the ubiquitous white-tailed deer were likely hunted mostly during the wet season (May to November). On the contrary, results from Sitio Sierra show that white-tailed deer were hunted preferentially during the early dry season (December to April) when productive varieties of maize would have been nearing collection or already harvested, and rapidly consumed during seasonal festivities evinced by our taphonomic studies.

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6.2. Following white-tailed deer to the hilltop: A zooarchaeological and taphonomic analysis of deer hunting at Cerro Mangote, a Late Preceramic (7800-4600 cal yr BP) site in central Pacific Panama

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Following white-tailed deer to the hilltop: A zooarchaeological and taphonomic analysis of deer hunting at Cerro Mangote, a Late Preceramic (7800-4600 cal yr BP) site in central Pacific Panama

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ABSTRACT

The white-tailed deer (*Odocoileus virginianus* Zimmermann 1780) was an apex species for Precolumbian subsistence in the anthropogenic savannas and tropical dry forests bordering Parita Bay on the central Pacific coast of Panama. This paper focusses on Late Preceramic Cerro Mangote, a multi-component site whose domestic occupation corresponds to a maximum time-period of 7900 and 4600 cal BP. At this time, this site's inhabitants developed mixed subsistence strategies including farming and hunting, along with coastal fishing and invertebrate collection. Communities across the seasonally dry and windy plains and foothills of the central Pacific practiced swidden agriculture – a variety of plant food production that would have favored "garden hunting" (*sensu* Linares 1976), which, in this region, most likely involved white-tailed deer because of this species' acknowledged attraction to cultivated plots. Zooarchaeological and taphonomic analyses of white-tailed deer bone, tooth and antler samples from Cerro Mangote are based on two sequential Late Preceramic occupation layers. Results reveal that the same strategies for white-tailed deer hunting and for the treatment of their carcasses continued without change throughout the Late Preceramic period at Cerro Mangote.

1. Introduction

Human occupations in the Isthmus of Panama are well documented after ca 13,200 BP and are represented by both Clovis and Fluted Fishtail Point Paleoindian traditions. They continue without apparent hiatuses into post-contact time (Cooke and Ranere, 1992b; Cooke et al., 2013; Ranere and Cooke this issue). There is a hint of an earlier human presence in the Isthmus in the form of two fragmentary bifaces that resemble El Jobo points dated to ca 15,800 BP at the Venezuelan site of Taima-Taima (Bryan et al., 1978; Bryan et al., 1979; Cooke et al., 2013). This inference is indirectly backed up by mtDNA research based on present-day Panamanian populations (Perego et al., 2012). Hunting of megafauna by groups using Clovis points in North America and Fluted Fishtail Points in South America is well documented. A number of pre-Clovis (and pre-Fluted Fishtail) sites in South America also provide evidence for the hunting of megafauna, including Taima-Taima (Venezuela), Monte Verde (Chile), Huaca Prieta (Peru), Tibitó (Colombia), and Arroyo Seco-2 (Argentina) (Bryan et al., 1978; Correal, 1981; Casamiquela and Dillehay, 1989; Dillehay, 1997; Adovasio and Pedler, 2016; Politis et al., 2016). But coastal fishing and gathering were prominent subsistence activities at others pre-Clovis sites including Monte Verde (Chile) and Huaca Prieta (Peru) (Dillehay, 1997; Dillehay et al., 2017). Fishing, hunting and gathering continued along the Pacific coast of northern South America at the Los Vegas sites in Ecuador (Stothert, 1985; Stothert et al., 2003; Stahl and Stothert, 2020) and in the Nanchoc Valley in the foothills of northern Peru (Dillehay, 2011) along with the important addition of cultivating plants.

Although there are Late Pleistocene paleontological sites in Central Pacific Panama with megafauna, they are not associated with humans (Lucas, 2014) and may all date back to ca 47,000-45,000 BP (Pearson, 2005). Faunal remains were not preserved in any of the sites in Panama with deposits dated to either the Paleoindian period (ca 13,200-11,700 BP) or the Early Preceramic Period (ca 11,700-8200 BP). Archaeofaunal evidences are first found in the Panama archaeological sequence at sites

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dating to the first part of the Middle Holocene in middens with abundant marine invertebrate remains, or in relatively dry rockshelter deposits. An abundance of marine shell enhances the survival of other organic remains in the otherwise acidic soils typical of Panama's humid tropical climate (cf. Carvajal-Contreras et al., 2008). Cerro Mangote is one of the few Mid-Holocene sites that has yielded well-preserved faunal samples.

White-tailed deer (*Odocoileus virginianus* Zimmermann 1780) are one of the most abundant mammals at Late Preceramic Cerro Mangote and, when body mass is considered, are dietarily and culturally by far the most important. This species is widely distributed in North, Central and northern South America (Gallina et al., 2010). All Central and South American deer are of late Tertiary Nearctic origin, and this species is one of the largest surviving mammals in this region (Baker, 1984). It possesses an average body mass of 50 kg for males and 30 kg for females (Emmons, 1999). "Whitetails" are very adaptable animals being able to live in a wide range of habitats and environments, from deserts to tropical forests, due largely to their notably plastic diets. They prefer to focus their feeding on young leaves, but will consume grass, sedges, nuts, fungi, fruits, and fallen flowers. They also forage on several kinds of crops (Eisenberg, 1989; Smith, 1991; Gallina et al., 2010).

The archaeological, paleoecological and chronometric records for Central Pacific Panama indicate significant forest clearance by 9500 BP, likely for garden plots for growing arrowroot (*Maranta arundinacea*), leren (*Calathea allouia*), squash (*Cucurbita* spp.) and bottlegourd (*Lagenaria siceraria*) (Piperno et al., 1991; Piperno and Pearsall, 1998). These same records indicate an intensification of forest clearing by ca 7900 BP, which is believed to signal the introduction of swidden cultivation in the region (Piperno et al., 1991; Piperno and Jones, 2003; Piperno, 2011). Starch grains and phytoliths of maize (*Zea mays*) – an exogenous crop of northern (Mexican) origin – were recovered in the Aguadulce Shelter (Coclé province) at ca 7900 BP, and at Cueva de los Ladrones (Coclé) (where Preceramic maize pollen was also recovered) at ca 7700 BP (Piperno, 2011). Starch grains from manioc (*Manihot esculenta*) – a southern exogenous cultigen – was recovered in the Aguadulce Shelter at ca 7700 BP (Piperno, 2011).

Hunting is a subsistence strategy that impacts both the exploited animals' populations, and the communities in which the hunters lived (Ojasti, 2000). However, human impacts are not always negative, because people learn how to manage animal populations for their own benefit. A wild population of a given species can be managed in order to increase its numbers – if it is beneficial – or to decrease them – if it is harmful. Management also enables harvesting a given species on a regular basis, as well as monitoring the favorable and unfavorable behaviour it might present, such as suddenly moving elsewhere, or becoming too aggressive (Sinclair et al., 2006). The strategy of sustainable harvesting consists of culling an animal population at the same rate at which it increases under natural conditions (Sinclair et al., 2006), i.e., people need to apply hunting strategies that allow animals to be extracted without decreasing the population. Some examples of management are: (1) hunting a constant proportion of animals each year, (2) fixing a harvesting season, (3) establishing hunting areas, (4) focusing hunting on males rather than females, and (5) orienting hunts towards older rather than younger age groups (Sinclair et al., 2006).

An indirect practice for managing a wild animal population is simultaneously to manage its food sources (Ojasti, 2000; Sinclair et al., 2006). Linares (1976) proposed the concept of "garden hunting", which refers to the hunting and consumption of animals that are attracted to plants that grow in gardens. Feeding by animals on garden produce has two major effects: (1) animal populations increase more than under natural conditions, and (2) animals are easier to catch or hunt, for example, by using pit-falls and traps, which do not interfere directly with tending gardens.

The management of white-tailed deer was an important task for the human groups that inhabited communities located in the environs of Parita Bay (Cooke et al., 2007). Early 16th century CE colonial documents (1515–1550 CE) relate how white-tailed deer in the Central Pacific lowlands were managed *socially and ritually* through the establishment of special hunting grounds, and the imposition of strict taboos against eating "meat" (read: deer). This new method of ritually mediated management was arguably better suited to individual territories with social hierarchies typical of tropical chiefdoms, which are clear in the cultural archaeological record for Central Panama (Cooke, 2005).

The white-tailed deer is considered to be of Least Concern according to The IUCN (International Union for Conservation of Nature) Red List of Threatened Species. This publication adduces that the present-day status of this species is stable in light of its adaptability. This view is based primarily on the fact that this species increased considerably in North America during the last century. On the other hand, white-tailed deer populations in Central America and northern South America are small and in decline (Gallina and López Arévalo, 2016). Recently, archaeozoologists have become increasingly interested in applying their knowledge of past animal populations and their management to improving present-day management strategies (i.e Lyman, 2006, 2011; 2012; Bjorkman and Vellend, 2010; Faith, 2012; Rick and Lockwood, 2013; Faith and Lyman, 2016).

In the lowland plains of Coclé province white-tailed deer were still quite common in the early 1970s when RGC began his archaeological research there. But soon after rich citizens began hunting the deer using repeating rifles fired from double traction vehicles, and wild populations plummeted (RGC personal observation). Nowadays, however, white-tailed deer are being corralled, and at some properties in Coclé (i.e. near Aguadulce, not far from Cerro Mangote, and near Penonome), large numbers of whitetails are penned up and breeding. But these are commercial enterprises for selling deer meat and hides. It is highly doubtful whether knowledge of past human management practices is being applied, and it is open to investigation whether a proportion of the corralled populations is being released into the wild. Taking into account the importance of deer in Panama and the contributions that zooarchaeology can give to modern wild life managers, the aim of this paper is to describe deer hunting patterns at Cerro Mangote in order to identify hunting management strategies. To achieve so, we propose a multi-proxy zooarchaeological and taphonomical analysis.

2. Regional setting: Cerro Mangote

Cerro Mangote is located in Coclé province on the central Pacific coast of Panama (Fig. 1). A noteworthy variety of vertebrate remains and cultural materials, consisting mostly of lithics, was recovered there (McGimsey, 1956; Ranere, 1979; Cooke and Ranere, 1992a, 1992b). It is a Late Preceramic habitation site with a large midden component that contains abundant remains of marine invertebrate exoskeletons (mostly crab and mollusks). After its abandonment by the Late Preceramic residential occupants, Cerro Mangote continued being used as a burial ground for peoples using Early Ceramic and Middle Ceramic pottery wares (following the ceramic sequence of Greater Coclé [see Isaza Aizpurua, 2007]). These ceramic-using people likely resided at the Cerro Girón (Co-2/AG-2) site, which is located very close to the northern (Coclé) bank of the River Santa Maria (Ladd, 1964).

The nature of Cerro Mangote's location is relevant to understanding its Late Preceramic residence pattern: on top of a 48 m-high hill on the north bank of the Santa María River, at the inland edge of a high tidal flat, or "albinas" (now [2020] largely turned into commercial shrimp tanks). Inland from the hill, the present-day environment comprises sugarcane fields, cattle pastures, remnants of wooded savannas, and swamps and ox-bow lakes, which represent earlier undated meanders of the river (Cooke and Ranere, 1989: Fig. 1). Today the site's eastern edge is 8 km from the active marine shoreline of Parita Bay. However, sedimentation at the mouth of the Santa Maria River has moved the coastline seaward at a rate of nearly 1 km every thousand years (Barber, 1981; Clary et al., 1984), so that at the time Cerro Mangote was first

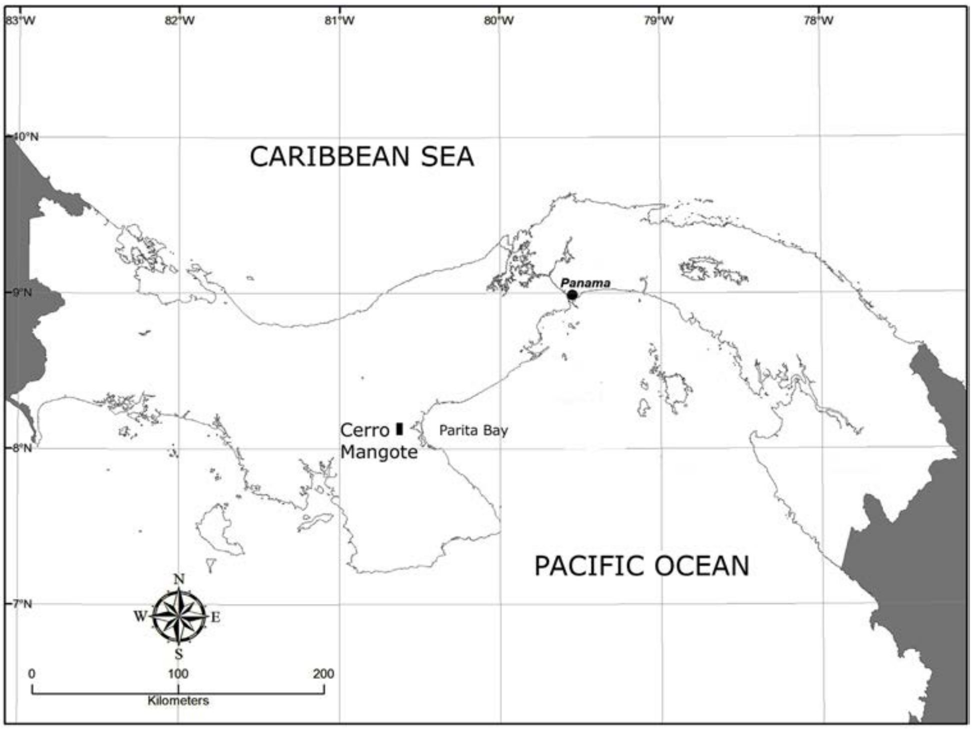

Fig. 1. Cerro Mangote geographical localization.

Table 1
Cerro Mangote dates (Ranere, 1979; Cooke and Ranere, 1992b). Dates in this paper are all calibrated with INTCAL 13 using marine 13 for calculating shell date.

Zone	Sample	Lab. Sample #	^{14}C date	Sigma	Cal BP
Red	Charcoal	Y-458d	6810	110	7845–7465
Brown	*Protothaca*	TEM-206/Beta-1703	6710	175	7964–7165
Brown	*Crassostrea*	TEM-208/Beta-1704	4650	165	5302–4437

occupied, the shoreline was only 1–2 km distant (Ranere, 1979; Cooke, 1984; Cooke and Ranere, 1992a, 1992b; 1999).

Archaeological remains are distributed in an area measuring 70 m (east-west) by 25 m (north-south) on the north slope of the ridge just below the crest. Two archaeological investigations were carried out, the first one, by McGimsey in 1955 and 1956, and the second one by Ranere in 1979 (McGimsey, 1956; Ranere, 1979; McGimsey et al., 1986; Cooke and Ranere, 1992b).

McGimsey's excavation strategy consisted of opening two trenches and four pits. The west trench was 6 m long and 1 m wide and the east trench was 8.5 m long and 1 m wide. The pit dimensions varied from 1 × 1 m to 2 × 2 m. Sterile red clay and rock were found at a depth of 180 cm in the south end of the site and 90 cm in the north end (McGimsey, 1956; McGimsey et al., 1986).

The objective of Ranere's excavations was to expose undisturbed deposits in two or three excavation units measuring 1 × 2 m in order to collect samples of flora, archaeofauna, charcoal, lithics, and other cultural materials in addition to the sediments themselves. Upon arrival at the site, Ranere and his crew discovered a number of large open looter's pits. These pits were cleaned out and their walls straightened in order to examine them for undisturbed deposits. In total, four units were excavated in 1979 measuring 1 × 3 m, 1 × 3 m, 1 × 2.5 m and 1 × 1.5 m. All undisturbed deposits were excavated with hand tools by natural strata divided into 10 cm excavation levels in strata thicker than 10 cm. All deposits were screened on site through ¼ inch mesh (6.35 mm). In a number of undisturbed 10 cm levels, ca 50 L of deposits were screened using 1/8 inch (3.175 mm) mesh. In addition, 15 L from each excavation level in two units were water sieved back in the field laboratory. Seven column samples of sediments from the excavations were also collected.

Ranere interpreted the stratigraphy of Cerro Mangote as having two major culture-bearing zones: the "red zone" (6810 ± 110 BP [7845–7465 cal BP]) and the "brown zone" (6670 ± 215 BP [7964-7165 cal BP] to 4650 ± 165 [5302-4437 cal BP]) (Table 1 and Fig. 2). During the red zone occupation, the intensity of human activities was not enough to change the natural character of the red clay sediments (Ranere, 1979; Cooke and Ranere, 1992b).

The most common artifact remains from Cerro Mangote are chipped stone tools and the flakes resulting from their manufacture. The flakes and cores from which they are struck are made of a variety of cryptocrystalline silicates, including petrified wood and, more rarely, quartz crystal and andesite. Flakes are removed from irregular cores and bifacial cores with hard hammerstone percussion. These flakes are then used for a variety of tasks, usually with no further modification. Where present, secondary retouch normally consists of steep unifacial flaking along the flake edge. Additional tools in the lithic assemblage include choppers, chopper-grinders, one-hand manos, edge ground cobbles, boulder milling stone bases, nutting stones, a fragment of cobblestone bowl, and a stone disc. An important feature of the stone tool

Fig. 2. Cerro Mangote stratigraphic profile, based on Ranere (1979). A description of the stratigraphy follows:
2.A layer of silt 10–15 cm thick caps the pit fill zone and represents the post-occupational deposit at the site.
3a.-3b. A series of horizontally bedded lenses composed in large part of shell, crab and bone, often heavily crushed, lies over the red silty clay layer. Known as the "brown zone", this is the densest occupational refuse on the site. This zone is not a single depositional unit, however, since the inhabitants constantly cut pits into each other, so that the upper 80–100 cm of the "brown zone" consists of pit fill of one sort or another.
4. A layer of light red silty clay, approximately 20 cm thick. overlies the red clay layer. Occupational debris is more abundant than in the previous layer.
5. A layer of red clay from 25 cm to over 100 cm thick overlies the andesite boulders. The base of this deposit is culturally sterile, but the upper portion contains the earliest cultural materials at the site.
6a.-6b. Andesite boulders underlie all sediments at the site; in places, these boulders are exposed on the surface, while in other areas they are buried by more than 2.5 m of deposits.

assemblage are "edge ground cobbles," e.g. hand-sized river cobbles that were used for pounding and grinding on their edges, rather than on the flatter areas of the tool (McGimsey, 1956; Ranere, 1975, 1979; Cooke and Ranere, 1992a). These tools are commonly found in Late Preceramic and Early Ceramic occupations at a large number of sites in Central Panama.

The zooarchaeological record of the site identified terrestrial taxa that customarily frequent mud flats, mangroves, riverine woods and open areas in the close vicinity of the site (Cooke et al., 2007). The most frequently taken mammals were raccoons (*Procyon lotor*) and white-tailed deer. Black and green iguanas (*Iguana* spp.) were also common in the site's middens. The best represented birds in them are coastal waders (Scolopacidae spp.) and white ibis (*Eudocimus* sp.) (Cooke et al., 2013). Estuary-tolerant taxa dominate the fish remains and include: marine catfish (Ariidae spp.), snook (*Centropomus* spp), corvinas (*Cynoscion* spp.), toadfish (*Batrachoides* spp.), and small-sized Pacific sleepers (*Dormitator latifrons*) (Cooke and Ranere, 1989, 1992a; 1992b, 1999).

Two particularly interesting zooarchaeological finds were reported at Cerro Mangote, one being the presence of the distal tips of two manatee ribs (*Trichechus manatus*). Manatees do not exist today on the Pacific coast of tropical America nor did they in the past. This fact demonstrates that these specimens were brought to the site from the Caribbean coast (Cooke and Ranere, 1992b). The second find is the oldest record for a domestic dog (*Canis lupus familiaris*) in Central America, represented by a humerus of a form that, subjectively, recalls a collie-like breed (Cooke and Ranere, 1992b).

McGimsey's team recovered 67 human individuals in the 1955 and 1956 excavations, and Ranere's team 12 individuals during the 1979 tests (McGimsey, 1956; Ranere, 1979; McGimsey et al., 1986). Nevertheless, associated artifacts and radiocarbon dates suggest that most of the human burials at the site likely postdate the Late Preceramic midden, perhaps by thousands of years (McGimsey et al., 1986:151; Huard, 2013: Table 2.2).

3. Materials and methods

3.1. Materials

McGimsey's work team in 1955 and 1956 did not use sieves. They gathered large vertebrate bones as they came across them while digging. In the 1970s, Ralph Medlock analyzed the abundant white-tailed deer sample and estimated an MNI of 41 individuals from 1189 bones (Cooke and Ranere, 1992b: Table 2). These materials were stored at the University of Arkansas and were returned to Panama in 2015. They are now housed in the Archaeology Laboratory of the Smithsonian Tropical Institute (STRI) in Panama City.

Ranere's excavation units were all sieved using ¼ inch (6.35 mm) mesh and selected units were kept back for sieving over 1/8 inch (3.175 mm) mesh. In addition, fifteen liters of sediment from undisturbed levels in units 1 and 2 were water sieved. These materials are also stored at the STRI Archaeology Laboratory.

For this study, we analyzed the white-tailed deer remains recovered during AJR's 1979 and McGimsey's 1955–1956 excavations organizing them by the red zone (n = 270) and brown zone (n = 1812). These remains were analyzed and identified by using a modern reference collection housed at STRI Archaeology Laboratory.

3.2. Methods

The units of quantification are used in zooarchaeology to estimate relative frequencies of taxa in the faunal assemblages. This way, it can study environmental fluctuations, successions, taphonomic, recovery and sampling biases and synchronic and diachronic cultural differences (Reitz and Wing, 2008).

Our zooarchaeological analysis employed several units of quantification:

1. Number of Remains (NR): This refers to the total number of remains that make up the zooarchaeological assemblage, without taking into account the degree of taxonomical and anatomical determination precision that was attained (Reitz and Wing, 2008).
2. Number of Identified Specimens (NISP): This index takes into account only the bone remains that were determined taxonomically. This index usually is less than the NR (Reitz and Wing, 2008).
3. Minimum Number of Elements (MNE): Lyman (1994: 290) defines MNE as the "Minimum number of complete skeletal elements necessary to account for all observed specimens". This index quantifies the elements belonging to an individual, whether they are whole or fragmented. For this quantification, it is necessary to take into

Table 2
Cerro Mangote white-tailed deer (*Odocoileus virginianus*), NISP (Number of Identified Specimens) and MNE (Minimal Number of elements).

Element	Red zone				Brown zone			
	NISP	NISP%	MNE	MNE%	NISP	NISP%	MNE	MNE%
Occipital	0	0.00	0	0.00	9	0.50	6	0.56
Basisphenoid	0	0.00	0	0.00	3	0.17	3	0.28
Presphenoid	1	0.37	1	0.65	1	0.06	1	0.09
Temporal	1	0.37	1	0.65	0	0.00	0	0.00
Frontal	0	0.00	0	0.00	8	0.44	6	0.56
Antler	12	4.44	8	5.23	36	1.99	20	1.87
Nasal	0	0.00	0	0.00	5	0.28	5	0.47
Premaxila	0	0.00	0	0.00	2	0.11	2	0.19
Maxilar	3	1.11	3	1.96	29	1.60	15	1.40
Tympanic bulla	0	0.00	0	0.00	5	0.28	5	0.47
Mandible	13	4.81	8	5.23	70	3.86	40	3.73
Incisive	0	0.00	0	0.00	1	0.06	1	0.09
Molar	2	0.74	2	1.31	8	0.44	8	0.75
Premolar	2	0.74	2	1.31	9	0.50	9	0.84
Atlas	1	0.37	1	0.65	21	1.16	19	1.77
Axis	1	0.37	1	0.65	14	0.77	14	1.31
Lumbar vertebrae	19	7.04	10	6.54	75	4.14	68	6.34
Thoracic vertebrae	9	3.33	7	4.58	74	4.08	70	6.53
Cervical vertebrae	5	1.85	5	3.27	76	4.19	70	6.53
Sacral vertebrae	2	0.74	2	1.31	4	0.22	3	0.28
Caudal vertebrae	0	0.00	0	0.00	2	0.11	1	0.09
Sternum	0	0.00	0	0.00	5	0.28	5	0.47
Ribs	17	6.30	10	6.54	114	6.29	97	9.05
Scapula	12	4.44	7	4.58	40	2.21	32	2.99
Humerus	17	6.30	11	7.19	90	4.97	72	6.72
Ulna	6	2.22	0	0.00	36	1.99	34	3.17
Radius	7	2.59	4	2.61	60	3.31	42	3.92
Trapezium	0	0.00	0	0.00	1	0.06	1	0.09
Uncinate	0	0.00	0	0.00	3	0.17	3	0.28
Lunate	1	0.37	1	0.65	1	0.06	1	0.09
Metacarpus	6	2.22	5	3.27	34	1.88	24	2.24
Rud. metacarpus	0	0.00	0	0.00	1	0.06	1	0.09
Acetabulum	0	0.00	0	0.00	7	0.39	7	0.65
Ileum	3	1.11	2	1.31	32	1.77	22	2.05
Ischium	2	0.74	2	1.31	28	1.55	20	1.87
Pubis	1	0.37	1	0.65	3	0.17	3	0.28
Pelvic girdle	2	0.74	2	1.31	3	0.17	3	0.28
Femur	23	8.52	15	9.80	121	6.68	66	6.16
Tibia	13	4.81	7	4.58	90	4.97	48	4.48
Patella	0	0.00	0	0.00	3	0.17	3	0.28
Metatarsus	8	2.96	7	4.58	86	4.75	52	4.85
Astragalus	8	2.96	8	5.23	64	3.53	64	5.97
Calcaneus	7	2.59	7	4.58	28	1.55	22	2.05
Cuboid	2	0.74	2	1.31	7	0.39	7	0.65
Cuneiform	1	0.37	1	0.65	3	0.17	3	0.28
Intern cuneiform	1	0.37	1	0.65	0	0.00	0	0.00
Perciform	0	0.00	0	0.00	2	0.11	2	0.19
Metapods	1	0.37	1	0.65	23	1.27	13	1.21
Phalanx prox.	6	2.22	6	3.92	35	1.93	35	3.26
Phalanx med.	2	0.74	2	1.31	13	0.72	13	1.21
Phalanx dist.	0	0.00	0	0.00	11	0.61	11	1.03
Craneum fragment	1	0.37			1	0.06		
Vertebrae fragment	5	1.85			23	1.27		
Long bone	44	16.30			390	21.52		
Flat bone	0	0.00			1	0.06		
Spongy bone	2	0.74			1	0.06		
Indeterminate	1	0.37			0	0.00		
TOTAL	270	100.00	153	100.00	1812	100.00	1072	100.00

account different variables of each identified bone fragment, such as the area of the bone, the face, its position in the skeleton, the number of times that it appears in the skeleton and its age.

4. Minimum Number of Individuals (MNI): This index defines the minimal number of animals that could be present in the assemblage. This index does not reflect the real abundance of the animals, and is only a guide to the minimum number of individuals present in the assemblage. In addition, this index does not imply that the animals were complete when the accumulation was formed. This index is calculated by summing the most frequent sided element taking into account laterality, age and size (Sensu White[MNI]; Reitz and Wing, 2008).
5. Minimum Anatomical Units (MAU): is obtained by dividing the number of elements identified by the number of anatomical units present in a complete skeleton. The norming procedure involves dividing all observed MAU values by the greatest observed MAU values and multiplying by 100 to scale the values between 0 and 100. Subsequently, the MAU% was compared against the utility index proposed for the white-tailed deer by Madrigal and Holt (2002) modification of the index proposed by Binford (1984) and the simplified index of Metcalfe and Jones (1988). For this purpose, the MAU of the long bones was obtained by dividing by two, the

phalanges dividing into eight, the cervical vertebrae dividing into five (excluding the atlas and the axis), the thoracic vertebrae dividing into twelve and the lumbar vertebrae into seven (Sauer, 1984; Madrigal and Holt, 2002).

The age at death of white-tailed deer was established by reference to epiphyseal fusion, tooth eruption sequence, and tooth wear. Two categories were used: sub-adults ($<$ 24 months) and adults ($>$ 24 months) (Severinghaus, 1949; Purdue, 1983). Taking into account that this species exhibits sexual dimorphism, we distinguished males when antlers were present (Smith, 1991).

Bone differential destruction may be influenced by its own characteristics, such as its density and also for the interaction and intensity of the external forces acting on the bone (Lyman, 1994). In order to determine sample integrity, MAU and its frequencies were calculated (Lyman, 2008), as well as the conservation differential in relation to bone density (VD). We used Lyman (1994) values averaged following Reitz and Wing (2008). We plotted volume density (VD) against NISP, and calculated a correlation coefficient (Pearson's r) between these variables. In order to study skeletal completeness, we compared archaeological bone frequencies with the expected frequencies if the deer skeleton was complete, applying the following equation:

$$d = (\mathrm{Ln}X)\text{-}(\mathrm{Ln}Y)$$

where X is the percentage of each skeletal portion and Y is the percentage of the same portion in a complete skeleton, both are standardized by using the natural logarithm (Ln). Positive values show that the skeletal portion is more abundant compared to the standard and negative values that show that the skeletal portions are underrepresented (Reitz and Wing, 2008).

The remains found in archaeological sites are characterized by the high degree of fragmentation, which could be caused by different taphonomic agents such as biological agents and/or physical processes (Fernández-Jalvo and Andrews, 2016). The inherent characteristics of the bone produce different break patterns when the bone is fresh or dry (Bunn, 1983; Villa and Mahieu, 1991). Fresh bones have a high degree of plasticity, but they could break when the pressure is greater than their strength. In these cases, the fracture follows the natural lines of the bone. The fractures are produced by biological agents when the bone is fresh, because their intention is to obtain the nutrients that are inside the bones (Bunn, 1983; Villa and Mahieu, 1991). The opposite case is the fragmentation of the dry bone, because the physical characteristics of the bone have changed, now the bone has lost its moisture and its organic properties, the bone is fragile and brittle. At this moment the bone reacts differently to pressure, forming perpendicular cracks. This kind of fragmentation is produced by physical processes without any intentionality (Bunn, 1983; Villa and Mahieu, 1991). To study long bone representation, we recorded the anatomical zone (proximal, medial, distal, whole) of the long bones (humerus, radius, femur, tibia, and metatarsal). The taphonomic analysis focused on bone breakage and surface alteration. In order to evaluate bone breakage, we distinguished color changes in the outlines and also fracture angle in order to discriminate an old breakage (occurring at or near the time of deposition) from a new breakage (occurring during or after the excavation) (Steadman et al., 2002).

Surface alterations were identified macroscopically and microscopically. All skeletal specimens were examined using a stereomicroscope (Leica Wild M10, up to 120x). The analysis of cut marks took into account the number of striations, location on the anatomical element, distribution over the surface (isolated, clustered and crossed), orientation with respect to the longitudinal axis of the bone (oblique, longitudinal and transverse) and delineation (straight or curved) (Binford, 1981; Potts and Shipman, 1981; Shipman and Rose, 1983). Six degrees of thermal damage were identified [from 0 (unburned) to 5 (calcined) and 6 when 2 burning colors were observed] using the criteria of Stiner et al. (1995).

Tooth marks were analyzed and compared systematically in order to distinguish between human and non-human marks (i.e. those made by carnivores, and rodents). Human tooth marks were classified as pits (ovoid shape and shallowness) and scores (elongated shape and internal crushing) (Landt, 2007). Carnivore and rodent marks were classified as pits, punctures and scores (Binford, 1981; Selvaggio, 1994). Other damage produced during consumption, such as notches, crenulated edges or pitting, was recorded; their distribution, orientation and dimensions were taken into account. Finally, post-depositional modifications were recorded, such as manganese, adhering concretions, root damage, and weathering probably commensurate with humidity (Grayson, 1988; López-González et al., 2006).

In order to identify the differences between the two occupations (red zone and brown zone), a *t-test* was performed in cases where all assumptions were accepted or the *Mann Whitney* test when the assumptions were not met.

4. Results

The white-tailed deer remains recovered at Cerro Mangote during Ranere's 1979 excavations and McGimsey's 1955–1956 excavations, and studied for this analysis, numbered 2082 of which 270 were found in the red zone and 1812 in the brown zone (Table 2). The Late Preceramic inhabitants of Cerro Mangote used a single strategy for exploiting and managing white-tailed deer during the red zone and brown zone occupations. A total of 45 individuals was identified, all of them were adults and at least 14 were males (Table 3). None of the innominate specimens were suitable for sexing, so the only criterion available was the presence or absence of antler pedicles. We identified 3 individuals with unfused antler pedicles and 11 with antlers attached. There are very few cranial bones in the collection. The overrepresentation of antlers could reflect the selective retention of frontal/antler pieces by the ancient inhabitants of the site. For this reason, it is possible that the sex ratio of the deer population is not reflected in the archaeological collection. Differences between the NISP% of the brown and the red zone were not significant ($z = -0.497$; $p = 0.618$) and the MNE% ($z = -0.682$; $p = 0.494$).

Volume density (VD) results shows an insignificant negative correlation between NISP and VD in the red zone ($rp = -0.26$, $p = 0.20$) and brown zone ($rp = -0.34$, $p = 0.09$) (Fig. 3). This results suggest that the taphonomical process that is mediated by the structural density of the skeletal parts did not exert a major influence on the frequencies of skeletal parts in the Cerro Mangote deer samples. The anatomical representation in both edaphic zones shows that whole deer were taken up to the dwellings. They continued to consume the same kinds of fish as well, and the fact that they took quite large fish 50 m up to the hill top makes it likely that their dwellings were there (Cooke and Ranere, 1999).

The highest MAU% values in the red zone were for the femur

Table 3
Cerro Mangote white-tailed deer (*Odocoileus virginianus*), NISP (Number of Identified Specimens) and MNI (Minimal Number of Individuals) by age categories and sex ratio.

Zone			
	Red	Brown	Total
NISP	270	1812	2082
NISP %	12.97	87.03	100
MNI	9	36	45
MNI%	20	80	100
Sub-adults	0	0	0
Adults	9	36	45
Males	3	11	14
Males %	33.33	30.56	100

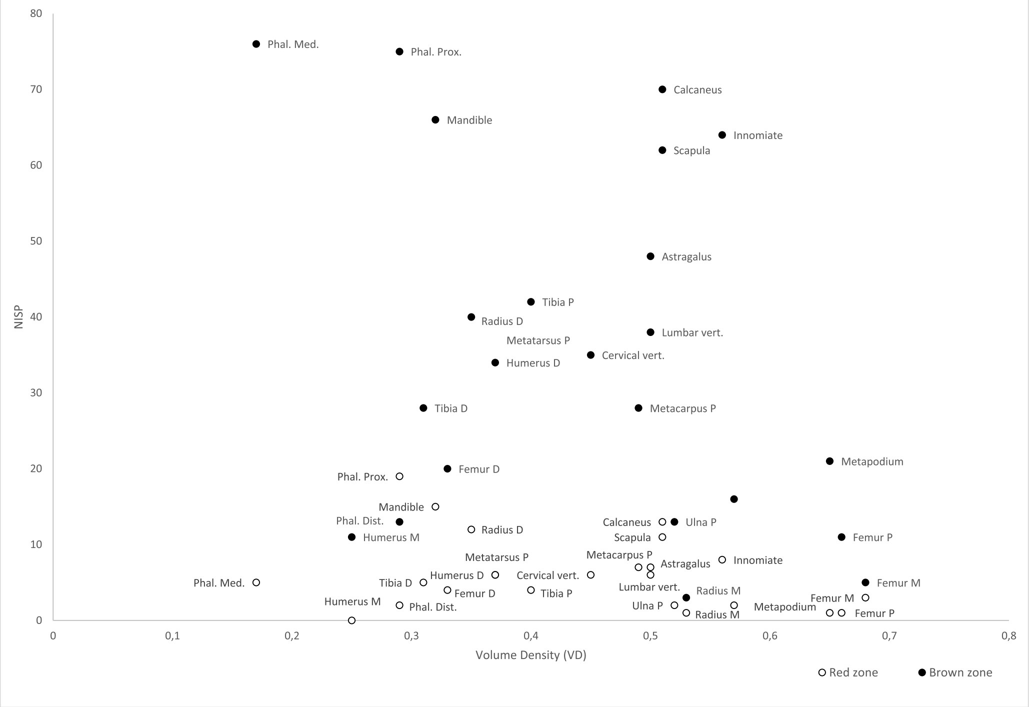

Fig. 3. NISP (Number of Identified Specimens) against VD (Volume density) values of white-tailed deer (*Odocoileus virginianus*) identified at Cerro Mangote.

followed by the humerus, and in the brown zone the highest MAU% values were for the humerus followed by the femur (Table 4). There are no significant differences in the MAU% between the brown and red zones ($z = -1.329$; $p = 0.183$). According to these results consumers preferred the meatiest elements (Madrigal and Holt, 2002). At Cerro Mangote, the forefoot and the foot were under-represented, however the hindfoot is well represented in both zone samples (Fig. 4). The *t-test* suggests that there are not significant differences between the two occupations ($t = 0.006$; $p = 0.995$). This pattern may be related to working deer skins because foot elements generally remain attached to them. Besides, their nutritive value is poor (Madrigal and Holt, 2002). Alternatively, domestic dogs, which we know were present at the site (Cooke and Ranere, 1992b), may have consumed or run off with them, because we do not find any evidence of carnivores in the deer bone analyzed, indicating no evidence for in situ ravaging by dogs.

In terms of long bone representation, 555 remains were long bones (26.65%), and the most represented zone was the distal, followed by the proximal, and lastly the medial. At Cerro Mangote no complete long bones were found. The length of the deer remains varies between 10 and 80 mm (Fig. 5). There are no significant differences between the two occupations ($z = -0.04$; $p = 0.96$). 257 (12.34%) deer remains show the characteristic fracture pattern of fresh breakage. Percussion marks were observed in 160 (62.25%) elements. Also identified were: percussion cones (n = 43; 16.73%), negative cortical flakes (n = 17; 6.61%) and medular flakes (n = 43; 16.73%) (Fig. 6:c.). The absence of complete elements and the fresh fracture patterns observed in the samples from both occupation zones suggest that the ancient inhabitants of Cerro Mangote took advantage of deer bone marrow.

Anthropic modifications were identified in 434 remains (20.84%), and most of them were fractures (12.34%), burning damage (6.62%) and cut marks (1.72%) (Table 5). Only 66 cut marks were identified in 36 elements representing 1.72% of the total sample. Most of them were found in the brown zone. These marks are fairly superficial and have 1) straight incisions (69.70%), 2) superficial scraping (25.76%) and 3) deeper hack marks (4.55%). The position of the cut marks infers 1) defleshing (63.41%), 2) skinning (29.27%), and 3) disarticulation (7.32%) (Fig. 6:a.). The cut marks identified are related to all processes of deer preparation and consumption, (i.e., defleshing, skinning and disarticulation); but the great majority of marks is related to defleshing (Table 6). Cooked meat was consumed to judge from the patterns of burning discoloration identified in some elements. 138 (6.62%) elements show thermal alteration. Color grade 2 and 3 were the most frequent (Fig. 6:d.). Ribs were peeled clean with the teeth (Fig. 6 b.), as we identified in three elements with cortex loss (0.14%) (see Table 5). Post-depositional modifications were identified in 686 remains (32.94%), the most prevalent being concretions (31.65%) followed by root damage (0.72%), manganese stains (0.48%), and rodent gnawing (0.09%) (Table 7).

5. Discussion

We have interpreted Late Preceramic Cerro Mangote as a site where small groups lived in order to farm, hunt, fish, and collect shellfish and crabs in mangrove channels, along the marine shore, and in tide pools. Similar sites were scattered over the landscape of lowland central Pacific Panama (Cooke and Ranere, 1992a). The variability of white-tailed deer diet — evinced by tooth wear at the moment they were hunted -– points towards their wet season feeding (Martínez-Polanco et al., 2019). This makes sense in a garden hunting scenario because maize and manioc planted nearby would have been tender and leafy in the wet season. Collecting the most frequent crab species – the mouthless crab (*Cardisoma crassum*) – would have occurred

Table 4
MNE (Minimal Number of Elements), MAU (Minimal Animal Units), MAU% of White-tailed deer (*Odocoileus virginianus*) from Cerro Mangote. Occ.: Occurrence.

Element	Red zone				Brown zone			
	MNE	OCC.	MAU	MAU%	MNE	OCC.	MAU	MAU%
Mandible	8	2	4.00	53.33	40	2	20.00	55.56
Maxilar	3	2	1.50	20.00	15	2	7.50	20.83
Atlas	1	1	1.00	13.33	19	1	19.00	52.78
Axis	1	1	1.00	13.33	14	1	14.00	38.89
Lumbar vertebrae	10	7	1.43	19.05	68	7	9.71	26.98
Thoracic vertebrae	7	12	0.58	7.78	70	12	5.83	16.20
Cervical vertebrae	5	5	1.00	13.33	70	5	14.00	38.89
Ribs	10	26	0.38	5.13	97	26	3.73	10.36
Scapula	7	2	3.50	46.67	32	2	16.00	44.44
Humerus	11	2	5.50	73.33	72	2	36.00	100.00
Ulna	0	2	0.00	0.00	34	2	17.00	47.22
Radius	4	2	2.00	26.67	42	2	21.00	58.33
Trapezium	0	2	0.00	0.00	1	2	0.50	1.39
Uncinate	0	2	0.00	0.00	3	2	1.50	4.17
Lunate	1	2	0.50	6.67	1	2	0.50	1.39
Metacarpus	5	2	2.50	33.33	24	2	12.00	33.33
Acetabulum	0	2	0.00	0.00	7	2	3.50	9.72
Ileum	2	2	1.00	13.33	22	2	11.00	30.56
Ischium	2	2	1.00	13.33	20	2	10.00	27.78
Pubis	1	2	0.50	6.67	3	2	1.50	4.17
Femur	15	2	7.50	100.00	66	2	33.00	91.67
Tibia	7	2	3.50	46.67	48	2	24.00	66.67
Patella	0	2	0.00	0.00	3	2	1.50	4.17
Metatarsus	7	2	3.50	46.67	52	2	26.00	72.22
Astragalus	8	2	4.00	53.33	64	2	32.00	88.89
Calcaneus	7	2	3.50	46.67	22	2	11.00	30.56
Cuboid	2	2	1.00	13.33	7	2	3.50	9.72
Cuneiform	1	2	0.50	6.67	3	2	1.50	4.17
Intern cuneiform	1	2	0.50	6.67	0	2	0.00	0.00
Perciform	0	2	0.00	0.00	2	2	1.00	2.78
Phalanx prox.	6	8	0.75	10.00	35	8	4.38	12.15
Phalanx med.	2	8	0.25	3.33	13	8	1.63	4.51
Phalanx dist.	0	8	0.00	0.00	11	8	1.38	3.82

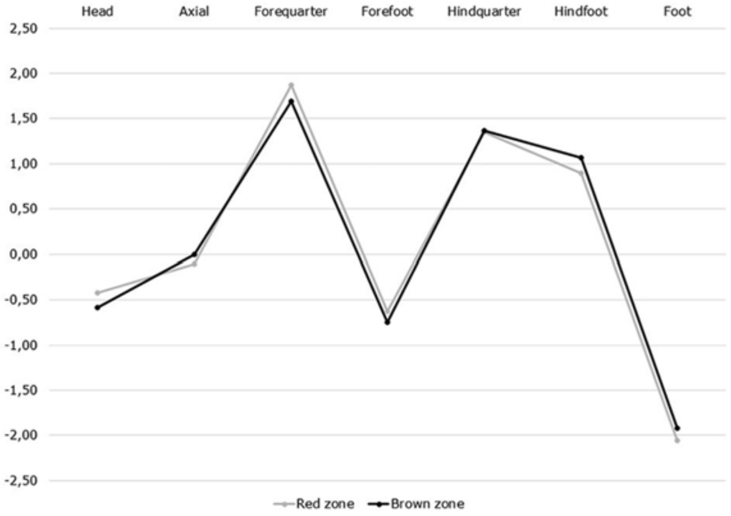

Fig. 4. Ratio diagram of skeletal portions using NISP (Number of Identified Specimens) of white-tailed deer (*Odocoileus virginianus*) identified at Cerro Mangote.

preferentially in the early wet season (May–June) at the time when massive nuptial displays make it easier to harvest large numbers. Wading birds (Scolopacidae) identified at Cerro Mangote to species or species pairs are all migratory in central Pacific Panama and are most widespread in the dry months, i.e, western or semipalmated sandpipers (*Calidris mauri* and *C. pusillus*), knot (*Calidris canutus*), willet (*Tringa semipalmata*), and whimbrel (*Numenius phaeopus*) although all these species occur in smaller numbers in the wet season. Black and green iguanas, osprey (*Pandion haliaetus*), great egrets (*Ardea alba*), yellow-lored parrots (*Amazona ochrocephala*), and the doves that could be

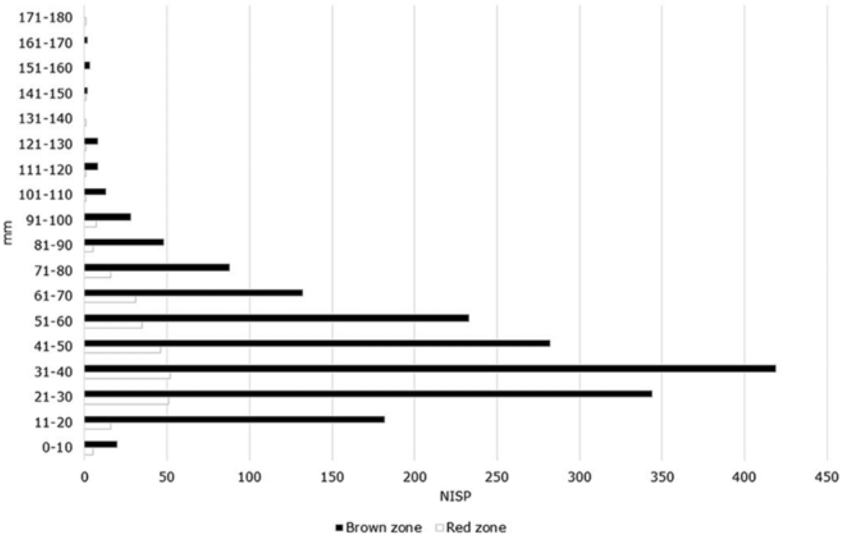

Fig. 5. Longitude of the archaeological white-tailed deer (*Odocoileus virginianus*) fragments measures taken in millimeters at Cerro Mangote.

identified to genus or species are present year-round.

Two factors suggest that Cerro Mangote experienced year-round occupations, especially during the brown zone episode: 1) the presence of manatee bone from the Caribbean, which points to established coast-to-coast trade routes and hints at crafting on the site (taking into consideration the appropriateness of manatee ribs for this activity (Cooke and Jiménez-Acosta, 2010), and 2) the fact that animal food was continually carried up to the top of the hill where the houses would have been.

The analyzed data point towards the management of white-tailed deer populations, which allowed a stable and sustained harvest during the maximum Cerro Mangote Late Preceramic occupation (7900-4600 BP) although improved dating precision will probably narrow this estimate. The management consisted principally of emphasizing the hunting of adults. This strategy enabled younger animals of reproductive age to breed while the mature adults had already fulfilled their reproductive purpose. In the archaeological record of Sabana de Bogota, Colombia, the same strategy has been observed at a ca 3000-year occupation at Aguazuque (5025 ± 40 BP [5895-5660 cal BP] to 2725 ± 35 BP [2880-2760 cal BP], where both adult female and male deer were hunted (Martínez-Polanco et al., 2015). This strategy is used today for managing white-tailed deer populations in North America (Jensen, 1996; Campbell et al., 2005). The zooarchaeological and taphonomical study of deer at Sitio Sierra (AG-3) – a large village located in the alluvial bottomlands of the Santa María river and occupied between about 2200 and 500 B.P. – shows evidence for different deer hunting patterns. In a sample of 38 individuals, 22 were sub-adults (58%) and 16 were adults (42%). At Sitio Sierra deer were used as the main course during feastings. Taking into account that the presence of young animals is a characteristic feature of feasting behavior, the meat of young individuals was preferred over adult meat (Martínez-Polanco and Cooke, 2019). At Sitio Sierra deer management was socially controlled, being proscribed periodically for prestigious members of the community (perhaps warriors) in order to protect deer stocks, and thus ensure sufficient carcasses for periodic feasts (Cooke and Ranere, 1989; Cooke, 1992).

Cultivation of crops near the settlement would have favored deer population density, taking into account that deer prefer second-growth vegetation enabled by the anthropogenic disturbance of primary forest cover by the expansion of agricultural fields (cf. Smith, 1991; Gallina et al., 2010; Cherry et al., 2018). Animals that approached the crops were targeted in the manner of garden hunting described by Linares (1976). At Cerro Mangote, such a hunting strategy in which no fawns or young were killed thus ensured that these animals reached adulthood and reproduced, guaranteeing a stable and long-term top-rank meat supply. The proximity of large salt flats in the *albinas* would have facilitated the storage of dried and salted carcasses. That this strategy was successful, is demonstrated by the fact that large white-tailed deer populations survived in the wooded savannas of central Pacific Panama until the Spanish conquest (Cooke et al., 2007, 2008), both of which reference the important eye-witness accounts of Spanish soldiers Pascual de Andagoya and Gaspar de Espinosa who belonged to governor Pedrarias Davila's first expeditions westwards and then south over the Central Cordillera from Santa Maria la Antigua and later Panama City. These soldiers had to live off the land or commandeer food from local leaders. White-deer populations held on during the Republica eras until recently when motorized hunting with powerful firearms led to a dramatic crash. But these deer are increasingly being penned up for provisioning restaurants and wealthy homes, and it is hoped that a release-to-the-wild protocol will soon be implanted by conservationists.

Cerro Mangote was not the only Late Preceramic site in the lowlands and foothills of the dry central Pacific coast to practice deer hunting. At Aguadulce Shelter, phytolith and starch grain evidence dates plant cultivation to ca 8600-7700 BP that includes a wider range of cultigens than currently reported at Cerro Mangote: leren, arrowroot, squash (*Cucurbita moschata*) and bottle gourd (Piperno et al., 2000; Piperno, 2009, 2011). Once again, the presence of crops would have increase the deer population, because it has been observed that deer prefer second-growth vegetation and would thus thrived through the disturbance of primary forest cover by the expansion of agricultural fields (Smith, 1991; Gallina et al., 2010; Cherry et al., 2018).

6. Conclusion

The white-tailed deer was dietarily and culturally by far the most important mammal at Late Preceramic Cerro Mangote between ca 7900

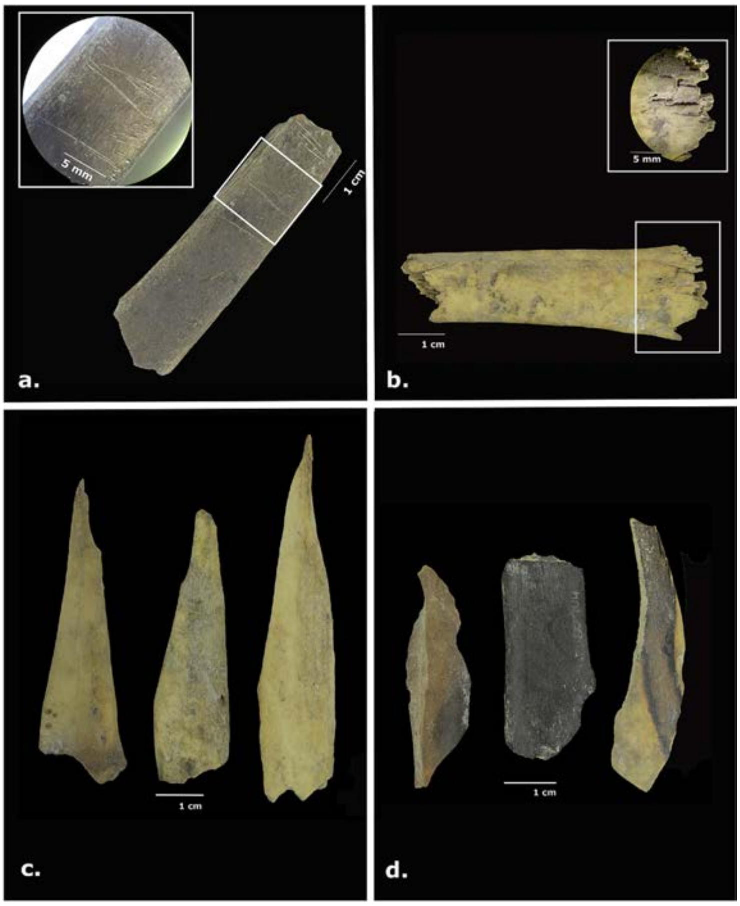

Fig. 6. Examples of anthropic modifications identified on White-tailed deer (*Odocoileus virginianus*) bones at Cerro Mangote. a. Cut marks in a rib; b. peeling in a rib; c. medular flakes; d. different burning colorations.

Table 5
Anthropic modifications to white-tailed deer (*Odocoileus virginianus*) bones at Cerro Mangote.NR: Number of remains.

Zone	Cut marks		Burning damage		Fractures		Bite marks		NISP
	NR	%NR	NR	%NR	NR	%NR	NR	%NR	
Red	6	16.67	21	15.22	20	7.78	1	33.33	48
Brown	30	83.33	117	84.78	237	92.22	2	66.67	386
Total	36	100.00	138	100.00	257	100.00	3	100.00	434

and 4600 BP, as it was at all sites with archaeofaunas that have been studied in the ancient anthropogenic savannas and dry forests of central Pacific Panama. This is predictable since disturbance of primary dry forest cover by the expansion of agricultural fields and their crops is well known to have been beneficial to white-tailed deer populations The fact that the manner of deer exploitation followed the same pattern in the two occupations identified at the site (one less intense [red zone], and the other more intense [brown zone]) indicates that a social group with the same traditions occupied the site throughout the Late Preceramic (although much more refined AMS radiocarbon dating with multiple samples is required to narrow down the time span). This is not at all surprising in a region where multiple lines of evidence have stressed strong population and cultural continuity since the early Holocene or even earlier. Detailed taphonomic evidence demonstrated that the Cerro Mangote hunters were managing deer populations in a more positive way (by preferentially culling adults) than in later ceramic-using periods when larger regional populations and more densely occupied villages likely exerted growing pressure on the environment, making earlier adult-focused conservationist strategies more difficult to maintain. Besides in these villages another kind of management came to the fore: the control of access to deer hunting by certain privileged persons of the community and at certain moments of the year.

Declaration of competing interest

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest

Table 6
Description of cut marks identified on White-tailed deer (*Odocoileus virginianus*) bones at Cerro Mangote. Trans: transversal; Obl: oblique; Long: longitudinal; Ant: anterior; Post: posterior; Lat: lateral; Prox: Proximal; Med: medial; Dist: distal; Sup: superficial. Maximum length taken in millimeters.

Zone	Element	Nº	Type	Orientation	Location		Distribution		Delineation	Measures	Action performed
Red	Ulna	1	Incision	Obl.	Post.	Prox.	Straight	Isolated	Deep	9	Defleshing
	Rib	11	Scraping (3)- incision (8)	Obl.	Ant.		Straight	Isolated	Sup.	6.62	Defleshing
	Rib	1	Incision	Trans.			Straight	Isolated	Sup.	8	Defleshing
	Long bone	4	Incision	Obl.			Sinuous	Isolated	Deep	5	
	Long bone	2	Incision	Obl.			Straight	Isolated	Sup.	1.25	
	Long bone	5	Scraping (3)- incision (2)	Obl.			Str.-Sin.	Isolated	Sup.	1.5	
Brown	Antler	1	Scraping	Obl.	Ant.	Dist.	Straight	Isolated	Sup.	6	Skinning
	Antler	3	Incision	Trans.	Ant.	Prox.	Straight	Parallels	Deep	10	Skinning
	Ulna	1	Incision	Trans.	Ant.	Prox.	Straight	Isolated	Sup.	4	Defleshing
	Ulna	1	Scraping	Obl.	Lat.	Prox.	Straight	Isolated	Sup.	6	Defleshing
	Humerus	2	Incision	Obl.	Post.	Dist.	Straight	Isolated	Deep	4.5	Defleshing
	Humerus	1	Incision	Trans.	Ant.	Dist.	Straight	Isolated	Sup.	5	Defleshing
	Metacarpus	1	Incision	Obl.	Post.	Med.	Straight	Isolated	Deep	4	Skinning
	Cervical vertebrae	1	Hack mark	Trans.			Straight	Isolated	Deep	3	Disarticulation
	Lumbar vertebrae	1	Incision	Trans.			Straight	Isolated	Sup.	14	Defleshing
	Pubis	1	Scraping	Obl.	Post.	Med.	Straight	Isolated	Sup.	1.5	Defleshing
	Femur	1	Incision	Obl.	Post.	Med.	Straight	Isolated	Sup.	1	Defleshing
	Femur	1	Scraping	Obl.	Post.	Med.	Straight	Isolated	Sup.	4.5	Defleshing
	Femur	3	Incision	Trans.	Post.	Med.	Straight	Isolated	Deep	4	Defleshing
	Astragalus	1	Incision	Obl.			Straight	Isolated	Deep	2	Defleshing
	Metatarsus	1	Scraping	Long.	Post.	Med.	Straight	Isolated	Sup.	1.5	Skinning
	Metatarsus	2	Incision	Obl.	Lat.	Dist.	Straight	Isolated	Deep	3.25	Skinning
	Metatarsus	2	Hack mark	Trans.	Lat.	Prox.	Straight	Isolated	Deep	1	Disarticulation
	Metatarsus	2	Incision	Trans.	Lat.	Dist.	Straight	Isolated	Deep	2.5	Skinning
	Phalanx prox.	1	Incision	Obl.	Post.	Med.	Straight	Isolated	Sup.	4.4	Skinning
	Phalanx prox.	1	Incision	Trans.	Ant.	Med.	Straight	Isolated	Sup.	1	Skinning
	Long bone	4	Scraping	Obl.			Straight	Isolated	Sup.	1.25	
	Long bone	1	Incision	Trans.			Straight	Isolated	Deep	6	
	Long bone	1	Scraping	Trans.			Straight	Isolated	Sup.	2	
	Long bone	1	Incision	Obl.			Straight	Isolated	Sup.	10	
	Long bone	1	Incision	Obl.			Sinuous	Isolated	Sup.	4	
	Long bone	1	Incision	Obl.			Straight	Isolated	Sup.	5	
	Long bone	1	Incision	Obl.			Straight	Isolated	Deep	7.68	
	Long bone	1	Incision	Obl.			Straight	Isolated	Sup.	2.8	
	Long bone	1	Scraping	Obl.			Straight	Isolated	Sup.	2.5	
	Long bone	2	Incision	Obl.			Straight	Isolated	Sup.	4.5	

Table 7
Post-depositional modifications identified on White-tailed deer (Odocoileus virginianus) bones at Cerro Mangote.

Zone	Rodent damage		Concretion		Root damage		Manganese		NISP
	NR	%NR	NR	%NR	NR	%NR	NR	%NR	
Red	1	0.37	76	28.15	4	1.48	2	0.74	270
Brown	1	0.06	583	32.17	11	0.61	8	0.44	1812

(such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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6.3. Zooarchaeological and taphonomical study of the white-tailed deer (Cervidae: Odocoileus virginianus Zimmerman 1780) at Sitio Sierra, a pre-Columbian village in Pacific Coclé province, Panama, with an evaluation of its role in feasts

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Abstract
The white-tailed deer (Cervidae: *Odocoileus virginianus*) was the most widespread sizeable mammal in the ancient anthropogenic savannahs of the Pacific watershed of Panama. This cursorial, browsing and gregarious species was not only a major component of human diet for several thousand pre-contact years but also an iconic mammal imbued with polysemic symbolism. Deer were the most frequently consumed mammal in most pre-Columbian refuse deposits, and deer bones and antlers were used to fashion several kinds of implements. Spanish eye-witness chroniclers of the years of conquest (1515–1550 CE) refer to cultural proscriptions against eating mammal meat by certain groups in the chiefdoms that bordered Parita Bay on the Pacific coast. Spanish soldiers extolled larders replete with dried and salted deer carcasses. This situation alludes to periodic "feasts", which are considered to be an important mechanism for enhancing social relations and for cementing alliances. We argue that feasting behaviour is identifiable at Sitio Sierra (AG-3), a large village located in the alluvial bottomlands of Coclé province near a major river (Santa María) and occupied between about 2200 and 500 cal yr. B.P. The representation of all deer body parts in some refuse piles at this site—including complete and articulated remains—is predicted correlate of rapid and mass consumption typical of feasting. Deer body parts with high meat values predominate. Young animals were consumed. Most of the observed cut marks on deer bones represent de-fleshing. There is little evidence for rodents' gnawing the bones and no evidence of carnivore gnawing. The zooarchaeological data are corroborated by data on ceramic vessels and by physical signs of cooking at the site.

Keywords *Odocoileus virginianus* · Cervidae · Feasts · Farming village · Social differentiation

Introduction

The white-tailed deer (*Odocoileus virginianus* Zimmermann 1780) is the largest of three deer species found today in Central America (Guatemala, Belize, El Salvador, Honduras, Costa Rica and Panama). It is (1) ecologically protean residing in deserts, savannahs, prairies, mountains and deciduous and tropical forests, (2) able to adapt well to agricultural landscapes, (3) trophically plastic and (4) an opportunistic feeder (Eisenberg 1989; Smith 1991; Teer 1994). It favours browsing on shrubs and trees but will feed on grass, sedges, nuts, fungi, fruits and fallen flowers (Eisenberg 1989; Gallina et al. 2010; Smith 1991). It is one of the largest extant mammals in the Neotropics, where body mass averages 50 kg for males and 30 kg for females (Emmons 1999).

The white-tailed deer played an important role in pre-Columbian intellectual systems. The Maya linked this species to agriculture, the sun, rain, the cyclical nature of time and fecundity and prosperity (Brown 2001; Pohl 1981). The Maya managed deer populations in order to ensure an adequate meat supply for feasting. They achieved this by preferentially hunting young adults, in order to guarantee

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reproductive success (Carr 1996; Masson 1999). Another kind of Maya management entailed the elite control of forests that were frequented by deer as a conservation strategy. It is known, too, that the Maya kept deer in captivity, taming and corn-feeding them (Carr 1996; Masson 1999; Masson and Peraza Lope 2008; Montero-Lopez 2012, 2009; Thornton 2011). Some contemporary Mexican First American groups, such as the Mayos and Yaquis in Sonora and the Tzotziles in Chiapas, still incorporate white-tailed deer into their rituals and feasts (Montolíu 1976; Viñas Vallverdú and Sánchez del Tagle 2000; Moctezuma 2007; Moctezuma and López Aceves 2007).

The white-tailed deer was important to pre-Columbian communities in the ancient anthropogenic savannahs of central Panama, not only as a food resource but also as symbols of standard cosmological spaces (Cooke 2005). Deer antlers and bones were commonly employed for making artefacts and ornaments (Cooke 2004a). Cooke and Ranere (1989) and Cooke (1992) inferred—on the basis of early sixteenth century CE chronicles—that deer hunting in the lowlands bordering Parita Bay was socially controlled, being proscribed periodically for prestigious members of the community (perhaps warriors) in order to protect deer stocks, and thus ensure sufficient carcasses for periodic feasts. Large quantities of dried and salted deer carcasses ("venado en cecina" is the Spanish-language term) were deposited in special store-houses in the village of Natá in the chiefdom controlled by a descent group of the same name.

Feasts and feasting: some general comments

Feasting is customarily considered by New World archaeologists to be a primary behavioural correlate of elites in pre-European chiefdom-level societies. However, feast occurs at every level of socioeconomic complexity, in egalitarian, transegalitarian, chiefly and state societies, although they play different roles (Hayden 2001; Russo 2004). Feasting is of greatest importance in transegalitarian groups (groups between egalitarian foragers and complex chiefdoms), because in these groups feasts provide a platform for advertising and consolidating the authority that comes from prestige at social gatherings (Rusell 2012). The universal ethnographic record shows that other social typologies, such as "tribal" societies in the tropical landscapes of New Guinea and New Ireland, indulge in this widespread cultural pattern, frequently in the context of ancestor veneration (e.g. Rappaport 1984; Bolyanatz 2000). In the archaeological record of the Southeast of the United States (South Carolina, Georgia and Florida) circular to U-shaped accumulations of oyster shell or rings of other shells (between 50 and 250 m in diameter) were recorded during the late Archaic (5000–3000 B.P.). These special features imply considerable organizational effort and draw attention to the fact that feasts play an important role in the egalitarian fisher/hunter communities of Late Archaic coastal societies (Russo 2004; Thompson et al. 2011).

In today's Panama, feasting is a traditional component of a complex ritual game spread over several days, which was—and occasionally still is—practiced by the populous First American cultural group, the Ngäbe, who traditionally live in small communities based on descent groups, which are scattered across mostly broken terrain. Proponents of the *balsería* or *krun* (the name of the game in Spanish and Ngäbére) must ensure a prodigious amount of plant foods—maize (*Zea mays*) (on the Pacific) and peach palm (*Bactris gasipaes*) (on the Caribbean)—in order to provide sufficient fermented beverages made of one or other of these plants for the invitees (Young 1976).

Brian Hayden (2001: 28) minimally defines a feast as any sharing between two or more people of special foods (i.e., foods not generally served as daily meals or offered for a special purpose or occasion). According to the same author, feasting comprised various behaviours principally designed to create or maintain important social relationships, such as follows: (1) mobilize labour, (2) establish cooperative relationships within groups or exclude other groups, (3) create cooperative alliances between social groups, (4) invest surpluses and generate profits, (5) attract desirable mates, labour, allies or wealth exchanges, (6) create political power through the creation of a network of reciprocal debts, (7) extract surplus produce from the general populace for elite use, (8) solicit favours and (9) compensate for transgressions (Hayden 2001).

Hayden (2001) divides feasting into the following four broad categories: (1) minimally distinctive feasts, (2) promotional/alliance feasts, (3) competitive feasts and (4) tribute feasts. He argues that several feasting traits may be distinguished in archaeological contexts, some of which are related to special locations and/or facilities for holding feasts to spacious storage facilities and to unusually commodious cooking facilities (Brown 2001; Clarke 2001; Hayden 2001, 1996; Hull 2014; Kirch 2001; Masson 1999; Twiss 2008; Vega-Centeno Sara-Lafosse 2007; Wiessner 2001). Hayden also proposes that wealth or status may be displayed during a feast with prestige or ritualized items and with serving accoutrements of unusual quality (Hayden 1996; Junker 2001; Perodie 2001; Twiss 2008; Wiessner 2001). Other cultural traits of feasting behaviour are linked to the consumption of food and fermented beverages, such as follows: (1) unusually large accumulations of food remains known as "feasting middens", (2) large quantities of vessels used for preparing and serving food, food preparation or serving vessels, which include unusual types, sizes, quality or materials, (3) high frequency of carcass-processing, (4) high frequency of young animals, (5) consumption of rare or costly-to-obtain foods, (6) emphasis on large animals, (7) low frequency of post-depositional modifications, (8) wanton discard of edible material (i.e. articulated joints and unprocessed bone) and (9) special properties of certain resources (i.e. abundance, intensified exploitation, invulnerability to overexploitation) (Altamirano-Sierra and Vargas-Nalvarte 2016; Clarke 2001; DeBoer 2001; Dietler 2001; Hayden 2001, 1996; Kelly 2001; Knight 2001; Masson 1999; Montero-Lopez 2012, 2009; Montero López and Varela Scherrer 2017; Twiss 2008; Vega-Centeno Sara-Lafosse 2007; Wiessner 2001).

The aim of this article is to seek feasting traits in a Panamanian archaeological site—Sitio Sierra—through a zooarchaeological and taphonomical analysis of white-tailed deer remains. Based on the literature available and the characteristics of the Gran Coclé culture, we expected to find the following: (1) large quantities of vessels used for preparing and serving food, and which include unusual types and sizes, and uncommonly high quality of materials and/or decoration, (2) high frequency of carcass-processing, (3) high frequency of young animals, (4) low frequency of post-depositional modifications and (5) wanton discard of edible material (i.e. articulated joints and unprocessed bone). In sum, our zooarchaeological analysis is enhanced by evidence for special kinds of social behaviour inferred by pottery and by cooking practices in order to reconstruct a more complete view of feasting situations.

Gran Coclé culture

Archaeologists place Sitio Sierra in the Greater Coclé culture areas ("Gran Coclé") whose geographical boundaries are broadly defined by the manufacture or regular use of a distinctive semiotic system, which is manifested in painted and modelled pottery, lapidary work, semi-monumental sculpture, goldwork, resin, marine shell and bone (Lothrop 1942, 1937). The Greater Coclé culture area was never geographically finite or static and exhibits non-linear regional variations in material culture through time, as well as fluctuating frontier zones (Cooke 2011).

In central Pacific Panama, white-tailed deer were hunted in a Preceramic agricultural period (8000–4500 BP[1]) and a subsequent Early Ceramic agricultural period (4500–2500 BP) (Cooke et al. 2008). During this long time period, exogenous plant domesticated, such as maize (*Zea mays*), manioc (*Manihot esculenta*) and squash (*Cucurbita moschata*), entered Greater Cocle subsistence systems (Piperno 2011a). Subsistence activities and their relative importance varied greatly across a landscape full of multiple ecological niches (Piperno 2011b). Many excavated archaeological sites belonging to these periods are rock shelters or coastal settlements built up on and around shell-bearing middens with taxonomically varied vertebrate faunal remains (Cooke 1995; Cooke and Ranere 1989). Most sites belonging to these periods, which have been excavated, are rock shelters or coastal middens containing marine shell. One Early Ceramic site (Zapotal [PR-14]) was a 1-ha settlement with simple houses on an old beach ridge overlooking coastal habitats (Cooke 1995; Cooke and Ranere 1992a). However, it is unlikey that the known geographical distribution of sites of these two periods objetively reflects the real distribution of populations across the landscape to judge from the results of archaeological surface surveys (Cooke 1992; Cooke and Ranere 1992a) and of regional palaeovegetational records (Piperno 2006, 2011a).

In fact, the Greater Coclé semiotic system cannot be identified objectively until bi- and tri-chrome pottery began to be manufactured between about 2500 and 1700 BP (Cooke 2011). During and after this time period, settlements on the Pacific watershed nucleated and clustered mostly along major rivers with intervals between them averaging about 2 km in the lower and flatter reaches of the rivers (Cooke 1979; Isaza Aizpurua 2013, 2007). One village—La Mula-Sarigua—was located on a fossil beach ridge overlooking the Parita Bay coastline between 2200 and 1700 BP when the Pacific ocean would have been considerably closer than today because of coastal geomorphologcal changes (summarized in Clary et al. 1984; Hansell 1987, 1988).

Burial grounds

Two funerary precincts in the lowlands bordering Parita Bay were recipients of particularly intensive and informative excavations—Sitio Conte and El Caño (Lothrop 1942, 1937; Mayo and Mayo 2013). Some of the burials fulfil the criteria for being "elite", and the quality and quantity of the funerary furniture elucidate a society whose top-rank members were able to accumulate colossal wealth interred in earth-cut graves, which had very little stone architecture. Some well-endowed graves appear to have belonged to warriors (Mayo and Carles 2015) and others to specialist practitioners and artisans (Cooke and Jimenez 2010). The most likely maximum time span for these two precincts is 1250–900 BP. Both are located very close to each other, and it is not clear whether they are chronologically sequential—because changes in riverine drainage forced a change in burial location—or whether they belonged to two social groups, such as moieties within a single chiefdom.

The thousands of painted and modelled clay vessels that were unearthed from Sitio Conte and El Caño have allowed anthropological interpretations of the zoomorphic images of the Greater Coclé Semiotic Tradition, which includes abstract representations of the white-tailed deer. Whether complete animals or synecdoches—i.e. fragments that symbolize the

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[1] We use uncalibrated radiocarbon years (BP) for dates allotted to time periods, but when specific radiocarbon dates are given, the reported conventional date is placed first in years BP followed by the 2 sigma calibration run by INTCAL 13.

whole animal—images clearly depict branched antlers and thus exclude brocket deer (*Mazama* sp.) taxa as models (Cooke et al. 2008: figure 6-6 a–e). Cooke and Ranere (1992a): 285) argued that many Greater Coclé images that combine anthropomorphic and animal elements may represent mythical figures (i.e. cultural heroes or cosmological actors) and/or corporate group eponyms, whose symbolism could only be understood by members of the social unit. Shamanic transformation involving the most feared animals (sharks, crocodiles and jaguars) is likely also be involved (Labbe 1995; Cooke 2004b: 123–124).

The village at Sitio Sierra (AG-3)

A village was established at Sitio Sierra by the end of the second millennium BP, and there were people still living there at conquest (1515–1519 CE). There is no evidence that it was a high-ranked village. It is located 4 km south-east of La Loma village (Aguadulce District, Coclé Province, Panama) (Fig. 1) on a slight rise adjacent to the Santa María river and about 1 km north of its current channel. At this point—a straight-line distance of ~ 13 km from the marine shore of Parita Bay—the river Santa María runs completely fresh today although slight tidal influence occurs here (Cooke and Tapia 1994). Studies of palaeo-channels have not been undertaken, however, and it is conceivable that ox-bow lakes easily visible today just north of Sitio Sierra represent the major channel of the Santa María river during all or part of the village's occupation. In the 1970s, the vegetation was typical of dry wooded savannahs impacted by post-contact cattle-grazing. Swampy areas had large stands of "bucayo" or "gallito" (*Erythrina fusca*), which has edible new buds and leaves (Cooke 1972). The gallery forest along the Santa María was ecologically healthy and included some tall trees (e.g. "barrigón" (*Bombax barrigon* and "higuerón" (*Ficus* spp.)). The village appears to have been occupied continually based on ceramic sequences although the small quantities of pottery belonging to the Cubitá horizon (1500–1250 BP) (see Cooke 2011) may reflect a lull in occupation. Surface ploughing had altered the natural stratigraphy by 1970–1975 when the site was excavated, and domestic features dated after about 1300 BP were not found in a pristine

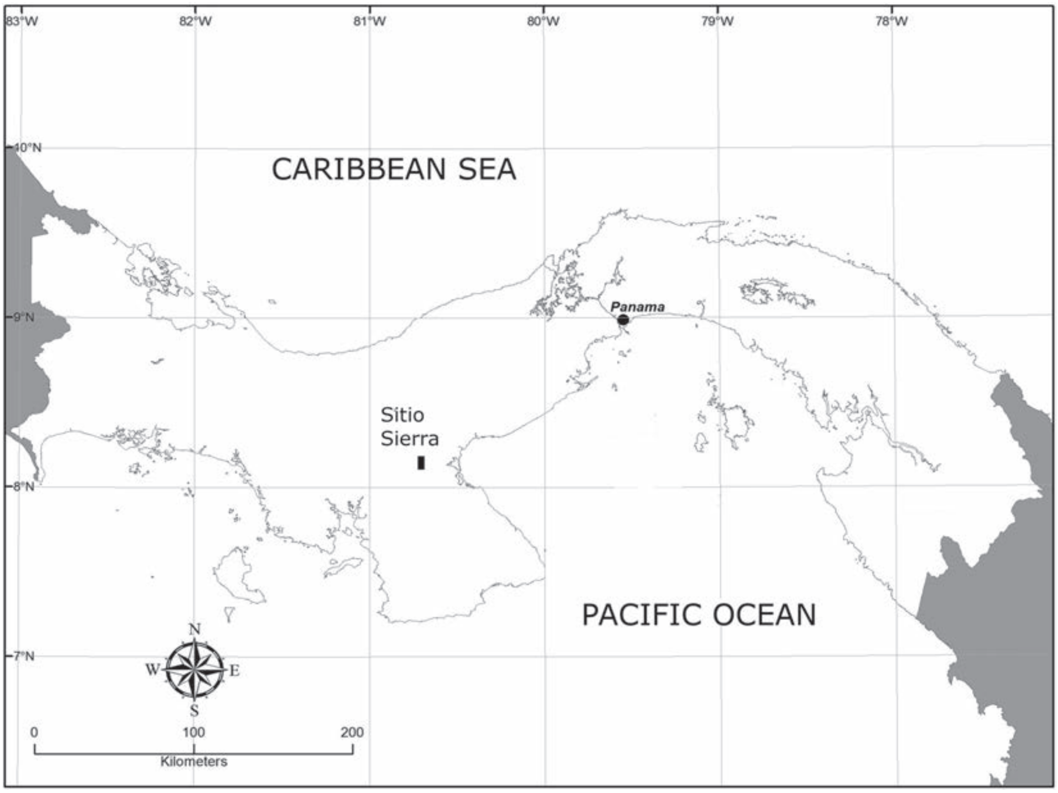


Fig. 1 Sitio Sierra (AG-3) geographical localization

state. The site has been a cane field belonging to the Ingenio Santa Rosa, since 1975.

Archaeological remains are distributed over 45 ha, although it is not known whether the whole area was ever simultaneously occupied. RGC's (24 m^2) excavations between 1970 and 1971 (Cooke 1972) employed only arbitrary levels of 10 cm. All pits were taken to bedrock. Small extensions to the initial pits were made in 1973 during a field course for the Institute of Culture students, and, in 1975, a considerably larger excavation was made during the entire dry season (December–May) using décapage techniques, which followed natural and cultural strata and located several discrete features, such as refuse lenses, structure floors with post moulds, various kinds of pits, earth ovens and two cemeteries (Cooke 1984, 1979; Isaza Aizpurua 2007, 1993). In this campaign, 3.4-mm sieves lying flat were used to recover faunal remains, and small columns were kept back for sieving with water over 2 mm mesh. "Slit" trenches, 0.75 m wide, were used to determine the spatial extent, depth and undulations of refuse lenses—with considerable success.

In the 1975 excavations, two major areas were opened and worked by décapage—cut A and cut B (Fig. 2). Table 1 presents a list of the features employed for this study together with their inferred functions. In most cases, animal remains were found on structure floors and in refuse lenses found adjacent to them or thrown over living floors.

In cut A, the lowest house floor was reconstructed as an oval about 8 × 4 m (Fig. 2), and the position of post moulds suggests multiple rehabilitation of the house in the same spot. A date of 1715 ± 90 BP (90–540 cal BCE, calibrated 2-sigma range) was based on wood charcoal from a small hearth, but $^{13}\delta$ (-25) was not calculated empirically at that time, and this omission could be a source of error. The typology of the pottery associated with the house (the early Aristides group) (Cooke 1976, 1972; Isaza Aizpurua 1993; Ladd 1964) is consistent with this date. Two hourglass-shaped pits with burned stones in a central position for placing cooking pots are inferred to be "hornillas" in local parlance—subterranean earth ovens, which are still in use in the region. A layer of soil with less cultural material infers the abandonment of the lowest house A-1-1, which was followed by a later house (A-2-1), of which only the edge was recovered (Fig. 2). Wasp nests in clay (*Sceliphron* sp.) had fallen into a shallow trough alongside the house floor of A-2-1, ostensibly made by water dripping from the palm frond roof. This inference was based on impressions of palm leaves on the back of some of the wasp nests. Others bore impressions of grasses (Poaceae), which allude to these nests having adhered to walls made of cane (Cooke 1979, 1984: 284). Another refuse lense (A-3)—probably from an unidentified house—was thrown over A-2, cutting deeply into the house floor (Fig. 2).

In cut B, a circular structure with post-moulds was found above and alongside the lowest burial ground. It was associated with two charcoal dates with $^{13}\delta$ inferred at -25: 2015 ± 80 BP (350 cal BCE–209 cal CE, calibrated 2-sigma range) and 1975 ± 80 BP (177 cal BCE–224 cal CE, calibrated 2-sigma range). The dates are earlier than those for cut A's bottom house and are consistent with the high proportion of La Mula group pottery in the house. La Mula is the first bi- and tri-chrome style in Greater Coclé (Cooke 1984, 1979, 1972; Isaza Aizpurua 1993) (Fig. 2). Feature B-3—exclusively a refuse lense—was deposited over the lowest structure (B-1), and an intermediate level of pits and trash heaps (B-2). This is a clear candidate for "Feasting midden".

Sitio Sierra subsistence patterns: some general observations

Carbonized macrobotanical remains were found in some quantity in houses and rubbish dumps at AG-3. Nearly 99% belong to maize, and many fragments of legged maize-grinding tables ("metates") and grinding stones ("manos")

Table 1 Sitio Sierra (AG-3) context descriptions and dates

Context	Description	Lab. #	Date[a]	Date cal.[b]
A3	Kitchen refuse probably from a dwelling outside the pit limits			
A2-1/A2-2	Kitchen refuse, dense accumulation	I-8556	1475 ± 110 BP	335–770 cal CE
404	Pit located at the base of A2-2			
A1-1/A1-2	Oval domestic structure with a hearth and two hourglass-shaped pits	I-8613 CEI-9701	1715 ± 90 BP 1835 ± 90 BP	90–540 cal BCE 21 cal BCE–395 cal CE
B4	Kitchen refuse accumulated gradually above B3			
B3	Kitchen refuse deposited rapidly over B2			
B2	Two superimposed structure floors alongside two hour-glass ovens			
B1	Floor of a circular structure	I-9702 I-9703	2015 ± 80 BP 1975 ± 80 BP	350 cal BCE–209 cal CE 177 cal BCE–224 cal CE

[a] Conventional C-14 age BP ± 1-sigma range

[b] Calibrated 2-sigma range BCE/CE

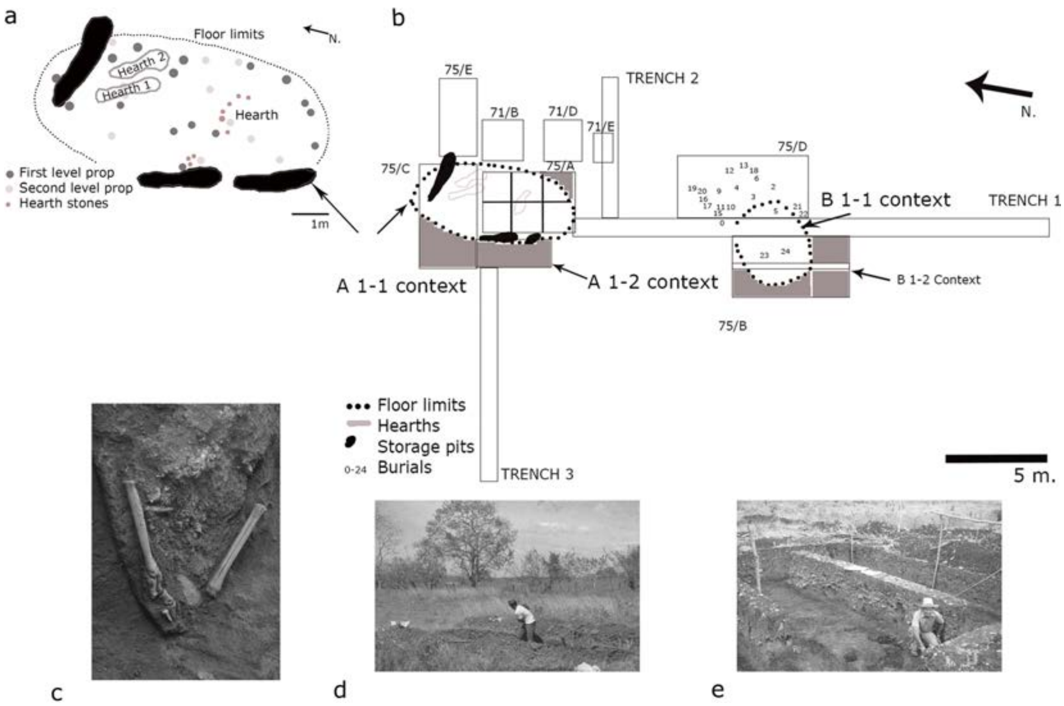


Fig. 2 Excavation plans and photographs of Sitio Sierra (AG-3). **a** A 1/1 context plan; there is an oval structure with hearths and storage pits. Adapted from Cooke (1979: 35). **b** Excavation pits made between 1969 and 1975. Adapted from Isaza Aizpurua (1993). **c** Deer remains founded at context A 2/1. **d** Site vegetation. **e** Profile B3 context. Photographs are from Cooke's personal archive

were deposited on structure floors and in trash heaps. Spanish contact-period chronicles, however, vouch for the cultivation of manioc (*Manihot esculenta*), sweet potatoes (*Ipomoea batatas*) and squash (*Cucurbita* sp.) in the colluvium alongside rivers that enter Parita Bay. Maize and manioc complement themselves agriculturally and dietetically. Squash pollen and phytoliths were identified in domestic contexts at Sitio Sierra. Carbonized palm nuts of *Attalea butyracea* ("corozo gunzo" in regional Spanish) were probably collected in nearby fields where these palms are usually left standing today during de-vegetation for pastures and fields (Dickau 2005).

The zooarchaeological record shows the consumption of marine shellfish (i.e. grand ark, *Larkinia grandis*; single-banded moonsnail, *Natica unifasciata*); mangrove crabs (i.e. mouthless crab, *Cardisoma crassum*); a wide variety of fish (70% marine/estuarine and 30% freshwater); frogs (*Leptodactylus insularum*) and toads (*Rhinella marina*); mud turtles (*Kinosternon scorpioides*); snakes (*Boa constrictor*) and iguanas (*Iguana iguana*); several species of birds and open land and gallery forest mammals, such as white-tailed deer (*Odocoileus virginianus*), paca (*Cuniculus paca*), armadillo (*Dasypus novemcinctus*) and opossum (*Didelphis marsupialis*) (Cooke and Ranere 1989, 1999, Cooke et al. 1996, 2008, 2013). The frog and the toad, whose remains are common, can both be eaten by humans after diligent skinning, and toad may have served a ritual function as well a culinary one (Cooke 1989).

Burial grounds I and II

The two cemeteries at Sitio Sierra were separated by more than 500 years. They exhibit different burial modes, and both are the antitheses of the sumptuous elite graves of Sitio Conte and El Caño mentioned previously. This fact must be taken into account when feasting is evaluated since Sitio Sierra was undoubtedly an egalitarian village where no sign was found of top-ranked elites. However, some degree of internal ranking is found in all egalitarian villages.

The oldest cemetery (I) comprised 23 individuals and belonged to a discrete burial zone underneath and alongside a circular feature with post-holes (B-1), which was some kind of structure. The burials were placed individually or in pairs and either in primary flexed mode or deposited secondarily in orderly or disorderly bundles. Burial goods have a domestic emphasis, consisting of one to five monochrome or bichrome vessels of the Aristides ceramic complex (Cooke 1979, 1976; Ladd 1964); a one-hand grinding stone; chalcedony prismatic blades and flake tools, including scrapers; complete basalt polished axes; polishing stones for axes, and basalt axe-sharpening stones. Four caudal spines of the spotted eagle ray (*Aeteobatus narinari*) constitute the only burial goods with a possible ritual function, being perhaps used for blood-letting (Cooke 2004b). Only one individual—a 1–2-year-old child—owned decorative goods: four perforated cubic beads of iron pyrite and twelve tear-shaped pendants of thorny oyster (*Spondylus princeps*) (Cooke and Sánchez Herrera 1997: figure 8k). One adult male, practised at repairing axes, was interred with basalt cobbles, broken basalt axes, several basalt polishing stones and chalcedony flake scrapers (Cooke 1978). His aural exostoses allude to activities in windy marine waters or to diving in cool water (Smith-Guzmán and Cooke 2018). Perhaps he himself fashioned or repaired the dug-out canoe that transported him down the river to Parita Bay and beyond.

Human dentin dates for four individuals in cemetery I (#0, 6, 17 and 22) range from 1950 ± 40 BP (41 cal BCE–129 cal CE, calibrated 2-sigma range) to 1770 ± 40 BP (135 cal BCE–379 cal BCE, calibrated 2-sigma range). A considerably older individual (B.23) was found protruding from the basal clay. It returned a date of 2840 ± 40 BP (Beta-148201; 1121–903 cal BCE calibrated 2-sigma range) and showed signs of a severe treponemal infection reminiscent of syphilis. Speculating, the remains may have been buried there when there was no one living at Sitio Sierra (cf. Smith-Guzmán et al. 2018, with reference to a sick person's being buried at an abandoned settlement in Bocas del Toro).

The twelve deceased recovered in cemetery II were placed mostly singly and in a fully extended position. The exceptions are a bundle and a supernumerary cranium. An adult male aged between 35 and 50 years possessed the greatest number and variety of grave goods: the partial skeleton of a scarlet macaw (*Ara macao*) heaped up over the tibiae; a string of 20, $<$ 0.8-cm-long trapezoidal beads of green feldspar (sericite) across the lower arms; and a broken flute made from the humerus of a brown pelican (*Pelecanus occidentalis*) resting against the cranium. Scattered around the body were placed four polished axes, four small plain buff and red-slipped vessels, and a small red-slipped pot-stand. Human dentin protein gave a ^{14}C date of 1020 ± 30 BP (909–1147 cal BCE; calibrated 2-sigma range). An adult female's mortuary objects consisted only of a broken and partial incense burner containing a calcined paca femur, and the partial skeleton of a crested bobwhite quail (*Colinus cristatus*)—a common ground-dwelling bird of dry and scrubby areas. The custom of placing partial artefacts in this cemetery was epitomized by the mid-shaft of a possible pot-stand in the late Macaracas or Parita style of Greater Coclé. Charcoal found within it dated to 920 ± 80 BP (988–1261 cal BCE calibrated 2-sigma range). This date is in harmony with a dentin date for the pot-stand's owner of 980 ± 30 BP (beta-41904; 993–1155 cal BCE; calibrated 2-sigma range).

Material and methods

Materials

All vertebrate remains recovered during the excavations at Sitio Sierra were separated from cultural materials in the field and then dried in the shade and bagged. They were transported to the Archaeology Laboratory of the Smithsonian Tropical Institute (STRI) in Panama City where they were analysed and identified by using a modern reference collection. The materials were organized by excavation unit and context. *Unit A*, contexts: A3; A2-1/A2-2; 404 (a pit); A1-1/A 1-2. *Unit B*, contexts: B4; B3; B2; B1 (Cooke 1984, 1979, 1972; Isaza Aizpurua 1993). A summary of the contexts whose deer remains were studied is given in Table 1.

Methods

The zooarchaeological analysis employed several units of quantification:

- Number of remains (NR): This refers to the total number of remains that make up the zooarchaeological assemblage, without taking into account the degree of taxonomical and anatomical precision that was attained (Reitz and Wing 2008).

- Number of identified specimens (NISP): This index takes into account only the bone remains that were identified taxonomically. This index usually is less than the NR (Reitz and Wing 2008).
- Minimum number of elements (MNE): This index quantifies the elements belonging to an individual, whether they are whole or fragmented. For this quantification, it is necessary to take into account different variables of each identified bone fragment, such as the area of the bone, the face, its position in the skeleton, the number of times that appears in the skeleton and its age. Each bone is divided into concrete portions, numbered from the nearest to the mouth to the furthest. Each bone is, in turn, composed of four faces, which together make up the anatomical element and allow its identification with a higher level of precision. 1, Anterior, cranial or dorsal; 2, posterior, caudal or palmar/plantar; 3, exterior or lateral; 4, interior or medial (Schmid 1972).

- Minimum number of individuals (MNI): This index defines the minimal number of animals that could be present in the assemblage. This index does not reflect the real abundance of the animals and is only a guide to the minimum number of individuals present in the assemblage. In addition, this index does not imply that the animals were complete when the accumulation was formed. This index is calculated by summing the most frequent element taking into account laterality and age size (Reitz and Wing 2008).
- Minimum anatomical units (MAU): The MAU is obtained by dividing the number of elements identified by the number of anatomical units present in a complete skeleton. MAU% is the relativized scale obtained by dividing between the standard (greater MAU) and multiplying by 100. Subsequently, the MAU% was compared against the utility index proposed for the white-tailed deer by Madrigal and Holt (2002)'s modification of the index proposed by Binford (1984) and the simplified index of Metcalfe and Jones (1988). For this purpose, the MAU of the long bones was obtained by dividing by two, the phalanges by eight, and the cervical vertebrae by five (excluding the atlas and the axis), the thoracic vertebrae by twelve and the lumbar vertebrae by seven (Madrigal and Holt 2002; Sauer 1984).

The age at death of white-tailed deer was established by reference to epiphyseal fusion, tooth eruption sequence and tooth wear. Two categories were used: sub-adults (< 24 months) and adults (> 24 months) (Purdue 1983; Severinghaus 1949). Purdue (1983) established a long bone fusion chart for white-tailed deer from North America. On the basis of Purdue's work, we established the following three degrees of fusion: (1) without fusion (in those cases where the epiphysis was separated from the diaphysis; (2) recent fusion, where the epiphysis is clearly united to the diaphysis but a line is observed between epiphysis and diaphysis; and (3) completely fused, in those cases where the diaphysis was firmly joined to the epiphysis. One must bear in mind that not all bone elements fuse at the same time. Some elements fuse before the animal has matured and others later. However, in order to fine tune age classes, data from contemporary animals are needed from which relationships can be established with the archaeofaunal samples. This is all very well in theory, but, as far as we know, there are no such studies of Neotropical deer for making direct comparisons.

In the case of white-tailed deer, it is counted on the classical research of Severinghaus (1949), who made a very detailed description of the process of eruption and dental wear of this species. He used an actual sample from New York (United States) and proposed a series of age classes and subclasses. However, the exact determination of the age is very difficult by using archaeological samples, especially in the case of Neotropical white-tailed deer because there are differences between populations in tooth chronology and tooth wear due to differences in habitat quality and environmental characteristics (Ojasti 2000). For this reason, we selected two broader categories, juveniles and adults; also, because they have a meaning in the dynamics of the populations.

In order to determine sample integrity, MAU and its frequencies were calculated (Lyman 2008), as well as the conservation differential in relation to bone density (VD). We used Lyman's (1994) values averaged following Reitz and Wing (2008), and we plotted volume density (VD) against NISP and calculated a correlation coefficient (Pearson's r) between these variables. In order to study skeletal completeness, we compared archaeological bone frequencies with the expected frequencies if the deer skeleton were complete, applying the following equation:

$$d = (\mathrm{Ln}X) - (\mathrm{Ln}Y)$$

where X is the percentage of each skeletal portion and Y is the percentage of the same portion in a complete skeleton. Positive values show that the skeletal portion is more abundant compared to the standard and negative values that the skeletal portions are underrepresented (Reitz and Wing 2008). To study long bone representation, we recorded the anatomical zone (proximal, medial, distal, whole) of the long bones (humerus, radius, femur, tibia, and metatarsal).

The taphonomical analysis focused on bone breakage and surface alteration. In order to evaluate bone breakage, we distinguished colour changes in the bone outlines as well as fracture angle in order to discriminate an old breakage (occurring at or near the time of deposition) from a new breakage (occurring during or after the excavation) (Steadman et al. 2002). Villa and Mahieu (1991) proposed a methodology for studying patterns of bone breakage, i.e. (1) fracture angle, (2) delineation morphology and (3) fracture surface. The fracture angle is established in relation to the cortical bone and can be straight, oblique or mixed. Delineation morphology is evaluated with respect to longitudinal bone axis and can be transverse, curved and longitudinal. The aspect of the fracture surface can be smooth or irregular.

Surface alterations were identified macroscopically and microscopically. All skeletal specimens were examined using a stereomicroscope (Leica Wild M10, up to 120). The analysis of cut marks took into account the number of striations, location on the anatomical element, distribution over the surface (isolated, clustered and crossed), orientation with respect to the longitudinal axis of the bone (oblique, longitudinal and transverse) and delineation (straight or curved) (Binford 1981; Potts and Shipman 1981; Shipman and Rose 1983). Six degrees of thermal damage were identified [from 0 (unburned) to 5 (calcined) and 6 when 2 burning colours were observed]; grade 0, no apparent alteration; grade 1, bone surface with small scattered spots of brown colour, conserving part of its collagen; grade 2, the bone presents a homogeneous brown colour; grade 3, the bone is charred, acquiring a black colour. The collagen has been completely lost in this phase; grade 4, grey and/or bluish coloration of the bone; grade 5, the bone is completely calcined, white (according to the criteria of Stiner et al. (1995)).

Tooth marks were analysed and compared systematically in order to distinguish between human and non-human marks (i.e. those made by carnivores and rodents). Human tooth marks were classified as pits (ovoid shape and shallowness) and scores (elongated shape and internal crushing) (Landt 2007). Carnivore and rodent marks were classified as pits, punctures and scores (Binford 1981; Selvaggio 1994). Other damage produced during consumption, such as notches, crenulated edges or pitting, was recorded, too; their distribution, orientation and dimensions were taken into account. Finally, post-depositional modifications were recorded, such as manganese, adhering concretions, root damage, and weathering probably commensurate with humidity (Grayson 1988; López-González et al. 2006).

Results

Zooarchaeological analysis

At Sitio Sierra, 2973 remains of white-tailed deer were found in our samples. A total of 38 individuals was identified. Twenty-two individuals were sub-adults (58%), and 16 were adults (42%) (Table 2). The greatest quantity of remains was found in context B-3, followed by A2-1/A-2-2 and A1-1/A1-2 (Table 2).

Anatomical representation—MAU The highest MAU% values by context are as follows: mandible (A3, B1), femur (A2-1/2-2, B3), ilium (A1-1/A1-2, B4), lumbar vertebrae (404), ulna (B4), humerus and radius (B2) (Supplementary material, Table 1).

Table 2 White-tailed deer (*Odocoileus virginianus*), by age groups, from Sitio Sierra (AG-3). NISP (number of identified specimens) and MNI (minimal number of individuals) by age categories from Sitio Sierra (AG-3)

	NISP	NISP%	MNI			NMI%
			Sub-adults	Adults	Total	
A3	225	7.57	2	1	3	7.89
A2-1/A2-2	618	20.79	4	3	7	18.42
404	64	2.15	2	2	4	10.53
A1-1/A1-2	291	9.79	3	2	5	13.16
B4	88	2.96	2	1	3	7.89
B3	1528	51.40	5	5	10	26.32
B2	62	2.09	3	1	4	10.53
B1	97	3.26	1	1	2	5.26
Total	2973	100.00	22	16	38	100.00

Volume density We observed that some elements with low density are often under-represented, but not in all cases (Fig. 3). There is a statistically insignificant negative correlation between NISP and VD at context B4 ($r_p = -0.29$, $p = 0.16$), B2 ($r_p = 0.001$, $p = 0.99$) and B1 ($r_p = -0.08$, $p = 0.69$), and there is a statistically significant negative correlation in the other contexts at A3 ($r_p = -0.48$, $p = 0.01$), A2-1/2-2 ($r_p = -0.44$, $p = 0.02$), 404 ($r_p = -0.55$, $p = 0.004$), A1-1/1-2 ($r_p = -0.53$, $p = 0.006$) and B3 ($r_p = -0.43$, $p = 0.03$). These results suggest that density-mediated attrition was not responsible for the varying frequencies of skeletal parts.

Skeletal completeness A general pattern is observed at Sitio Sierra: head, forefoot, hind foot and foot are under-represented in most of the contexts, while the forequarter and hindquarter are over-represented (Fig. 4).

Long bone representation A total of 252 remains were long bones (8.47%); the most represented zone was the distal, followed by proximal, whole and medial. In Fig. 5, the distribution of anatomical zone by context shows that context A2-1/A2-2 contains the largest number of complete elements.

Taphonomical analysis

Anthropic modifications

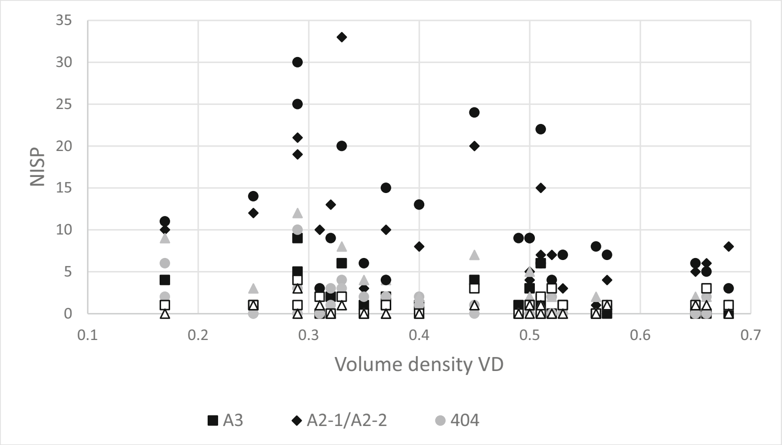
At Sitio Sierra, anthropic modifications were identified in 635 remains (21.35%), and most of them were burning damage and cut marks (Table 3, Fig. 6).

Bone fracture patterns: at Sitio Sierra, 161 (5.41%) deer remains show the characteristic fracture pattern of fresh breakage. The rank order of contexts that show fresh breakage is B3, A3, B4, A1/1-A1/2, A2/1-A2/2, B2 and B1 (Table 3, Fig. 6b).

Cut marks: 769 cut marks were identified in 187 elements representing 6.28% of the total sample. Context A2/1-A2/2 showed the largest number of cut marks, followed by B3, A1/1-A1/2, A3, 404, B2, B4 and B1. These marks are characterized by be fairly deep and straight incisions (64.23%), superficial scraping (27.43%) and deeper hack marks (8.32%). The position of the cut marks infers defleshing (59.69%), skinning (31.51%) and disarticulation (8.78%) (see Supplementary material, Table 2, Fig. 6c–e).

Burning damage: At Sitio Sierra, 285 elements show thermal alteration representing 9.58% of the sample. Most of them were founded in context B3. The majority of the remains shows colour grade 3 (Table 3, Fig. 6a).

Fig. 3 NISP (number of identified specimens) against VD (volume density) values of white-tailed deer (*Odocoileus virginianus*) identified at Sitio Sierra (AG-3)



Tooth marks: Two elements (0.32%) in unit A2/1-A2/2 show evidence of human tooth marks: a long bone with cortex loss and a rib showing peeling (Table 3). There is no evidence of carnivore tooth marks in the Sitio Sierra sample.

Post-depositional modifications

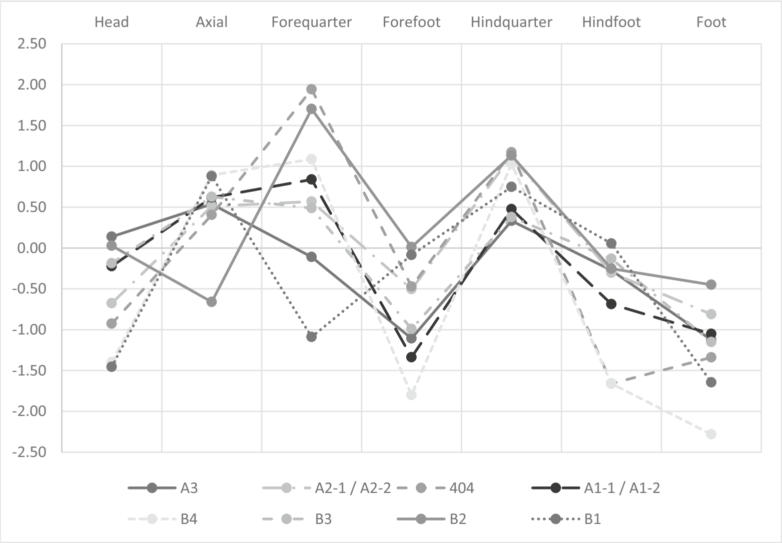
Post-depositional modifications were identified in 1156 remains (39%), and concretions (18.83%) and manganese stains (17.92%) were the most prevalent (Table 4, Fig. 7). We propose that all these changes were related to high humidity. Other post-depositional modifications include the following:

Rodents: Only eight (0.26%) remains indicate gnawing. They were identified in contexts A1/1-A1-2 and B3 (1.03 and 0.33%) (Table 4, Fig. 7).

Concretions: 560 (18.83%) remains present concretions, and most of them are from context B3, followed by A2/1-A2/2, B4, 404, A1/1-A1/2, A3, B2 and B1 (Table 4, Fig. 7b).

Root damage: 45 (1.51%) deer bones present root damage. Principally, in contexts 404, A2/1-A2/2, A3, A1/1-A1/2, B4, B3 and B1 (Table 4, Fig. 7a).

Fig. 4 Ratio diagram of skeletal portions using NISP (number of identified specimens) of white-tailed deer (*Odocoileus virginianus*) identified at Sitio Sierra (AG-3)



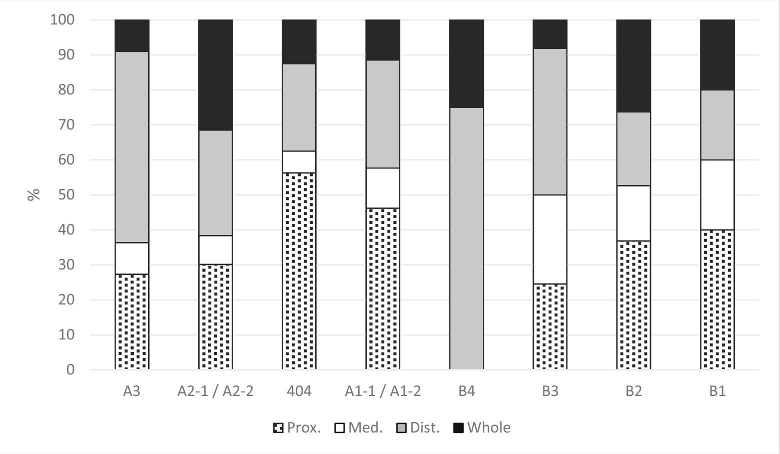


Fig. 5 Anatomical representation of long bones of white-tailed deer (*Odocoileus virginianus*) identified at Sitio Sierra (AG-3)

Manganese: 533 (17.92%) remains at Sitio Sierra show manganese stains. Most of them in B3, followed by A2/1-A2/2, A1/1-A1-2, A3, B2, B4, B1 and 404 (Table 4, Fig. 7c).

Weathering: This type of modification was identified in 18 remains (0.60%), mostly in A2/1-A2/2, B3, 404, A1/1-A1/2, B4 and B2 (Table 4, Fig. 7d).

Discussion

The sampling at Sitio Sierra was by no means perfect overall, since B-3 was the only context excavated in its entirety and sampled amply, from six 1 × 1.5-m units over 3.4 mm mesh. B-3 shows the clearest indication of being a "feasting midden" according to the following criteria: (1) large quantities of vessels used for preparing and serving food, food preparation or serving vessels, which include unusual types, sizes, quality or materials; (2) high frequency of carcass-processing; (3) high frequency of young animals; (4) low frequency of post-depositional modifications and (5) wanton discard of edible material (i.e. articulated joints and unprocessed bone). B-3 shows the clearest indication of being a "feasting midden." Deer remains represented 51.4%, followed by context A 2-1/2-2, with 20.8%. The representation of all body parts in these contexts suggests that deer were brought back to the site where they were processed in situ.

Context A2-1/A2-2 also accords well with feast-related activities although it exhibits qualitative differences with B-3, with which it is broadly coeval on the basis of shared ceramics. Complete and articulated deer remains represented (31.6%) (Fig. 2c), while, in context B-3, fewer elements were found complete (8.2%). In contexts A2-1/A2-2 and B-3, there is a special focus on body parts with high meat values, such as femur. Madrigal and Holt (2002) established that the white-tailed deer femur has a high meat values. However, the

Table 3 Anthropic modifications to white-tailed deer (*Odocoileus virginianus*) bones at Sitio Sierra (AG-3). NR, number of remains

	Cut marks		Burning damage		Fractures		Human tooth marks		NR
	NR	%NR	NR	%NR	NR	%NR	NR	%NR	
A3	15	6.67	3	1.33	38	16.89	0	0.00	225
A2/1-A2/2	61	9.87	37	5.99	18	2.91	2	0.32	618
404	15	23.44	0	0.00	0	0.00	0	0.00	64
A1/1-A1/2	28	9.62	9	3.09	25	8.59	0	0.00	291
B4	6	6.82	9	10.23	29	32.95	0	0.00	88
B3	48	3.14	221	14.46	44	2.88	0	0.00	1528
B2	10	16.13	0	0.00	4	6.45	0	0.00	62
B1	4	4.12	6	6.19	3	3.09	0	0.00	97
Total	187		285		161		2		2973

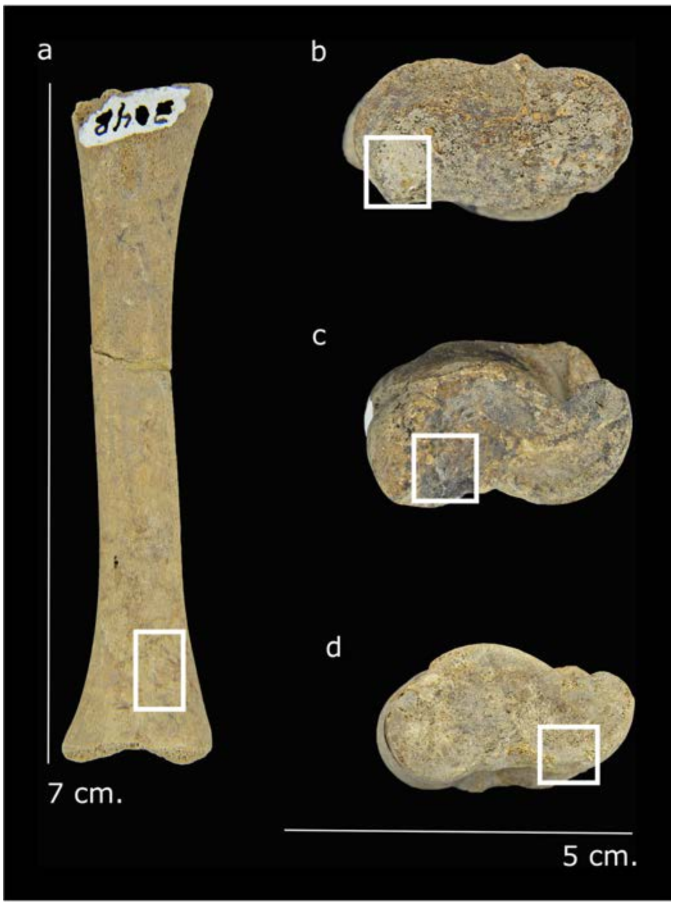


Fig. 6 Examples of anthropic modifications identified on white-tailed deer (*Odocoileus virginianus*) bones at Sitio Sierra (AG-3) B3 context. **a** Sacral vertebrae with thermal damage (stage 3). **b** Long bone percussion cones. **c** Vertebrae shows a cut mark (hack mark). **d** Mandible with cut marks (deep and superficial incisions). **e** Mandible with cut marks (deep and superficial incisions)

forequarters were over-represented in almost all contexts except A-3 and -B4.

The taphonomical analysis shows that contexts A2-1/A2-2 (9.9%) and B3 (3.1%) contained the highest frequency of cut marks. In B-3, cut marks were particularly concentrated on mandibles, humerus and femur (Fig. 6). The marks are located at identical positions on several elements that could be explained for the similar anatomy of the deer and the sharing of traditional practices between generations. Heat damage is not frequent in the overall Sitio Sierra deer samples but attains the highest frequencies in contexts B-3 (14.5%) and A2-1/A2-2 (6%). Most bones have a grade 3 staining pattern that can occur at a temperature that varies between 300 and 400 °C (Nicholson 1993). There is little evidence for gnawing by rodents even though mouse and rat bones are frequent at the site (mostly common cane mouse, *Zygodontomys brevicauda*). No bones show evidence for gnawing by carnivores, and very few canid elements were found at Sitio Sierra. Overall, there is a slight preference at Sitio Sierra for the consumption of meat from young animals (58%). Yet, there are no data to support deers being bred in captivity. However, the slightly higher number of young individuals at Sitio Sierra may suggest that people took fawns and fed them before the feastings.

A depositional feature that signals a feasting role for B-3 are the finds of the following several partial animal skeletons: (1) charred mud turtles (some of these deposited with conjoining carapace elements) [173/10]; (2) unusually large numbers of marine toad elements, including some with snapped sacral vertebrae indicative of in situ butchering (Cooke 1989) [184/20]; (3) a burnt nine-banded armadillo [119/5]; (4) a burnt and charred Muscovy duck (*Cairina moschata* [domesticated male]) [15/1] (Cooke et al. 2013) and (5) a white-faced whistling duck (*Dendrocygna viduata*)

Table 4 Post-depositional modifications identified on white-tailed deer (*Odocoileus virginianus*) bones at Sitio Sierra (AG-3)

	Rodents		Concretion		Roots		Manganese		Weathering		NR
	NR	%NR	NR	%NR	NR	%NR	NR	%NR	NR	%NR	
A3	0	0.00	9	4.00	6	2.67	37	16.44	0	0.00	225
A2/1-A2/2	0	0.00	112	18.12	7	1.13	123	19.90	8	1.29	618
404	0	0.00	10	15.63	15	23.44	5	7.81	2	3.13	64
A1/1-A1/2	3	1.03	9	3.09	6	2.06	37	12.71	1	0.34	291
B4	0	0.00	24	27.27	6	6.82	8	9.09	1	1.14	88
B3	5	0.33	382	25.00	3	0.20	289	18.91	5	0.33	1528
B2	0	0.00	6	9.68	0	0.00	28	45.16	1	1.61	62
B1	0	0.00	8	8.25	2	2.06	6	6.19	0	0.00	97
Total	8		560		45		533		18		

[22/1] (Cooke and Ranere 1992a: table a) (in square brackets: number of specimens followed by minimum number of individuals). It seemed to the excavator (RGC) that the carcasses of large marine catfish (*Ariidae*) were thrown from the oven or barbecued directly onto the refuse pile since the neurocrania of several large specimens had the component bones still joined or clustered together. The largest tropical eastern Pacific marine catfish (*Sciades dowii*) produced 333 elements from 18 individuals, with a total body mass of 35.45 kg—as much as an immature white-tailed deer (Cooke and Ranere 1999: Table 4).

The pottery

Pottery, in the contexts that we are arguing are bona fide feasting events, is much more numerous than in other contexts in spite of the fact that sherds are on average much larger. Context B-3 contained 14,518 sherds, and contexts A-2-1 and A-2-2, 18,419. In contrast, contexts B-1 and B-2—rejected as feasting locations—have much less pottery (total 7633 sherds), and vessel size is much smaller. Fine pottery is found in B-1 and in A-1-1—but not in the feasting contexts. In context B-1, chronologically the oldest in the sample, fine La Mula wares represent 37% of painted wares. Context A-1—200–300 years more recent—contains a short-lived and well-made bowl with a strongly everted rim and a remarkably thin wall (the Zumbito type). The flat rims are decorated with abstract deigns filled with kaolin. Beautifully painted Tonosí Polychrome sherds were best represented in context A-2-1 in accordance with its chronological placement in the Greater Coclé sequence of fine painted wares (Cooke 2011). In contexts A-2-1, A-2-2 and B-3, on the other hand, large sherds of the Aristides group pervade the refuse, comprising shallow bowls (Girón and Cocobó types and large urns with tall, slightly everted necks, which are optimal for heat retention or liquid storage (Escotá type) (Cooke 1976, 1972). In fact, vessel fragments from features A-2-1, A-2-2 and B-3 are noticeably larger than in all other contexts and appear to have been buried quickly (Cooke 1979).

Cooking

The frequency of hearths and clepsydra-shaped cooking pits at Sitio Sierra, inside or just outside structures, confirms that cooking was undertaken in houses, probably on a daily basis for preparing the kind of victuals that were regularly consumed, including broths and gruels that included large amounts of small fish (< 300 g). Underneath the large refuse pile of B-3, an hour-glass-shaped pit had post-holes at the periphery. This oven may have been used during the feast responsible for B-3's accumulation, being filled in once the feast was over. To sum up, we propose that contexts A2-1/A2-2 and B3 meet some of the criteria for being "feasting middens". It is not straightforward to interpret the hypothetical feasts, and feasible explanations are multiple, i.e., ancestor worship (bearing in mind the presence at Sitio Sierra of two cemeteries), rites of passage like the modern Guna *chicherías*, celebrations of cultural awareness and group oral history—similar to the Ngäbe balsería—and political gatherings designed to enhance the reputation of the provider. In the last case, the providers at Sitio Sierra did not reward the invitees with sumptuous goods as in the potlaches of the American north-west or, one assumes, at feasts at high status Sitio Conte and El Caño. Speculating, perhaps the feast represented by context A2-1-1/A2-1-2 was of the "minimally distinctive" kind (Hayden 2001)—a small-scale household and moderate-sized lineage solidarity feast, which took place in and around the cane and palm thatch residence. Another possibility is an end-of-fast feast in honour of males who were forbidden deer meat for diverse reasons, and, when the taboo was over, gorged themselves on deer meat from storage houses.

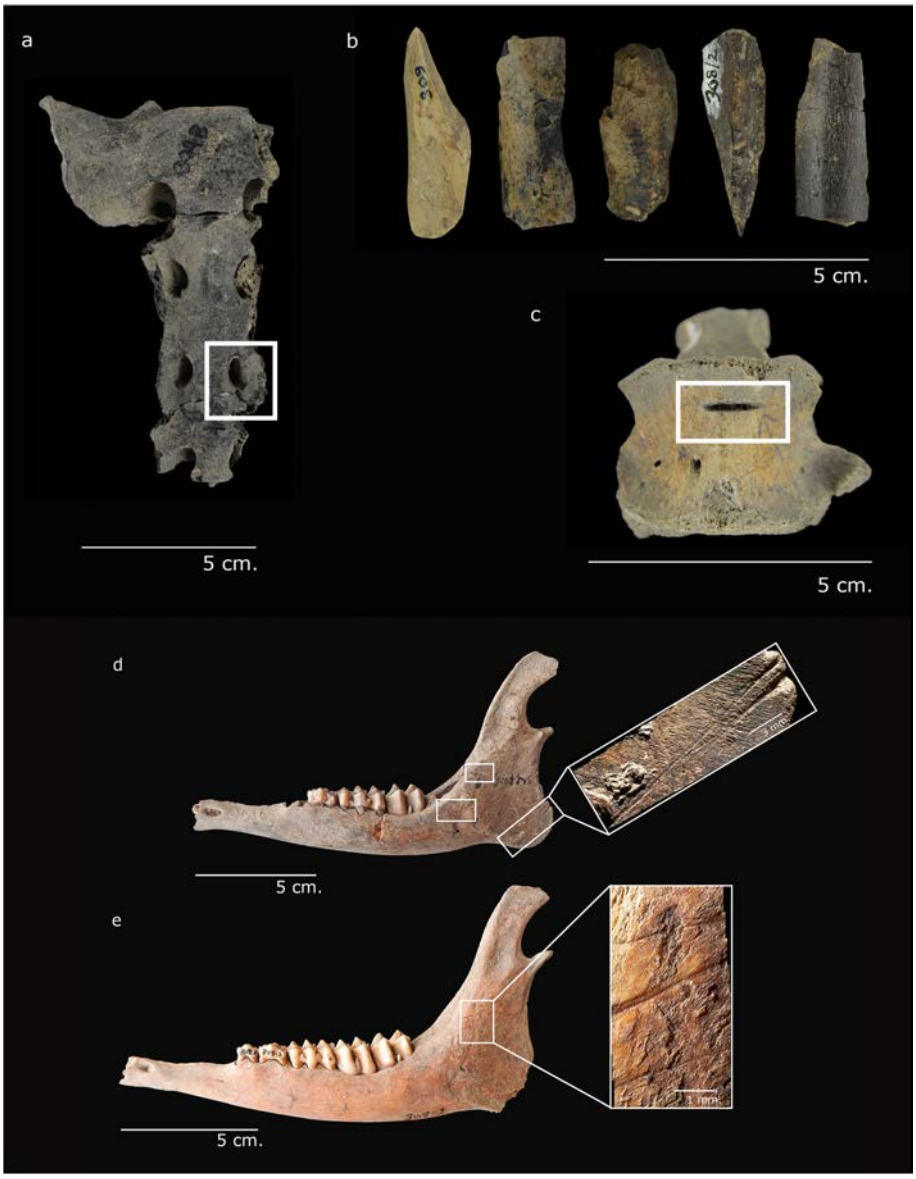


Fig. 7 Examples of post-depositional modifications identified on white-tailed deer (*Odocoileus virginianus*) bones at Sitio Sierra (AG-3) B3 context. **a** Radius with root damage. **b** Astragalus with concretions. **c** Astragalus shows manganese stains **d** Astragalus shows weathering

Final comments

Early sixteenth century CE Spanish chronicles observed that deer were very abundant in Parita Bay as they had been for 5500 years. This infers a stable white-tailed deer population in the central Pacific wooded savannahs in spite of continuing human predation. The Spanish soldiers who doubled as observant eye-witness chroniclers noticed that deer hunting was communal and that deer were frightened and corralled by firing the savannah. This kind of communal hunting has a modern analogy among the Huaorani—an Ecuadorian Amazonian hunter-gatherer group—who hunted collared peccary (*Pecari tajacu*) by using spears. Hunting these peccaries was a special event for the Huaorani involving the entire community, and collective efforts were necessary because peccaries move in herds and are very destructive of crops and gardens. After such a hunt, all the meat was consumed quickly in a peccary feast (Rival 2001).

The early sixteenth century CE chroniclers, Pascual de Andagoya [1514] and Gaspar de Espinosa [1517], observed that hunting deer and other mammals was forbidden in chief Parita's territory—located in the south of Sitio Sierra—but not in neighbouring territories (de Andagoya 1994; de Espinosa 1994). The most logical explanation for the Spaniards' observations is that they came across a temporary proscription in forcé in this particular territory, which was not being enforced at that time in other chiefdoms. But, there are other reasons; Cooke and Ranere (1992b) suggested a deer proscription along totemic lines (i.e. for a high-ranked deer clan). Such is the ubiquity of animal images on the art objects of Greater Coclé, that some form of totemism probably played an important role in human–animal relations. After all, the Bribri (a present-day First American group in Costa Rica) have a ranked system of naming clans after animals of different kinds and behaviours (Nygren 1998; Stone 1961). This situation accords with Lévi-Strauss's (1964) view that totemism is an intellectual system that reflects a social unit's classificatory schemes based on natural species organization. Totemism used empirically observable discontinuities among natural species in order to organize society conceptually. In the Nukak's—a Colombian Amazonian hunter-gatherer society—case, some animals, i.e. tapir, deer and jaguar contain or represent spirits of the ancestor, and, hence, they are "like people" (Politis and Saunders 2002). This accounts for the ritual avoidance of hunting these animals. Similarly, the Huaorani's peccaries are not related to people and that allowed them to hunt and consume these animals on some occasions (Rival 2001). The Makuna, who are a people from the Colombian Amazon, only fished and hunted terrestrial prey beyond immediate family needs when a ritual feast was organized for several families and under the supervision of a shaman (Arhem 2001). Politis and Saunders (2002) note that for the Nukak the edibility of a particular food depends on the physical and ritual state of the consumer. Adult males of Sitio Sierra and its social environs could perhaps only hunt and gorge themselves on deer after a prior ritual preparation; deer hunting was mediated by ritual activities linked to special occasions.

Conclusion

By studying the deer sample from Sitio Sierra in conjunction with the evidences of the ceramic and the cooking, we conclude that ritual activities mediated the feasts that are inferred by the zooarchaeological, taphonomical and archaeological evidences at Sitio Sierra. We clearly identify several characteristics of feasting according to the literature such as the following: (1) large quantities of vessels used for preparing and serving food, food preparation or serving vessels, which include unusual types, sizes, quality or materials; (2) high frequency of carcass-processing; (3) high frequency of young animals; (4) low frequency of post-depositional modifications and (5) wanton discard of edible material (i.e. articulated joints and unprocessed bone). White-tailed deer meat was clearly the most important animal food in the feasts that we have hypothesised, which likely served guests large quantities of fermented maize *chicha* as well as grilled sweet potatoes, manioc and squash, whose cultivation is inferred by microbotany and contact period documentary evidence. However, the refuse pile in context B-3 included carcasses of particularly tasty birds and mammals that would have complemented the feast. This special menu contrasts with the everyday meals at Sitio Sierra whose remains were widely scattered around houses and comprised foods, such as marine and river fish, iguanas and small turtles. Offering roast deer meat in a feast—an animal with restricted access because of its polysemic ritual significance—would have been an honour for the guests and proof of the provider's status in an essentially low-status village.

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6.4. Crafting white-tailed deer (*Odocoileus virginianus*) bone and antler at Cerro Juan Díaz (LS-3), Greater Coclé Culture Area, Panama*

Abstract

This paper refers to a feature at Cerro Juan Díaz (LS-3) in the Central Pacific coastal plains of Panama bordering Parita Bay. Covering 200 ha, this site was occupied between 300 BCE and 1600 CE. The feature was cross-dated with pottery of the Cubitá stylistic horizon to 500-700 CE andcontained abundant fragmented cultural and faunal materials. Analyses of human-modified mammal bones indicated that this trait, named "Operation [Op.] 1/1B," represented a craft-specific work area. In Op. 1/1B, white-tailed deer (*Odocoileus virginianus*) remains were used for making tools and ornaments. Their taphonomy and usage are the primary concerns of this paper. The refuse in Operation 1/1B at Cerro Juan Díaz clearly represents the waste of a deer bone and antler workshop. In this site, we did not find the final products that were used at elite graveyards such as Sitio Conte. This workshop appears only to have prepared tubes fashioned from white-tailed long bones. Knowledge of bone industry techniques and methods may have been passed down from generation to generation within a family nucleus.

Key words

White-tailed deer-Bone-Antler-Workshop-Panama-Complex societies

6.4.1. Introduction

The white-tailed deer (*Odocoileus virginianus Zimmermann* 1780) is widely distributed from southern Canada to Brazil (Eisenberg 1989; Smith 1991. It is a polytypic species that has become well adapted to a wide range of habitats from temperate to subtropical, and semi-arid environments to rainforest, and savannas (Eisenberg 1989; Emmons 1999). This species is well adapted to Neotropical wooded savannas (Emmons 1999). This biome prevailed over much of the Holocene landscape of Lower Central America, especially along the seasonally dry Pacific side of Panama, where it became one of the most important species over time to human populations that inhabited this area (Cooke, Jiménez-Acosta, and Ranere 2007, 2008; Cooke and Ranere 1992; Eisenberg 1989).

White-tailed deer antlers and bones served as raw materials to craft artifacts and ornaments throughout the Americas, for instance in Canada (Gates St-Pierre 2010; Gates St-Pierre, Boisvert, and Chapdelaine 2016; Gates St-Pierre et al. 2016; Berg and Bursey 2000), United States of America (Martin 1976; R. Moore 2017; Byrd 2011; Wheeler and Coleman 1996; Penders 2005), Mexico (Blasco Martín et al. 2019; Valentín and Pérez Roldán 2010; Pérez Roldán 2013; Pérez Róldan 2005; Paris et al. 2020), Guatemala (Emery and Aoyama 2007; Emery 2008, 2009), Belize (Boileau and Stanchly 2020), West Indies (Giovas 2018), Panama (Cooke and Jiménez-Acosta 2010; Cooke 2004), Colombia (Correal 1990; Groot 1992) and Ecuador (Stahl and Athens 2002). In archaeological sites from these areas, deer bone workshops are articulated to a particular social and economic organization and in some cases, they could also be linked to a symbolic and ritual world.

Wealth is seen through items of ritual significance, rare, or highly desirable items meant to be displayed. While, subsistence goods include food, drugs, and production technology used to meet basic household needs (Brumfiel and Earle 1987). The objects made from bone was a powerful symbol of status and prestige and could represent the prestige value of the animal in the spiritual or symbolic world (deFrance 2009).

Animal bone objects or artifacts usually are produced by a specialist. Specialized artisans are usually a minority of the group, and they dedicate most of their time to the manufacture of their products, which prevents them from dedicating themselves to other basic subsistence activities, being forced to exchange their crafts for basic products (Brumfiel and Earle 1987). That means that specialization involves economic differentiation and interdependence. The definition of specialization focused

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*Book that compiles the presentations of the 13th Meeting of the Worked Bone Research Group (WBRG) of the International Council for Archaeozoology (ICAZ). Book chapter in press.

on differential participation on economic activities (Costin 1991). In the archaeological record, the most common evidences of specialization are: 1. the presence of raw materials; 2. The concentration of manufacture debris; 3. The abundance of tools and 4. facilities associated with production (Costin 1991).

Political development is usually accompanied by an intensification of elite-sponsored artisanal production. This is because the production, exhibition, and distribution of wealth are politically important activities. It is through the use of these artifacts that leaders define their own social statuses and those of others, and at the same time, define it with all their rights and obligations (Johnson and Earle 2000).

This paper addresses the crafting of tools and ornaments made from white-tailed deer bone and antler based on a single feature within an extensive village known as Cerro Juan Díaz (LS-3). This is one aspect of the multi-faceted symbiosis between the white-tailed deer and pre-Columbian human groups on the Isthmus of Panama. Based on the literature available and the characteristics of the Gran Coclé culture, we expected to find evidences of specialization, in particular: the presence of raw materials and the concentration of manufacture debris, concentrated within the same space in the settlement.

6.4.1.1. Presentation of the site

Cerro Juan Díaz (LS-3) (Fig.1 b.) is located on both banks of the La Villa River (Fig.1 a.). Today this river divides two provinces: Herrera to the north and Los Santos to the south. In macro-geographical terms, these two provinces belong to the Azuero peninsula. A multi-annual archaeological project (1992-2001), supervised by Richard G. Cooke, documented human occupation at Cerro Juan Diaz (LS-3) (Fig. 1 c.). Excavations began as a salvage operation requested by Panama's Institute of Culture because looters (known regionally as huaqueros) violated graves containing goldwork and caused a disorderly disarray to the site (Cooke and Sánchez Herrera 1997; Cooke et al. 1998). Fieldwork had to adapt to extensive damage caused by random looting (Cooke and Sánchez 2004). Over nine years, eleven field "operations" ("Ops.") were undertaken. These varied in size from 2×1 m test-pits (Ops. 3a and 22) to ~800 m2 (Op. 31). The features identified during the field operations varied greatly with regards to depth, topography, complexity, function and cultural and biological content. All the operations except one (Op. 2) showed evidence for some form of mortuary activity. Structures at Cerro Juan Díaz including domestic ones had puddled clay floors and roofs supported by stout poles. One that was completely cleared was circular and associated with small family-type cemetery (Carvajal-Contreras, Sánchez, and Cooke 2006).

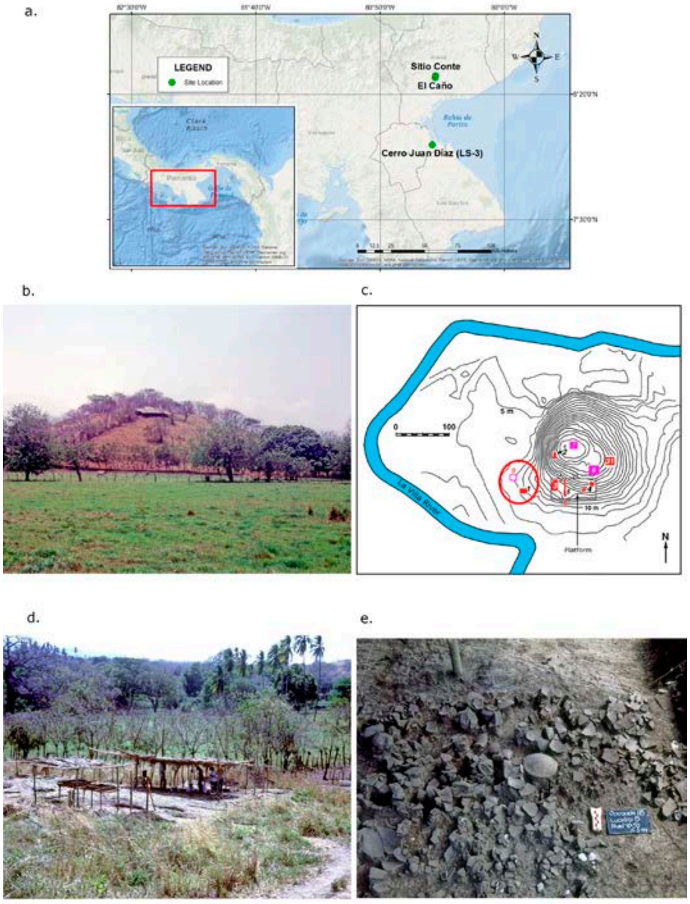

Figure 1. a.Cerro Juan Díaz (LS-3), Sitio Conte and El Caño geographical location; b. View of Cerro Juan Díaz; c. Operations location at Cerro Juan Díaz, Operation 1/1B is located at the southwest corner of the archaeological site near Operation 8 (Red circle). Adapted from Cooke and Sánchez Herrera (1997); d. Operation 1/1B during excavation. e. Detail of square 5, level:40-50 cm, Operation 1/1B.

Cerro Juan Díaz was an archetypal ecotonal settlement. Subsistence practices and their emphases reflected this: agriculture had plentiful maize fields in alluvial zones; fishing in inshore marine waters and in the mixing zone of estuaries; invertebrate collection in marine-coastal habitats and tidal rivers; hunting of iguanas, birds, medium-sized mammals and deer along river banks, in open areas and in wooded savannas; and gathering of wild fruits mostly from human-tended palms (Carvajal-Contreras 1998; Cooke, Jiménez-Acosta, and Ranere 2007, 2008; Cooke et al. 2013; Dickau 2010; Jiménez-Acosta and Cooke 2001).

The first clear indication of human settlement at LS-3 goes back to about 300 BCE. Potsherds of the La Mula Phase of the Greater Coclé ceramic tradition (Cooke 2011; Cooke, Isaza Aizpurua, et al. 2003; Labbe 1995) are abundant in the basal layers that accumulated on the southern side of the 42 m-high eponymous hill (Cerro Juan Díaz) where the original inhabitants faced off a slope and levelled the land behind. This small earthen platform was used for burials (Ops. 3 and 4) (Fig.1.c). Pottery from all the diachronic sub-divisions of the Greater Coclé ceramic sequence are recorded at LS-3. This confirms regularity of occupancy although occasional withdrawal from the site cannot be ruled out. Pre-Columbian people stopped living there after violent Spanish incursions in the second decade of the 16th century CE (Sauer 1966). However, the site was briefly occupied later in this century (ca. 1575 CE) when an "Indian town" or "pueblo de indios" was founded by colonial managers on and around the central eponymous hill with non-local Native Americans of mixed cultural heritage (Cooke, Sánchez Herrera, et al. 2003).

The treatment and placement of the dead varied both synchronously and diachronically. These behaviors show a ranked society where some social groups had more privileges than others as evidenced by the burial associated elements that accompanies them. These were made with shells and in some cases with animal bones such as deer, also lithic and pottery and in a few cases, gold elements were found (Carvajal-Contreras 1998; Cooke, Jiménez-Acosta, and Ranere 2007, 2008; Cooke et al. 2013; Jiménez-Acosta and Cooke 2001; Díaz 1999). Field work in 1992 suggested that one individual in feature 2- Op.3 either had a high relative rank in the community or age group or practiced a particular occupation (*e.g.*, that of shaman-curer) (Cooke et al. 1998:104-107). The objects that supports this interpretation were two hammered high carat gold plaques with convergent raised spirals, about 400 elongate (4-5 cm long) *Spondylus* beads, and 24 jaguar *(Panthera onca)* and puma *(Puma concolor)* canines. The inventory of artifacts in Op.3, Feature 1 also included two ribbon-handled and red-slipped pottery incense burners. These have stylistic counterparts in graves in the south of the Azuero Peninsula where mortuary pottery belongs to the Tonosí Phase (200-500 CE) (Cooke et al. 1998).

In the shaft of Op. 3, Feature 2, seven tight bundles were carefully placed together in the west and south quadrants. Four AMS dates run on bone from four individuals in this group have a combined 2σ range of 345-583 cal CE (Smith-Guzmán 2017). A polished agate bead (c.f. Ichon 1980: Fig.86a) was found with package 8 in this group, which was a probable female aged between 18 and 21 years old (Smith-Guzmán 2017). Other agate beads of the same type were found with package 7 (a 35 year old probable male) as well as with the very commingled package 2 and 11. Five perforated canines of jaguar and puma were deposited in package 2

In Op.3, Feature 16, all artifacts were deposited with children (Smith-Guzmán 2016). Items made of marine shell artifacts and animal teeth prevail. For example, 33 *Spondylus* shell pendants were found with an infant aged one or two. In another bundle, a six- to seven-year old child wore the most impressive array of ornaments in the grave unit: a hammered pure copper ring suspended (probably from the nasal septum) with twisted cotton string; 31 dog-shaped *Spondylus*; two polished stone bars, the largest of which was made from an unidentified bluish stone and is perforated longitudinally, and 74 perforated canines (55 puma canines in one group, while the other contained canines of two pumas, 12 ocelots *[Leopardus pardalis]*, and four raccoons *[Procyon lotor]*). In terms of the relative material and symbolic wealth this group of children appears to have been internally ranked. If this holds true, it would suggest that their families or descent groups were also hierarchically ranked.

A different use for the sub-oven graves at Cerro Juan Diaz was provided by Feature 94 in Operation 3, which was cut by one of the stone-walled ovens. Consisting of a box-shaped tomb, it was used twice. The second burial 14C dates to 1500 ± 40 BP (429-643 cal CE). The second interment, that of a young woman, was primary and flexed on the back. After being placed in the grave, large sherds from three deep ceramic bowls painted in the Cubitá style (typological age: 500-700 CE) were thrown in along with a legged metate of volcanic stone (Cooke and Sánchez Herrera 1997: Fig.6 a; Cooke, Sánchez Herrera, and Udagawa 2000: Fig. 8.6 bottom right). The Cubitá style is the one that prevails in the crafters' middens in Operation 1/1B. Also buried with the young woman in Feature 94 was a carved and polished frog with an anomalously long tail (Cooke, Sánchez Herrera, and Udagawa 2000: Fig. 8.7 u.), which had been mended with a string. The shiny white shell is likely a Pacific giant conch (Lobatus galeatus) and therefore possibly crafted in Op. 8, that is described as a shell workshop (Mayo 2004). Underneath the young woman, scattered human remains from an earlier interment were found intermingled with 97 ornaments made of mother-of-pearl (*Pinctada mazatlanica*) and a single perforated margin snail (*Prunum sapotilla*), a small ivory-colored marine gastropod.

The likelihood that the burials in the platform at Cerro Juan Díaz referred to a descent group or one of its components is corroborated by the placement of graves in Operation 4 (Díaz 1999). This cemetery was used later in time rather than the sub-oven graves in Op. 3. Mortuary pottery and 14C dates point to usage between 900 and 1200 CE. The cemetery is dominated physically by a large, deep pit cut into bedrock (Op. 4., Feature 4). Diaz estimated that 27 individuals were buried in Feature 4 (20 adults and seven children and infants) (Díaz 1999: Table 3, c). The person buried at the bottom of Feature 4 was an adult woman placed near a very fine polychrome urn painted in the Late Macaracas style (Cooke, Sánchez Herrera, and Udagawa 2000: Fig. 8.9 a.). Seven extended burials were laid around the edge of Feature 4 but not in the center of the pit. Perhaps these individuals represented lower-ranked individuals of a particular descent group or sub-division thereof. Other burials in Operation 4 were remarkably heterogeneous in size, form, and numbers and types of burial treatments. A family or descent group focus is indicated by single graves housing many forms of burial: in urns; primary extended; primary and secondary flexed, alone or in groups; and niches cut into bedrock (often containing several skeletons or parts of skeletons). Skulls without bodies were included in some graves. Tombs were constantly re-used (Cooke, Sánchez Herrera, and Udagawa 2000: Fig. 8.6, a-d). This funerary behavior is remarkably similar to the one observed at Playa Venado, ca. 200 km east. The few artifacts that were placed with the dead in Operation 4 are comprised of monochrome and polychrome ceramic vessels, *Spondylus* animal effigies, abstract mother-of-pearl pendants and bone ornaments including trapezoidal plaques with perforations probably fashioned from deer long bones and deer tooth pendants (Díaz 1999; Cooke 2004: Fig. 8 k.).

6.4.1.2. White-tailed deer bone and artifacts operation 1/1B

Our study of white-tailed deer bone artifacts and ornaments refers to Operation 1/1B (Fig.1.c.d.e.). The first excavation named Op. 1 was directed by Luis Alberto Sánchez and Adrián Badilla in 1992. They opened a 2 x 5 m area of excavation in a small alluvial flat on the south-western edge of Cerro Juan Díaz (LS-3) and about 30 m from the La Villa River (Fig. 1 b.). They identified an ellipsoidal accumulation of sherds, lithics, shells and animal bones about 1.1 m on the longer axis, and about 0.2 m in depth (Rasgo 1, Op. 1). It seems to have built up quickly, as many sherds could be refitted indicating little post-depositional disturbance. The sherds were mixed with large amounts of marine shells and vertebrate remains: fish, amphibians, reptiles, birds and mammals. The pottery belongs to the Cubitá ceramic group, which, as described above, dates between about 500 and 700 CE. The frequency of the "*Ciruelo*" type of plates confirms contemporaneity with burial feature 94 among the sub-oven graves in Operation 3.
Two years later, in 1994, Olman Solis expanded the original excavation to 6 x 13 m and revealed the full extent of the feature, which rested in a slight depression on a flat terrain (Fig.1. d.e.). The refuse lay stratified with post-holes, which form the edge

of a circular or oval structure (Cooke and Sánchez Herrera 1997). The pristine artifact-bearing layer (Stratum B) is consistently about 20 cm thick but it would originally have been thicker as it extends into the 30 cm plow zone above it whose materials were collected but were thrown away for formal analysis (Stratum A). The matrix is mostly fine silt and ash (Fig. 1 e). Only one organic sample in the midden was radiocarbon-dated: a well-carbonized fragment of a maize cob. Its AMS date of 1470 ± 90 BP (390-764 cal CE) [TO-4594] is consistent with the ceramics associated with the feature but needs to be re-run since $\delta^{13}C$ was not calculated.

6.4.2. Materials and methods

6.4.2.1. Materials

We analyzed white-tailed deer remains recovered during excavations conducted in 1992 and 1994 in Operation 1/1B at Cerro Juan Díaz. An undisturbed layer about 20 cm thick (Stratum B) was selected for analysis. It contained 3379 bone fragments inferred to belong to white-tailed deer, since this species is the only deer reported from this seasonally dry area of Panama, and the only one identified by zooarchaeological analysis at other sites. In Op. 1/1B, the term 'Stratum A' was used for the plow zone. It was not included in the deer bone analysis because of the possibility of sediment-mixing. These remains were analyzed and identified by using a modern reference collection housed at the Smithsonian Tropical Research Institute (STRI) Archaeology Laboratory in Panama City.

6.4.2.2. Methods

María Fernanda Martínez Polanco's zooarchaeological analysis employed several units of quantification:

1. Number of Remains (NR): This metric refers to the total number of remains that make up the zooarchaeological assemblage. It takes into account the total of the remains conserved as a whole, without considering the precision of the taxonomical or anatomical determination (Reitz and Wing 2008).
2. Number of Identified Specimens (NISP): This index considers only the bone remains that were identified taxonomically (Class and below). This index usually provides lower numbers than the NR (Reitz and Wing 2008).

3. Minimum Number of Elements (MNE): Lyman (1994: 290) defines MNE as the "Minimum number of complete skeletal elements necessary to account for all observed specimens". This index quantifies the elements belonging to an individual, whether they are whole or fragmented. For this quantification, it is necessary to take into account different variables of each identified bone fragment, such as the area of the bone, the face, its position in the skeleton, the number of times that it appears in the skeleton and its age.

4. Minimum Number of Individuals (MNI): This index is calculated by summing the most frequent anatomical element that belongs to a taxon, taking into account laterality, age and size (sensu White 1953; Reitz and Wing 2008). It does not reflect the real abundance of an animal and is only a guide to the real number of individuals present in the death assemblage. Neither does this index imply that the animals were complete when the accumulation was formed (Reitz and Wing 2008).
5. Minimum Anatomical Units (MAU): MAU is obtained by dividing the number of taxonomically identified elements (MNE) by the number of times this element appears in a complete skeleton. %MAU is the relativized scale obtained by dividing the MAU for each element by the greatest MAU and multiplying by 100. Subsequently, the %MAU was compared against the utility index proposed for white-tailed deer by Madrigal and Holt's (2002) modification of the index proposed by Binford (1984), and the simplified index of Metcalfe and Jones (1988). For this purpose, the MAU of the long bones was obtained by dividing by two, the phalanges by eight, the cervical vertebrae by five (excluding the atlas and the axis), the thoracic vertebrae by twelve and the lumbar vertebrae into seven (Madrigal and Holt 2002). Then a scatter graph was produced, on the X axis is the utility index and on the Y axis the %MAU and a correlation coefficient (Spearman's rho) was calculated between these variables.
The age at death of white-tailed deer was established by reference to epiphyseal fusion, tooth

eruption sequence, and tooth wear. Two age categories were used: sub-adults (<24 months) and adults (>24 months) (Severinghaus 1949; Purdue 1983). This deer species exhibits sexual dimorphism, and María Fernanda Martínez Polanco identified males when antlers were present (Smith 1991).

The differential destruction of bone may be influenced by its intrinsic characteristics, such as its density. Another influence is the intensity of external forces that act on the bone (Lyman 1994). In order to determine sample integrity, MAU and its frequencies were calculated (Lyman 2008) as well as the conservation differential in relation to bone density (VD). We used Lyman's (1994) averaged values following Reitz and Wing (2008). We plotted volume density (VD) against NISP and calculated a correlation coefficient (Spearman's rho) between these variables. In order to determine skeletal completeness, we compared archaeological bone frequencies with the expected frequencies if the deer skeleton were complete, applying the following equation:

$$d = (LnX)-(LnY)$$

X is the percentage of each skeletal portion (% NISP) and Y is the percentage of the same portion in a complete skeleton; both are standardized by using the natural logarithm (Ln). In this type of graphic, positive values imply that the skeletal portions are overrepresented and negative values indicate that the skeletal portions are underrepresented compared to the standard (Reitz and Wing 2008). The skeletal portions were organized as a follows: Head (cranium, mandible, maxilla); Axial (Atlas, axis, lumbar, thoracic, cervical, and sacral vertebrae, sternum, ribs); Forequarter (scapula, humerus, ulna, radius); Forefoot (acetabulum, ilium, ischium, femur, tibia); Hindquarter (scaphoid, trapezium, uncinated, lunate, metacarpal, rudimentary metacarpal); Hindfoot (Patella, metatarsal, astragalus, calcaneus, cuboid, cuneiform, intern cuneiform) and foot (metapodials, proximal, medial, and distal phalanx) (Reitz and Wing 2008).

To study long bone representation, we recorded the anatomical zone (proximal, medial, distal, whole) of the long bones.

The remains found in archaeological sites are characterized by the high degree of fragmentation, which could be caused by different taphonomical agents such as biological agents and/or physical processes. In order to, distinguish the agent of the fragmentation (physical or biological) two different concepts could be used fragmentation when the cause is a physical process and fracture when a biological agent is the responsible (Fernández-Jalvo and Andrews 2016).

The inherent characteristics of the bone produce different breakage patterns depending if the bone is green or dry (Bunn 1983; Villa and Mahieu 1991). Green bones have a high degree of plasticity, but they could break when the pressure is greater than their strength. In these cases, the fracture follows the natural lines in the structure of the bone. The fractures are produced by biological agents when the bone is fresh, because their intention is to obtain the nutrients that are inside the bones (Bunn 1983; Villa and Mahieu 1991). The opposite case is the fragmentation of the dry bone; because the physical characteristics of the bone changed, now the bone has lost its moisture and its organic properties, and it becomes fragile and brittle. As such, dry bones reacts differently under pressure, forming perpendicular cracks. This kind of fragmentation is produced by physical processes (natural processes) without any intentionality (Bunn 1983; Villa and Mahieu 1991).

For the purpose of identifying the biological agent causing the bone breakage and the surface alteration we distinguished color changes in the outlines and also fracture angle for distinguishing an old breakage (occurring at or near the time of deposition) from a new breakage (occurring during or after the excavation) (Steadman, Plourde, and Burley 2002). Villa and Mahieu (1991) observed that the fractures are curved with oblique angles and smooth surfaces, while fragmentation is transversal with straight angles and smooth or irregular edges.

Butchering consists of a set or series of sets of human activities directed towards the extraction of consumable resources from a carcass (Lyman 1994). Preparing carcasses for consumption involves a series of activities that includes the extraction of external nutrients (skin, meat, and tendons) to obtaining internal resources (fat and marrow) (Binford, 1981). Butchery marks can be identified in the archaeological record; they are known as cut marks. They are linear grooves, with a variable longitude and width. The transversal section of a cut mark has a "V" shape, and their walls and the bottom present microestriae (Potts and Shipman, 1981; Shipman and Rose, 1983a; 1983b). According to Binford (1981), cut marks can result from three activities: 1) skinning; 2) disarticulation and 3) filleting (Binford, 1981). Skinning is the activity that refers to the extraction of the animal's skin, separating it from the rest of the body. This type of cut mark is produced in areas with little muscle mass, such as the skull, mandible, distal radius and tibia, and in the metatarsals (Binford, 1981). The disarticulation consists of dismembering the animal into quarters. This type of activity is carried out to facilitate the transport of the animal and is done following the anatomy of the animal. The disarticulation marks are located at very specific points, on articular surfaces of the ends of long bones and on the surfaces of vertebrae or pelvic parts (Binford, 1981). Defleshing is the extraction activity of meat, which is attached to the bones. This process is one that leaves the greatest number of marks. Although they can be found on all the skeletal parts of the animal, more frequently in the parts with less muscle mass. They are very frequent in the diaphysis of the long bones, but also in the metaphyses of the bones, particularly in areas of muscle insertions (Binford, 1981).

A series of activities involves the manufacture process. Abrading is the reduction of the surface material using a grinding implement such as a sandstone abrader. Abrasion used in the manufacture of tools results in striations, a series of thin, parallel lines. Chopping is a percussive action where a relatively heavy tool cuts into the raw material resulting in a series of notches in the chopped surface. Cutting is produced with sharp tools which are pushed and pulled over the surface leaving incisions in the form of small channels. Grooves are generally larger, deeper versions of incisions. Incising and grooving are two actions that are performed during the cutting of the raw material. Scraping is an action aiming at reducing and shaping the surface of the raw material by pulling and pushing a scraping tool over the surface while applying pressure. The resulting debris is often dust-like pieces of material. Finally, polishing is an action which adds luster to the surface of osseous tools, achieved through abrasion with a very fine stone and often soft materials such as hide (Nagy 1990; Pérez Róldan 2005; Pérez Roldán 2013).

Surface alterations were identified macroscopically and microscopically. All skeletal specimens were examined using a stereomicroscope (Leica Wild M10, up to 120x). The analysis of cut marks took into account the number of striations, location on the anatomical element, distribution over the surface (isolated, clustered and crossed), orientation with respect to the longitudinal axis of the bone (oblique, longitudinal and transverse) and delineation (straight or curved). By studying the anatomical location and orientation of a cut mark and the function of a particular category of mark suggested by its location and orientation the cut mark could be assigned to a different activity (Binford 1981; Potts and Shipman 1981; Shipman and Rose 1983). The pictures of the cut marks were taken with a 3D digital microscope (HIROX KH-8700, MXG-2500REZ, 35-250x). Six degrees of thermal damage were identified [from 0 (unburned) to 5 (calcined); degree #6 was used for specimens with two or more burning hues using the criteria of Stiner et al. (1995).

Tooth marks were analyzed and compared systematically in order to distinguish between human and non-human marks (i.e., those made by carnivores and rodents). Human tooth marks were classified as pits (ovoid shape and shallowness) and scores (elongated shape and internal crushing) (Landt 2007). Carnivore and rodent marks were analyzed; carnivore marks would be classified as pits, punctures, and scores (Binford 1981; Selvaggio 1994). Other damage produced during consumption, such as notches, crenulated edges or pitting, was recorded; these marks' distribution, orientation and dimensions were all recorded. Finally, post-depositional modifications were also recorded, such as manganese, adhering concretions, root damage, and weathering probably commensurate with humidity (Grayson and Delpech 1998; López-González, Grandal-d'Anglade, and Vidal-Romaní 2006).

6.4.3. Results

6.4.3.1. Zooarchaeological analysis

In Op.1/1B at Cerro Juan Díaz, 3379 remains of white-tailed deer were found in our samples; the MNE calculated for the assemblage is 604 (Tab. 1). A total of 11 individuals was identified and 9 of them were adults, two were subadults - at least seven males and one female.

Table 1. NISP (Number of Identified Specimens) and MNE (Minimal Number of Elements) of white-tailed deer (Odocoileus virginianus) in Operation 1/1B at Cerro Juan Díaz.

Element	NISP	%NISP	MNE	%MNE
Occipital	3	0.09	2	0.33
Basioccipital	3	0.09	3	0.50
Exoccipital	8	0.24	7	1.16
Supraoccipital	1	0.03	1	0.17
Presphenoid	2	0.06	1	0.17
Parietal	1	0.03	1	0.17
Interparietal	1	0.03	1	0.17
Squamosal	5	0.15	3	0.50
Frontal	4	0.12	2	0.33
Antler	36	1.07	20	3.31
Zygomatic	5	0.15	4	0.66
Premaxilla	1	0.03	1	0.17
Maxilla	3	0.09	3	0.50
Tympanic bulla	16	0.47	14	2.32
Mandible	26	0.77	19	3.15
Incisor	2	0.06	2	0.33
Molar	35	1.04	35	5.79
Premolar	30	0.89	30	4.97
Atlas	6	0.18	5	0.83
Axis	1	0.03	1	0.17
Lumbar vertebrae	10	0.30	8	1.32
Thoracic vertebrae	15	0.44	15	2.48
Cervical vertebrae	13	0.38	7	1.16
Sacral vertebrae	3	0.09	3	0.50
Sternum	6	0.18	3	0.50
Ribs	40	1.18	20	3.31
Scapula	31	0.92	14	2.32
Humerus	35	1.04	17	2.81
Ulna	25	0.74	14	2.32
Radius	34	1.01	17	2.81
Scaphoid	8	0.24	8	1.32
Trapezium	9	0.27	9	1.49
Uncinate	8	0.24	8	1.32
Lunate	9	0.27	9	1.49
Metacarpal	23	0.68	12	1.99
Rudimental metacarpal	13	0.38	13	2.15
Acetabulum	2	0.06	2	0.33
Ilium	2	0.06	2	0.33
Ischium	2	0.06	2	0.33
Femur	51	1.51	28	4.64
Tibia	45	1.33	21	3.48
Patella	4	0.12	4	0.66
Metatarsal	39	1.15	16	2.65
Astragalus	18	0.53	18	2.98
Calcaneus	19	0.56	13	2.15
Cuboid	9	0.27	9	1.49
Cuneiform	6	0.18	6	0.99
Intern cuneiform	2	0.06	2	0.33
Metapodials	34	1.01	29	4.80
Phalanx prox.	54	1.60	51	8.44
Phalanx med.	49	1.45	44	7.28
Phalanx dist.	25	0.74	25	4.14
Phalanx unidentified	9	0.27		
Cranial fragment	7	0.21		
Vertebra fragment	29	0.86		
Long bone fragment >2cm	640	18.94		
Long bone fragment <2cm	1862	55.11		
TOTAL	3379	100.00	604	100

Anatomical representation-MAU: The highest %MAU values were femur, followed by tibia and mandible (Table 2). At operation 1/1B, it is observed that MAU is insignificantly correlated with meat gross yield ($rs = 0.12$; $p = 0.75$) and significantly correlated with marrow gross yield ($rs = 0.75$; $p = 0.02$) (Fig.2). There is no evidence of differential transport of high-yield meat bones to the site. In contrast, bones with higher marrow gross and return rates are more abundant and are more fragmented. Positive correlations between long-bone element abundances and marrow yields at operation 1/1B may show evidences of processing marrow and/or bone artefact production after bones had been brought back to the site.

It is interesting to point out the relatively high number of isolated teeth (NR=67: Incisor=2; Molar=35; Premolar=30) (Tab.1). It is possible that they were selected for crafting activities.

Table 2. MNE (Minimal Number of Elements), MAU (Minimal Animal Units), MAU% of white-tailed deer (Odocoileus virginianus) from Operation 1/1B Cerro Juan Díaz. Occ.: Occurrence.

Element	MNE	Occ.	MAU	%MAU
Mandible	19	2	9.50	67.86
Maxilla	3	2	1.50	10.71
Atlas	5	1	5.00	35.71
Axis	1	1	1.00	7.14
Lumbar vertebrae	8	7	1.14	8.16
Thoracic vertebrae	15	12	1.25	8.93
Cervical vertebrae	7	5	1.40	10.00
Ribs	20	26	0.77	5.49
Scapula	14	2	7.00	50.00
Humerus	17	2	8.50	60.71
Ulna	14	2	7.00	50.00
Radius	17	2	8.50	60.71
Trapezium	9	2	4.50	32.14
Uncinate	8	2	4.00	28.57
Lunate	9	2	4.50	32.14
Metacarpal	12	2	6.00	42.80
Acetabulum	2	2	1.00	7.14
Ilium	2	2	1.00	7.14
Ischium	2	2	1.00	7.14
Femur	28	2	14.00	100.00
Tibia	21	2	10.50	75.00
Patella	4	2	2.00	14.29
Metatarsal	16	2	8.00	57.14
Astragalus	18	2	9.00	64.29
Calcaneus	13	2	6.50	46.43
Cuboid	9	2	4.50	32.14
Cuneiform	6	2	3.00	21.43
Intern cuneiform	2	2	1.00	7.14
Phalanx prox.	51	8	6.38	45.54
Phalanx med.	44	8	5.50	39.29
Phalanx dist.	25	8	3.13	22.32

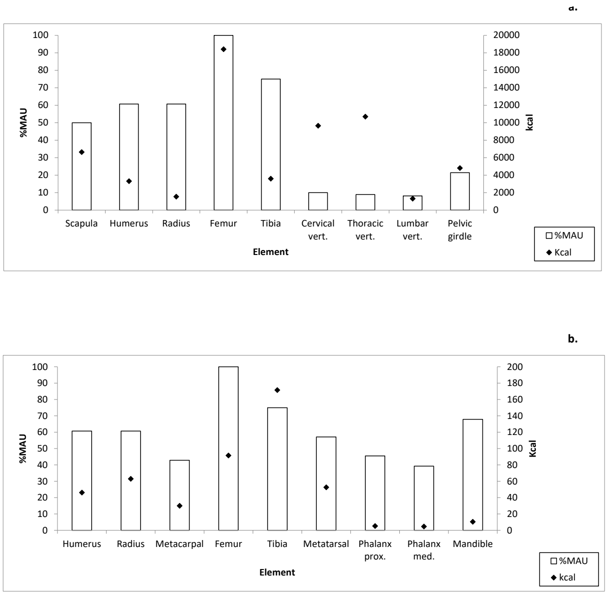

Figure 2. a. Scatter plots ratio kcal meat vs. %MAU and b. kcal bone marrow vs. %MAU.

Volume density (VD): There is a statistically insignificant negative correlation between NISP and VD (*rs*=-0.24, *p*=0.24) (Fig. 3). These results suggest that density-mediated attrition was not responsible for the varying frequencies of skeletal parts.

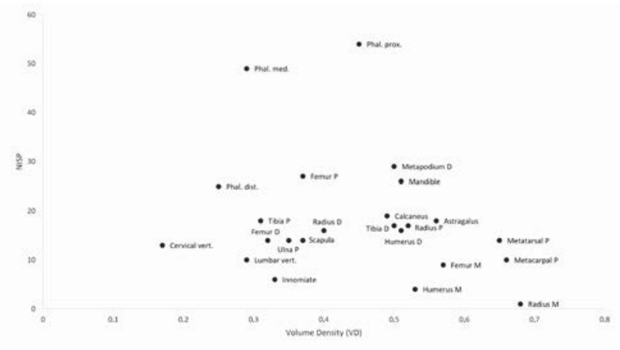

Figure 3. NISP (Number of Identified Specimens) against VD (Volume density) values of white-tailed deer (Odocoileus virginianus) identified at Operation 1/1B Cerro Juan Díaz.

Skeletal completeness: Forefoot, hindquarter, and hindfoot tend to be over-represented but not at the same level, as the forequarter and foot seems to be slightly under-represented but not as much as the axial skeleton (Fig. 4). These results imply that the animal was brought complete to the settlement.

Long bone representation: 252 remains belonged to long bones (7.45%); the best represented zone was the proximal, follow by distal, medial and whole bone (Fig. 5). All the long bones present shared the same pattern of zonal distribution except the ulna that only preserves the proximal portion.

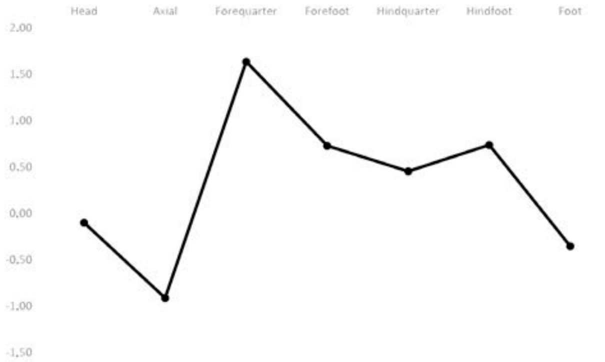

Figure 4. Ratio diagram of skeletal portions using NISP (Number of Identified Specimens) of white-tailed deer (Odocoileus virginianus) identified at Operation 1/1B Cerro Juan Díaz.

The long bone fragments are the most abundant in the sample (74.05%), this group was divided into two categories, those that measured less than 2 cm (55.11%) and those that measured more than 2 cm and less than 4 cm (18.94%) (Table 1). The smallest could be considered as debitage. These fragments do not have a standardized shape that can be allowed to classify them as beads for example. Unfinished deer bone tubes were found in Op. 1/1B but the majority of specimens are proximal and distal portions of long bones that had been cut to make tubes (Section debitage; NISP=32; 0.94%) (Fig. 5; Fig.6). The long bone > 2cm category includes specimens that present evidence of anthropic fractures (NISP=63; 1.86%). All of these specimens are considered as craft production remains. However, finished deer bone tubes were not found in this operation (Tab. 3).

Table 3. Percentages and frequencies of white-tailed deer (Odocoileus virginianus) bone reduction.

	NISP	%NISP	%NISP Total sample
Section debitage	32	1.63	0.94
Debitage (Long bones > 2cm) Fracture evidences	63	3.21	1.86
Debitage (Long bones <2cm)	1862	95.14	55.11
Finished deer bone tubes / artifacts	0	0	0
Total	1957	100.00	

In figure 6, it can be observed that the femur at different stages of fusion were used to produce bone tubes, it is important to mention that initial fusion of the proximal part begins at 20 months and finishes between 32-38 months. In the case of the distal end fusion, the timing is between 23-38 months (Purdue 1983). This implies that the Op-1/1B crafters selected young adult deer bones to produce bone tubes. In only two cases distal humeri without fusion were found; this part begins to fuse at 2 months, and it is completely fused between 12 and 20 months. This represents the two sub-adults of the sample. Figure 5 also illustrates the transversal clean cut both in the proximal (a. b. d. and d.) and distal (f. and g.) sectors of the femur.

The only bone tube found at Cerro Juan Díaz can been seen at Figure 6 e. The length of the tube is 106.5 mm, the width is 21.8 mm and the thickness is 2.54 mm. The proximal part of the tube has a series of fine horizontal grooves with a very shallow depth that may have been produced by abrasion when the thickness of the bone was being reduced. This tube is polished on all sides including the edges.

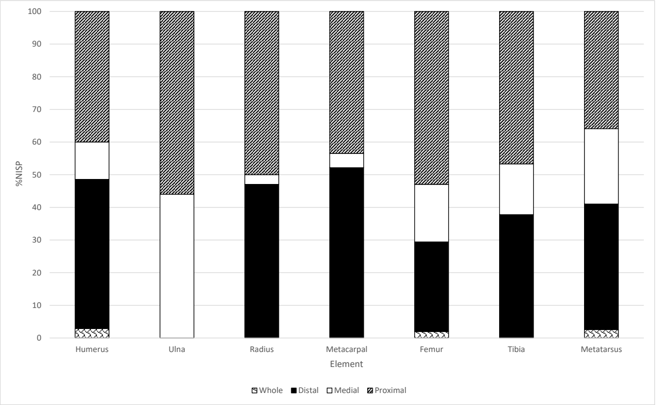

Figure 5. Long bone %NISP arranged by elements of white-tailed deer (Odocoileus virginianus) identified at Operation 1/1B Cerro Juan Díaz.

6.4.3.2. Taphonomic analysis

6.4.3.3.1. Anthropic modifications

Anthropic modifications to deer bones were identified on 192 remains (5.6%), and most of them consisted of burning damage, fractures, and cut marks (Table 3, Figure 6-7).

Figure 6. Long bone tube stages of manufacture made of white-tailed deer (Odocoileus virginianus) femur identified at Operation 1/1B Cerro Juan Díaz. a. Unfused right proximal femur; b. Fused right proximal femur; c. d. Fused left proximal femur; e. Bone tube from a right femur diaphysis; f. Unfused right distal femur; g. Unfused left distal femur. Scale is 2 cm.

Table 4. Anthropic modifications and post-depositional modifications on white-tailed deer (Odocoileus virginianus) bones at Operation 1/1B Cerro Juan Díaz.

Anthropic modifications				Post-depositional modifications			
	NISP	NISP Ant.mo	%NISP Total sample		NISP	%NISP Post. Mod.	%NISP Total sample
Cut marks	45	23.44	1.33	Rodents	21	22.83	0.62
Burning damage	84	43.75	2.49	Concretion	44	47.83	1.30
Fractures	63	32.81	1.86	Roots	25	27.17	0.74
				Manganese	2	2.17	0.06
NR	192	100.00		NR	92	100.00	

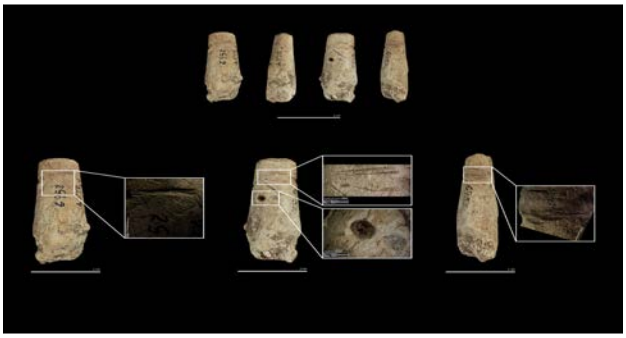

Figure 7. Details of white-tailed deer (Odocoileus virginianus) antler modifications (fairly deep straight incisions and small pit) recovered at operation 1/1B Cerro Juan Díaz. Scale is 2 cm.

Bone fracture patterns: 63 (4.15%) deer remains in Op-1/1B show percussion marks, cortical flake negatives and medullar flakes (Table 4).

Cut marks: 195 cut marks were identified on 45 elements representing 1.33% of the total sample. Cut marks are notable for being fairly deep straight incisions (61.53%). Superficial scraping (36.41%) and deeper hack marks (2.05%) were also observed. The position of the cut marks infers skinning (35.55%) more than other activities such as defleshing (33.33%) and disarticulation (17.77%) The remaining 13.33% are cut marks identified on antlers that could not be assigned to any of the former activities. Several cut proximal and distal portions of long bones were not only identified on the femur, but also on the radius, ulna, metacarpal, tibia, and metatarsal bones. Along the bone edges, cut marks were produced at the precise moment when the bones were cut (Fig. 6).

Burning damage: Eighty-four elements show signs of thermal alteration, representing 1.30% of the sample (Table 4). The majority shows double color (40.48%) and color grade 3 (39.29%). These results imply that cooked meat was consumed to judge from the patterns of burning discoloration identified in some elements. However, it is striking that 16 of the 84 elements were antlers. This may indicate that fire was used in some way in the process of making bone artifacts.

Tooth marks: We did not identify human tooth marks in the sample from Op. 1/1B.

6.4.3.3.2. Post-depositional modifications

Post-depositional modifications were identified on 92 remains (2.72%). Concretions (47.83%), root damage (27.17%), rodent gnawing (22.83%) and manganese stains (2.17%) were the most prevalent (Table 4). Carnivore tooth marks were not identified in the assemblage.

6.4.4. Discussion

At Cerro Juan Díaz, an important quantity of deer remains were found in Op. 1/1B, many of which show traces of human modifications, the most notable being traces of artifact manufacturing. These remains were deposited between 500 and 700 CE and were also placed there partly for nutritional purposes. This idea receives support from the deposition of bones with high meat values such as the femur and tibia, cut marks related to skinning, defleshing and disarticulation, and signs of burning which points to cooking activities.

Nutrition was not the only goal as many of the cut marks on antlers in Op. 1/1B are clearly related to non-subsistence activities (Fig. 7). The choice of materials for the crafting of tools was predicated upon availability, mechanics, the shape of the final product and traditional practice. Long bones (humerus, radius, metacarpal, femur, tibia, and metatarsal) were selected to produce bone tubes (Fig. 5).

Unfinished deer bone tubes were found in Op. 1/1B but the majority of specimens are the proximal and distal portions of long bones that had been cut to make tubes, and we consider these debitage (Fig. 6) (*i.e.* Cooke and Jiménez-Acosta 2010: Fig. 3.6 j). Small cut marks are visible al ong the edges of long bones prior to the final sectioning of the diaphysis from the proximal and distal ends. A complete tube made of an *Odocoileus virginianus* femur shaft was found in a burial (Feature 10) in Op. 4, suggesting that deer bone artifacts produced in Op. 1/1B were used in other sectors of the settlement.

The transformation of long bone into tubes implies the selection of bones of young adults. The extraction of the proximal and the distal end of the bones occurs first. Next, abrasion is used in order to reduce the thickness of the element or to obtain more regular surfaces and finally the polishing of the tube (Fig.5). The large number of long bone remains less than 2 cm may reflect the elaboration of other artifacts, but since we do not have many finished objects in the deposit, it is difficult to establish the elaboration process of any product. Although we did not find direct evidence of modifications in deer teeth, the relatively high number of isolated elements leads us to think about a selection or preselection of elements to produce pendants, such as those found in other operations (i.e. Op.4; Op.1/1B stratum A).

The Sitio Conte elite burial ground is located 12 km inland from the present-day Parita Bay coastline and about 43 km linear distance from Cerro Juan Díaz across Parita Bay (Fig.1.a.). Most graves are now estimated to belong to the period cal 750–950 CE, with a few being slightly earlier or later (700–750 and 950–1000 CE) (Cooke, Sánchez Herrera, and Udagawa 2000). At this site, mortuary goods were deposited abundantly near human remains and can be classified into three groups: 1) costume items such as helmets, necklaces, shirts, belts, danglers, and ankle decorations, 2) ritual objects such as batons, and 3) weapons such as spear, probable arrow points, and spear-throwers. These objects were made of different raw materials such as gold, resin, and animal bones (Summarized in: Briggs 1989; Cooke and Jiménez-Acosta 2010; Cooke 2004).

Bone and tooth ornaments and tools are diverse at Sitio Conte and often expertly crafted. The most remarkable item found is an exquisitely carved deer vertebra (see Lothrop [1937: figs. 192,193] the white-tailed species). Lothrop (1937:215) proposed that a "robust and powerful male" wore a "shirt" decorated with bone tubes, which reached from his shoulders to the middle of the thighs. A smaller cluster of bone tubes was found near the feet suggesting that they formed ankle decoration. These appear to be white-tailed deer long bones. Hollow green bones arranged in a group tend to rattle and this fact undoubtedly increased their impact in ceremonies.

Pérez Roldán (2009) divides the usage of the artifacts in three groups, according to their function: 1) practical objects that had a tool function; 2) ornamental objects that have the function of decorating the human body, such as pendants, beads, and ear flares, and; 3) votive objects made to be placed as offerings in burials and/or artifacts that were used by the individuals and were buried with them. The practical group includes tubes, defined by Valentín and Perez Roldán (2010), as pieces that has an elongated morphology and an annular section by fitting straight long bones of bird or mammal. The function of these is unknown. These authors report the presence of one deer bone tube (H44a) in the bone artifact collection from the archaeological site of Monte Alban (Oaxaca, México). In the case of deer bone tubes founded at Sitio Conte, their function is more related to the ornamental type, and in the case of the complete bone tube found at Cerro Juan Díaz also fits into this category.

Also part of the Sitio Conte mortuary attire were (1) large mammal teeth capped with gold (Lothrop 1937: fig. 166), (2) aprons of domestic dog teeth (Lothrop 1937: fig.105), (3) necklaces of peccary (Tayassuidae) tusks (Lothrop 1937: fig.130), (4) garments made with avian long bones including booby (*Sula* spp.) (Lothrop 1937: figs. 103, 104; Cooke and Jiménez 2010: fig. 3.7), (5) carved manatee ribs (*Trichechus manatus*) (Lothrop 1937: 170 and passim), and (6) a delicate hair-comb (Lothrop 1937: fig. 72).

In comparison with high-ranked sites (i.e. Sitio Conte), the bone mortuary goods found at Cerro Juan Díaz (LS-3) during the same period (750–950 CE) in Op. 3 (above ovens) and Op. 4 are strikingly sparse (Cooke and Jiménez 2010: Table 3.2). Only one white-tailed deer long bone tube from a young adult individual was found intact (in Op. 4, burial feature 10) (Cooke and Jiménez 2010: Fig. 3.6, h). In this context, 10 deer bone/antler artifacts and 20 perforated deer teeth probably used as pendants were found (Cooke and Jiménez-Acosta 2010: Table 3.2). One white-tailed deer bone artifact in Op. 1/1B (Stratum A) consists of a medial piece of a metatarsal, which seems to have been used as a spout perhaps for a gourd (Cooke and Jiménez 2010: Fig.3.6 d). In addition, a perforated 3rd right mandibular premolar was found (Cooke and Jiménez-Acosta 2010: Fig. 3.8 o).

The white-tailed deer was not the only vertebrate that was processed in Op.1/1B for making artifacts. The proximal and distal ends of avian long bones belonging mostly to boobies (*Sula* spp.) were discarded in the bone pile and the shafts were most likely taken elsewhere (Cooke and Jiménez-Acosta 2010: Fig. 3.7). In Op. 1/1B, at 'Stratum A' several bird bones that had been cut for use as artifacts were identified. Eighteen cut bones belonged to boobies: one carpometacarpal, 12 ulnae, four humeri, and one radius. Apparently, a member of this community was deft at working fragile bird bone and may even have travelled to booby breeding colonies at Isla Villa, 12 km south east of Cerro Juan Diaz to procure them (Cooke et al. 2013: 523). As we shall see below, this idea is not far-fetched. At Sitio Conte, the cut booby bones were ulnae and humeri, cut into long pieces with perforations for passing a string at the proximal and distal ends and/or on shorter lengths of the diaphysis (e.g., Lothrop 1937: figs, 103, 104). Boobies seem to have had great regional significance on a ritual plane: a blue-footed booby (*Sula nebouxii*) rostrum was reported in a pre-Columbian grave at Panamá Viejo (Mendizábal 2004: 149). These Parita Bay communities consumed large amounts of fish and it is understandable that boobies and ospreys were revered (Cooke and Jiménez-Acosta 2010).

6.4.4.1. Another workshop at Cerro Juan Díaz (LS-3)

A contemporaneous workshop was found at Operation 8 at Cerro Juan Díaz, located 15 meters from Op. 1/1B on the same small alluvial flat. Pottery found in the feature is largely from the Cubitá horizon. The primary activity of the feature was the preparation of marine shells for making ornaments and tools (Mayo 2004; Mayo and Cooke 2005; Mayo 2007). Ranked by weight (g) the species preferred for crafting were Pacific giant conch (*Lobatus galeatus*), thorny oyster (*Spondylus* spp.), Pacific crown conch (*Melongena patula*), giant mangrove cockle (*Larkinia grandis*), and pearl oyster (*Pinctada mazatlanica*). Cone shells (*Conus* spp.) were ranked above mangrove cockles by weight but Mayo (2004:127) considered that the most common species, *C. patricius*, which frequent nearby beaches today (*i.e.*, Monagre), was collected primarily to make perforators out of the *columellae.* vSpecies- and genus-specific ornaments made in Operation 8 include elongated pendant-beads crafted from Pacific giant conch. They are known to archaeologists as "*cuentas de bastón*" (walking-stick pendants) (Mayo 2004; Mayo and Cooke 2005; Mayo 2007). They were used to make necklaces, which were frequently placed in burials of the period 500-850 CE (Lothrop, Foster, and Mahler 1957). *Spondylus* ornaments produced in Op. 8 consisted mostly of "*chaquiras*" -- minute beads with an average diameter of 0.5 cm (Mayo 2004; Mayo and Cooke 2005; Mayo 2007). Operation 8 overlaps in time with Op. 1/1B. One hundred and fifty-eight "*chaquira*" beads of *Spondylus* were placed in Feature 16 in Operation 3 (Cooke and Sánchez Herrera 1997).

6.4.4.2. Deer bone-antler workshops and specialization

Cooke (2004) and Cooke and Ranere (1992) pointed out that 'Gran Coclé' society may have been organized into ranked and named clans, which would have used animal and plant identifiers. Genealogy and ancestry were probable determinants of rank and the chiefs only came from certain social groups. It is possible that the same pattern occurred among crafters, that artisans belonged to a distinct social group. Cooke and Jimenez (2010) point out that the greatest number of carved bone artifacts occurs in grave 32 at Sitio Conte. Some objects, such as the carved vertebrae, the bone box, and the spear-thrower guards, exhibit unusual crafting skills. In this grave, 3 adult males were found and probably belonged to a lineage of specialist bone carvers. Taking this information into account, it is feasible that the deer bone and antler artisans who worked in Op.1 / 1B in Cerro Juan Díaz belong to the same social group of specialists and the knowledge of bone and antler making techniques passed from one generation to another. Another support for the hypothesis of a specialization in the bone industry is related to the fact that all the evidence of manufacturing was found in the same place at Cerro Juan Diaz (southwest of the settlement), both the shell workshop (Op. 8) and the deer bone antler workshop (Op.1/1B).

However, this is not the case for examples in the Iroquoian sites of Mailhot-Curran and McDonald where there are no concentration of remains that could be associated with bone workshops. In these sites, manufacturing debris are equally distributed in each family space of the longhouses. That implies the existence of the sharing of technical knowledge about bone tool production between families and also between households. It is possible that anyone in the household was able to make bone objects (Gates St-Pierre et al. 2016; Gates St-Pierre, Boisvert, and Chapdelaine 2016).

At La Montesita site (Aguascalientes, Mexico), approximately dating to the Epiclassic period (600-900 AD), a specialized area devoted to bone and antler work was identified. According to the authors, this area reflects an ideal working space, with access to light, comfortable space, tools, and raw materials (Blasco Martín et al. 2019).

The Classic Maya site of Aguateca (Guatemala) shows an interesting pattern of bone crafting production. In this site, there is evidence that all the members of Maya nobility were also artisans, and they produced bone artifacts. This site also shows that certain parts of the bone crafting process were carried out in certain households and in separate areas of each structure. The zooarchaeological evidence found in this site pointed out that the Maya women were directly involved in crafting activities, particularly in those related to food and textile areas (Emery and Aoyama 2007).

6.4.5. Conclusion

The study of deer bone and antler permits an understanding of different human behaviors related to social and economic organization, but it is also linked to a symbolic and ritual world. Along with white-tailed deer distribution, these patterns were different and respond to a distinctive need. The refuse feature in Operation 1/1B at Cerro Juan Díaz clearly represents the waste of a deer bone and antler workshop. In this operation, we did not find the kinds of final products that were used at the elite graveyards such as Sitio Conte, i.e., awls, chisels, spear and/or arrowheads, spear-throwers, and hair-combs. This workshop appears only to have prepared tubes fashioned from white-tailed long bones. We identified evidence of the debitage produced by the manufacture of artisanal bone artifacts.

Knowledge of bone industry techniques and methods may have been passed down within families from generation to generation. Following the model proposed, the social status of the craftsman was inherited; birth within a certain family group determined the status of the new members of the group.

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6.5. Living on a continental island: Interactions between a dwarf deer (*Mazama* sp.) and a Mid-Holocene community (6.2-5.6 cal yr BP) on Pedro González island (*Pearl Island Archipelago, Panama*)

In this chapter, it will be presented all the results of the taphonomical study of the dwarf deer found at Playa don Bernardo, as well as the results from the analyses of microwear, mesowear, stable isotopes and geometric morphometric. The aim of these analyses was 1. to describe deer accumulation at Playa don Bernardo; 2. to study the Pearl Island dwarf deer's ancient diet; 3. to make inferences about current Pearl Island dwarf deer taxonomy, and 4. to evaluate Mid-Holocene human impacts on Pedro González island. Finally, a discussion of these aspects will be presented.

6.5.1. Results

6.5.1.1. Taphonomical analysis

At Playa don Bernardo, 2502 remains of deer were found in our samples. A total of 22 individuals were identified. Five subadults (22.7%), and 17 adults (77.3%) (Figure 6.5.1). The greatest quantity of remains was found in macrostratum III, followed by macrostratum II and macrostratum I.

Anatomical representation-MAU: The highest %MAU values by macrostratum are: femur (macrostratum I), ribs (macrostratum II) and mandible (macrostratum III) (Table 6.5.1).

There is no evidence of differential transport of high-yield meat or marrow bones to the site. These results imply that the animal was brought complete to the settlement (Figure 6.5.2).

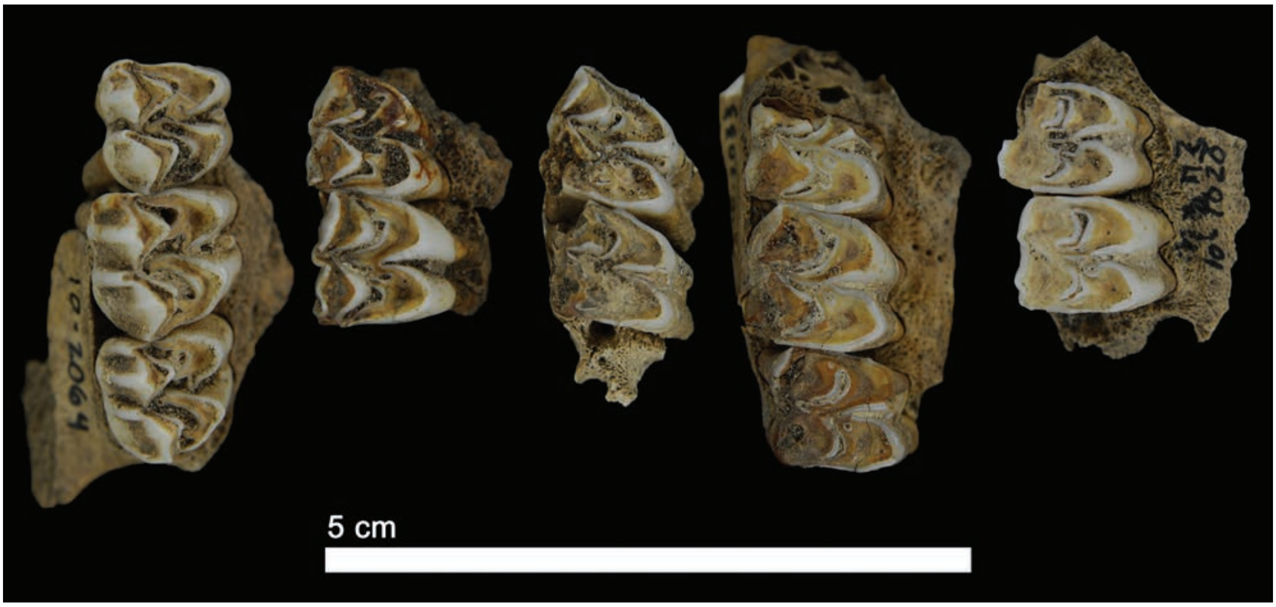

Figure 6.5. 1. Examples of individual dwarf deer of different ages identified at Playa don Bernardo.

Table 6.5.1 MNE (Minimal Number of Elements), MAU (Minimal Animal Units), %MAU of dwarf deer from Playa don Bernardo. Occ.: Occurrence.

Element	I				II				III			
	MNE	OCC	MAU	%MAU	MNE	OCC	MAU	%MAU	MNE	OCC	MAU	%MAU
Mandible	1	2	0.50	20.00	8	2	4.00	86.67	21	2	10.50	100.00
Maxilar	1	2	0.50	20.00	1	2	0.50	10.83	7	2	3.50	33.33
Atlas	0	1	0.00	0.00	0	1	0.00	0.00	2	1	2.00	19.05
Axis	0	1	0.00	0.00	3	1	3.00	65.00	3	1	3.00	28.57
Lumbar vertebrae	1	7	0.14	5.71	7	7	1.00	21.67	11	7	1.57	14.97
Thoracic vertebrae	0	12	0.00	0.00	8	12	0.67	14.44	20	12	1.67	15.87
Cervical vertebrae	2	5	0.40	16.00	12	5	2.40	52.00	13	5	2.60	24.76
Ribs	3	26	0.12	4.62	120	26	4.62	100.00	210	26	8.08	76.92
Scapula	0	2	0.00	0.00	8	2	4.00	86.67	12	2	6.00	57.14
Humerus	1	2	0.50	20.00	6	2	3.00	65.00	8	2	4.00	38.10
Ulna	0	2	0.00	0.00	5	2	2.50	54.17	5	2	2.50	23.81
Radius	0	2	0.00	0.00	2	2	1.00	21.67	10	2	5.00	47.62
Trapezium	0	2	0.00	0.00	0	2	0.00	0.00	1	2	0.50	4.76
Uncinate	0	2	0.00	0.00	1	2	0.50	10.83	1	2	0.50	4.76
Lunate	0	2	0.00	0.00	3	2	1.50	32.50	2	2	1.00	9.52
Metacarpus	1	2	0.50	20.00	2	2	1.00	21.67	8	2	4.00	38.10
Acetabulum	0	2	0.00	0.00	0	2	0.00	0.00	1	2	0.50	4.76
Ileum	1	2	0.50	20.00	4	2	2.00	43.33	6	2	3.00	28.57
Ischium	0	2	0.00	0.00	8	2	4.00	86.67	6	2	3.00	28.57
Pubis	0	2	0.00	0.00	2	2	1.00	21.67	2	2	1.00	9.52
Femur	5	2	2.50	100.00	5	2	2.50	54.17	9	2	4.50	42.86
Tibia	0	2	0.00	0.00	6	2	3.00	65.00	11	2	5.50	52.38
Patella	0	2	0.00	0.00	1	2	0.50	10.83	0	2	0.00	0.00
Metatarsus	0	2	0.00	0.00	5	2	2.50	54.17	7	2	3.50	33.33
Astragalus	0	2	0.00	0.00	4	2	2.00	43.33	7	2	3.50	33.33
Calcaneus	1	2	0.50	20.00	7	2	3.50	75.83	8	2	4.00	38.10
Cuboid	0	2	0.00	0.00	2	2	1.00	21.67	3	2	1.50	14.29
Cuneiform	1	2	0.50	20.00	3	2	1.50	32.50	2	2	1.00	9.52
Phalanx prox.	2	8	0.25	10.00	6	8	0.75	16.25	5	8	0.63	5.95
Phalanx med.	0	8	0.00	0.00	11	8	1.38	29.79	8	8	1.00	9.52
Phalanx dist.	1	8	0.13	5.00	3	8	0.38	8.13	6	8	0.75	7.14

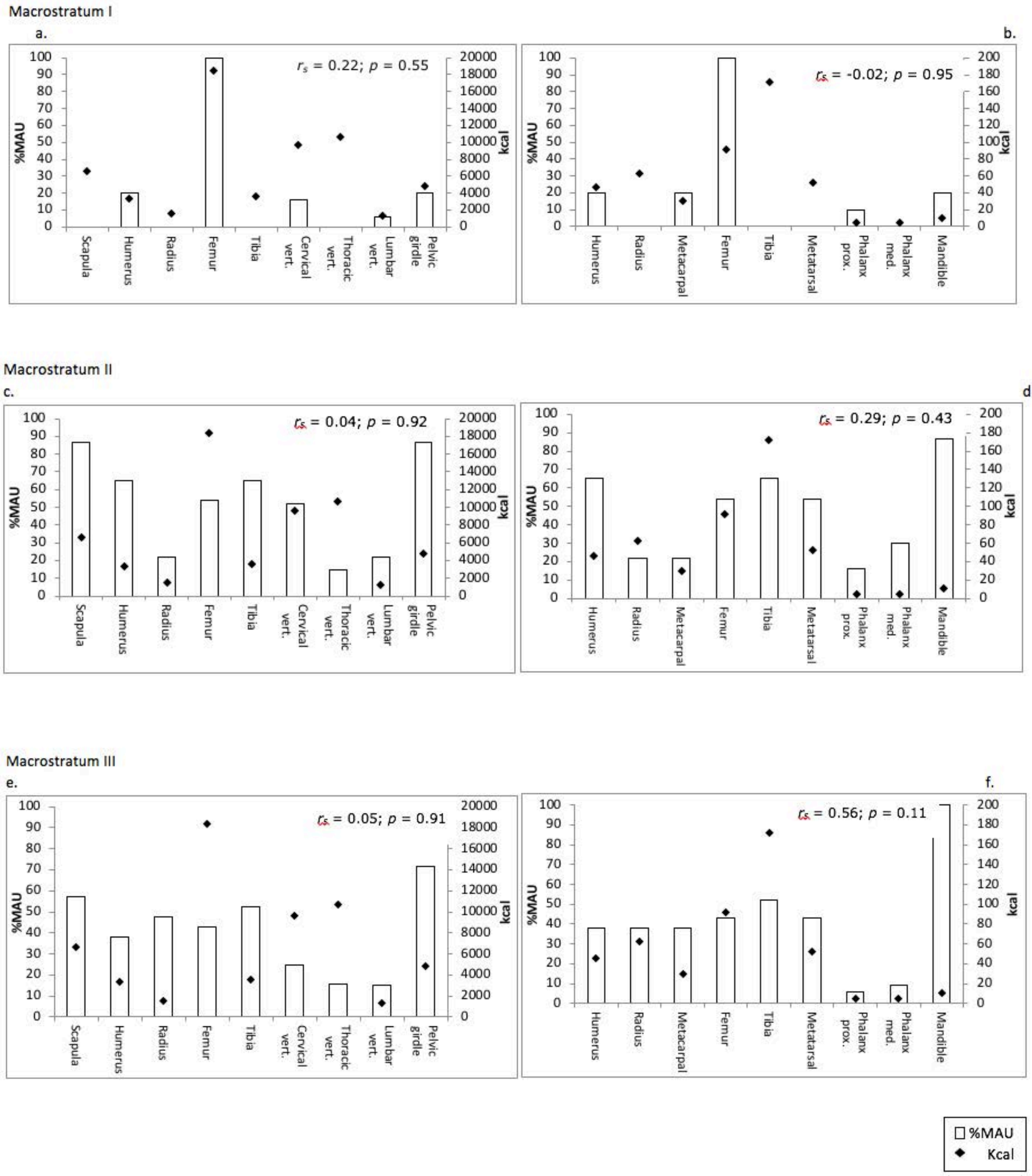

Figure 6.5. 2 a. Scatter plots %MAU vs. ratio kcal meat Macrostratum I; b. %MAU vs kcal bone marrow Macrostratum I; c. Scatter plots %MAU vs. ratio kcal meat. Macrostratum II; d. %MAU vs. kcal bone marrow Macrostratum II; e. Scatter plots %MAU ratio kcal meat Macrostratum III; f. %MAU vs. kcal bone marrow Macrostratum III. Kcal meat and marrow taken from Madrigal and Holt (2002) and used to calculate the Spearman coefficient (rs) and presented on the figures.

Volume density (VD): We observed that some elements with low density are often under-represented, but not in all cases (Figure 6.5.3). There is a statistically significant negative correlation between NISP and VD in macrostratum II (*rs*=-0.50, *p*=0.01) and III (*rs*=-0.45, *p*=0.02). Results for Macrostratum I are not presented because sample size is too low to get reliable statistical results. These results suggest that density-mediated attrition was not responsible for the varying frequencies of skeletal parts.

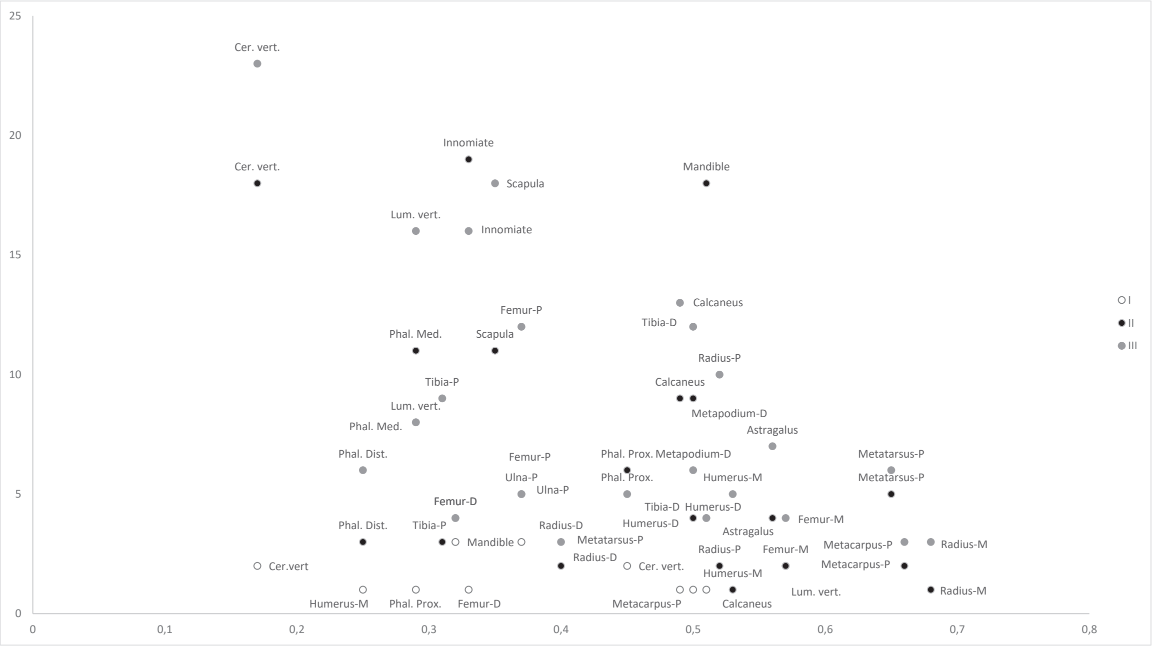

Figure 6.5. 3. NISP (Number of Identified Specimens) against VD (Volume density) values of dwarf deer identified at Playa don Bernardo.-P: Proximal; -M:Medial; -D:Distal; Phal.Prox: Proximal phalanx; Phal.Med: Medial phalanx; Phal.Dist: Distal phalanx.

Skeletal completeness: Foot is under-represented in all macrostratum and hindquarter in macrostratum II and III. Forefoot is overrepresented in macrostratum I. In general, the deer body representation in macrostratum II and III seems equally distributed (Figure 6.5.4).

Long bone representation: 162 remains were long bones (8.47%); the most represented portion was the distal, followed by proximal, and medial part. Complete elements were identified in macrostratum II and III (Figure 6.5.5.a). The length of the remains ranged between 10 and 40 mm (Figure 6.5.5.b).

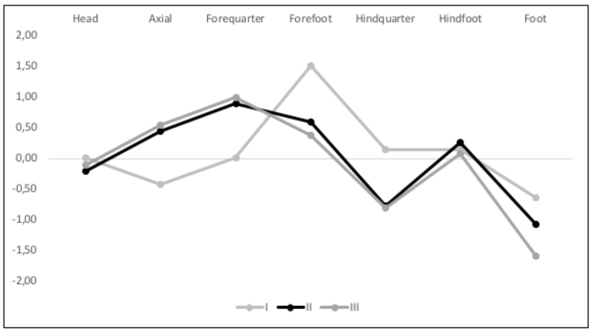

Figure 6.5. 4. Ratio diagram of skeletal portions using NISP (Number of Identified Specimens) of dwarf deer identified at Playa don Bernardo.

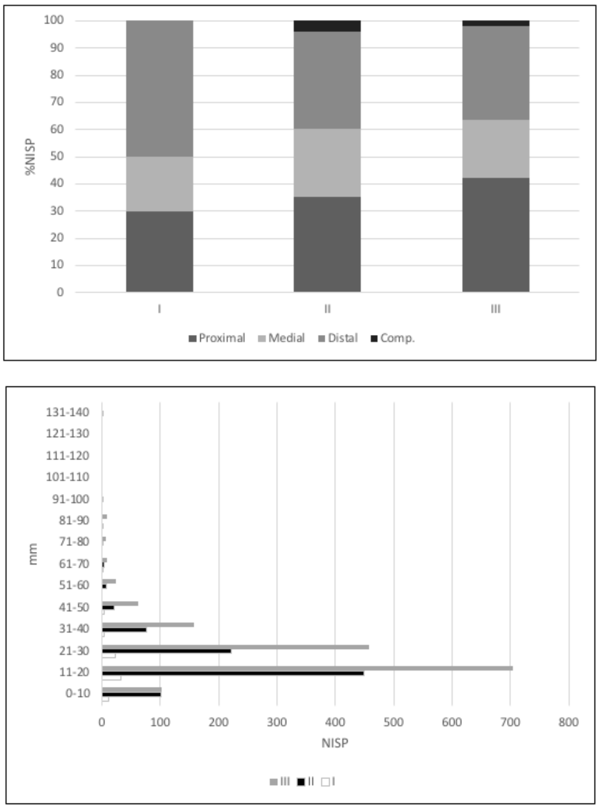

Figure 6.5. 5. a. %NISP of Long bone portion of dwarf deer identified at Playa don Bernardo. b. Lenght of the archaeological deer fragments identified at Playa don Bernardo measurements taken in millimeters. NISP-MS I: 78; NISP-MS II: 888; NISP-MS III: 1536.

Anthropic modifications: Anthropic modifications were identified on 370 remains (14.79%), and most of them were fractures (12.11%), cut marks (1.36%) and burning damage (0.68%) (Table 6.5.2). 112 cut marks were identified on 34 elements representing 1.72% of the total sample. Most of them were found in the Macrostratum II. These marks are fairly superficial and have 1) straight incisions (77%),

2) superficial scraping (20%) and 3) deeper hack marks (3%). The position of the cut marks infers 1) defleshing (26.47%), 2) skinning (14.70%), and 3) other activities (58.82%). The cut marks identified are related to the processes of deer preparation and consumption (i.e., defleshing and skinning); but the great majority of marks is related to other activities, such as preparation of artefacts or tools, taking into account that were found on fragmented long bones and antlers (Martínez-Polanco et al., 2015; Fig. 1). Cooked meat was consumed to judge from the patterns of burning discoloration identified in some elements. 17 (0.68%) elements show thermal alteration. Ribs were peeled clean with the teeth, as it was identified on 16 elements with cortex loss and human tooth marks (0.64 %).

Post-depositional modifications: Post-depositional modifications were identified on 373 remains (14.91%), and the concretions (10.83%) and manganese stains (1.56%) were the most prevalent followed by root damage (1.28%) and weathering (0.48%) (Table 6.5.3). It is proposed that all these changes were related to high humidity (Martínez-Polanco et al., 2015; Fig. 4). Other post-depositional modifications include rodents: 19 remains (0.76 %) remains indicate gnawing. They were identified in Macrostratum II and III (Table 6.5.3).

Artefacts: At Playa don Bernardo 10 finished artefacts were identified: 3 scrapers; 2 awls; 2 gorges; 1 possible projectile point; 1 flaking tool and 1 undetermined element. 70% were made in long bone and 30% in antler. These elements were made by a fracture and were then worn by abrasion to shape and some polishing as well (Table 6.5.4 and Figure 6.5.6). In all macrostratum artefacts were identified. The bone fracture patterns identified at PDB are related to the elaboration of artefacts. In general, percussion cones predominate (82%), all of these specimens are considered as craft production remains. These in general are produced by hitting the bone looking to give it a particular morphology. 9% corresponds to flakes, 7% to negative cortical flakes and 2% to percussion impacts (Martínez-Polanco et al., 2015; Fig. 3).

Table 6.5. 2. Anthropic modifications identified on deer bones at Playa don Bernardo.

	I		II		III				%NR TOTAL SAMPLE
	NR	%NR	NR	%NR	NR	%NR	Total	%Total	
Bone fracture	8.00	66.67	76.00	82.61	219.00	82.33	303.00	81.89	12.11
Cut Marks	2.00	16.67	10.00	10.87	22.00	8.27	34.00	9.19	1.36
Burning damage	2.00	16.67	6.00	6.52	9.00	3.38	17.00	4.59	0.68
Tooth marks	0.00	0.00	0.00	0.00	16.00	6.02	16.00	4.32	0.64
Total	12.00	100.00	92.00	100.00	266.00	100.00	370.00	100.00	14.79

Table 6.5. 3. Post-depositional modifications identified on deer bones at Playa don Bernardo.

		I		II		III				%NR TOTAL SAMPLE
		NR	%NR	NR	%NR	NR	%NR	Total	%Total	
Environmental modifications	**Concretions**	28.00	96.55	50.00	68.49	193.00	76.59	271.00	76.55	10.83
	Manganese stains	1.00	3.45	4.00	5.48	34.00	13.49	39.00	11.02	1.56
	Roots	0.00	0.00	17.00	23.29	15.00	5.95	32.00	9.04	1.28
	Weathering	0.00	0.00	2.00	2.74	10.00	3.97	12.00	3.39	0.48
	Total	29.00	100.00	73.00	100.00	252.00	100.00	354.00	100.00	14.15
Rodents	**Rodents**	0.00	0.00	9.00	0.00	10.00	0.00	19.00	100.00	0.76

Figure 6.5. 6. Artefacts made on deer long bone and antler identified at Playa don Bernardo.

Table 6.5. 4. Artefacts made on deer antler and long bone at Playa don Bernardo.

ID	MS	Element	Extraction tech.	Production tech.	Object	Length (mm)	Figure 6.5.5
10-1337	III	Long bone	Fracture	Abrasion/Polishing	Gorges	32.41	a.
10-1765	III	Long bone	Fracture	Abrasion/Polishing	Gorges	37.28	b.
10-1665	III	Long bone	Fracture	Abrasion	Scraper	46.64	...
9-619	III	Long bone	Fracture	Abrasion	Scraper	62.92	d.
10-1232	III	Long bone	Fracture	Abrasion/Polishing	Projectile point	3.33	e.
11-820	II	Antler	Fracture	Abrasion	?	61.84	...
9-803	II	Antler	Fracture	...	flaking tool	51.86	c.
10-1348	II	Antler	Fracture	Abrasion/Polishing	Awl	27.62	...
10-1008	I	Long bone	Fracture	Abrasion	Scraper	23.7	...
10-1213	I	Long bone	Fracture	Abrasion	Awl	71.42	...

6.5.1.2. Tooth mesowear

The results of mesowear analysis are presented in Table 6.5.5. The diet of the ancient dwarf deer in macrostratum III is inferred to be closed to today's *Mazama* browsers, fruit-browsers or browse-dominated mixed feeders. In macrostratum II, on the other hand, dwarf deer diet seems to be more similar to today's grazers or grass-dominated mixed-feeders (Figure 6.5.7). The Student's t-test shows that the difference between the two macrostratums (t=1.68; p=0.09) is statistically significant (90% confidence level). White-tailed deer diet on Coiba Island is similar to the extant browsers or browse-dominated mixed feeders while white-tailed deer diet on the Florida Keys is more browser-like (Table 6.5.5). In the case of *Mazama* species, differences between *Mazama* from Central America and South America are observed (F=4.11; gl=2; p=0.01) (Table 6.5.6). *Mazama temama* that inhabits Central America is a browse-dominated mixed feeder, while *Mazama Americana* and *Mazama nemorivaga* are more fruit-browsers and mixed feeders (Table 6.5.6).

Table 6.5. 5. Summary of mesowear data for the archaeological deer from Playa don Bernardo (PdB) by macrostratum and extant white-tailed deer (Odocoileus virginianus) from Coiba Island and Florida Keys; Amazonian brown brocket deer (Mazama nemorivaga) from Colombia, Venezuela, British Guiana, Brazil and Peru; Central American red brocket (Mazama temama) from Mexico, Guatemala, Nicaragua, Costa Rica and Panama; red brocket (Mazama americana) from Colombia, Venezuela, Ecuador, Bolivia and Brazil Abbreviations: MS: Macrostratums; n: sample size; MWS: Mesowear score; M: mean; SD: Standard deviation; CV: coefficient of variation.

MS		Mesowear	
		n	MWS
II	M	20	2.75
	SD		1.89
	CV		0.68
III	M	65	1.98
	SD		1.79
	CV		0.9
Odocoileus virginianus Coiba Island	M	6	1.66
	SD		2.06
	CV		1.24
Odocoileus virginianus Florida Keys	M	12	1.16
	SD		1.58
	CV		1.36
Mazama nemorivaga	M	20	2.00
	SD		1.73
	CV		0.87
Mazama temama	M	42	0.92
	SD		1.51
	CV		1.64
Mazama americana	M	55	1.74
	SD		1.58
	CV		0.91

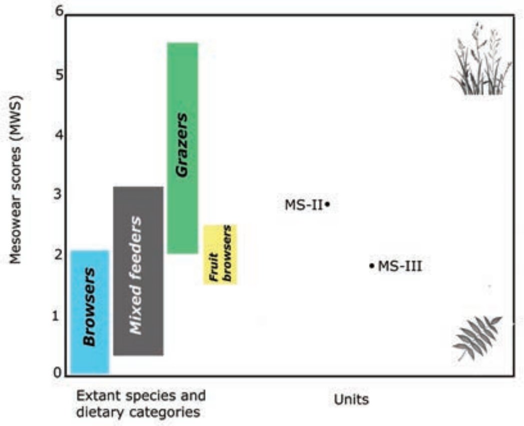

Figure 6.5. 7. Box plots of modern ungulates diet based on Fortelius and Solounias (2000) and Rivals et al. (2013, 2017) and mesowear results for the archaeological deer from Playa don Bernardo (PdB) MS-II and MS-III.

6.5.1.3 Tooth microwear

The number of scratches and pits is low in the samples from the two macrostratums (Table 6.5.7). The values fall in the lower part of the 95% confidence ellipse when compared with modern browsers (Figure 6.5.8). Microwear analysis also indicates that PDB deer were typical browsers at the time of death. There is significant difference in the number of scratches among the two macrostratums ($z = -1{,}68$ $p = 0{,}09$) (90% confidence level) there are no significant differences for the pits ($z = 0$ $p = 1$) according to the Mann–Whitney U test.

Table 6.5. 7. Summary of microwear data for the archaeological deer from Playa don Bernardo (PdB) by macrostratum. Abbreviations: MS: Macrostratums; n: sample size; NS: Number of scratches; NP: Number of pits; M: mean; SD: Standard deviation; CV: coefficient of variation.

MS		Microwear		
		n	NS	NP
II	M	15	8.6	4.96
	SD		2.16	2.18
	CV		0.25	0.44
III	M	25	7.26	5.16
	SD		2.19	2.92
	CV		0.30	0.56

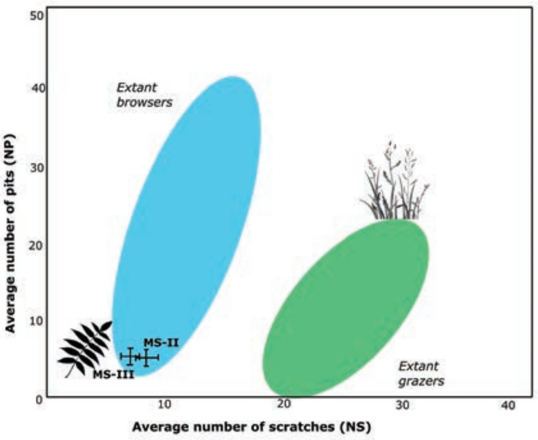

Figure 6.5. 8. Bivariate plot of the average number of pits and scratches for the archaeological deer from Playa don Bernardo (PdB) MS-II and MS-III. Error bars correspond to standard error of the mean (±1 SEM). Ellipses correspond to the Gaussian confidence ellipses (p = 0.95) on the centroid for the extant leaf browsers and grazers from Solounias and Semprebon (2002).

Table 6.5. 6. Tukey's pairwise comparison between mesowear scores of extant Mazama: Amazonian brown brocket deer (Mazama nemorivaga) from Colombia, Venezuela, British Guiana, Brazil and Peru; Central American red brocket (Mazama temama) from Mexico, Guatemala, Nicaragua, Costa Rica and Panama; red brocket (Mazama americana) from Colombia, Venezuela, Ecuador, Bolivia and Brazil.

Species	*Mazama nemorivaga*	*Mazama americana*	*Mazama temama*
Mazama nemorivaga		0.82	0.04
Mazama americana	0.84		0.04
Mazama temama	3.40	3.44	

6.5.1.4. Scratch variability

Scratch variability among deer in macrostratum II is low and the sample falls in Area a on the heat map, and thus corresponds to one season or shorter events (Figure 6.5.9). A different situation is observed in macrostratum III where scratch variability is higher (both CV and SD) and the sample falls in Area b of the heat map and thus corresponds to more-than-one-season events (Figure 6.5.9).

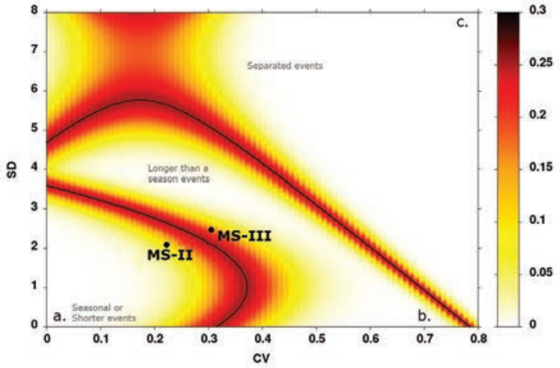

Figure 6.5. 9. Heat map of the standard deviation (SD) and coefficient of variation (CV) values (boundary lines of the three regions with the error probability) and the fossil samples from Playa don Bernardo (PdB) MS-II and MS-III. a. Seasonal or shorter events; b. Longer than a season events; c. Separated events (data from Rivals et al. 2015).

6.5.1.5. Stable isotope analysis

The number of samples of collagen and carbonate analyzed for this study is presented in Table 6.5.8. We could not extract collagen samples due to problems of preservation. Conversely, the carbonates are very well preserved. The results of the carbonate analyses are summarized in Table 6.5.9. $\delta^{13}C_{apatite}$ bone values average -11.63‰ in Macrostratum II and -12.10‰ in macrostratum III. As for tooth enamel, $\delta^{13}C_{apatite}$ values average -12.51‰ in macrostratum II and -12.34‰ in macrostratum III. These results are evidence for a primarily C_3 diet in both macrostratums (Figure 6.5.10). We did not find any significant differences between $\delta^{13}C_{apatite}$ bone values in both macrostratums ($z = -1{,}46$; $p = 0{,}14$); we did not compute the test in the case of teeth because the sample size is small.

Table 6.5. 8. Summary of samples of bone, teeth dentine and teeth enamel for collagen and apatite isotope analysis for the archaeological deer from Playa don Bernardo (PdB) by macrostratum.

MS	Collagen				
	Bone	Enamel	Total sample	Preserved (n)	Preserved (%)
II	7	0	7	0	0
III	23	0	23	0	0
MS	Carbonate				
	Bone	Enamel	Total sample	Preserved (n)	Preserved (%)
II	6	2	8	8	100
III	23	10	33	28	85

Table 6.5. 9. Descriptive statistics of deer carbonate values for the archaeological deer from Playa don Bernardo (PdB) by macrostratum. Abbreviations: MS: Macrostratums; n: sample size; SD: Standard deviation; CV: coefficient of variation.

Sample	MS-II								
		$\delta^{13}C_{apatite}$-VPDB (‰)				$\delta^{18}O_{apatite}$-VSMOW (‰)			
	n	Mean	SD	Min	Max	Mean	SD	Min	Max
Bone	6	-11.63	0.62	-12.36	-10.97	23.83	2.07	20.46	26.34
Enammel	2	-12.51	0.79	-13.45	-11.55	26.72	1.22	24.81	27.76
	MS-III								
		$\delta^{13}C_{apatite}$-VPDB (‰)				$\delta^{18}O_{apatite}$-VSMOW (‰)			
	n	Mean	SD	Min	Max	Mean	SD	Min	Max
Bone	18	-12.10	0.66	-13.21	-11.11	23.08	2.11	19.60	25.54
Enammel	10	-12.34	0.89	-14.49	-11.47	24.84	2.07	19.35	26.61

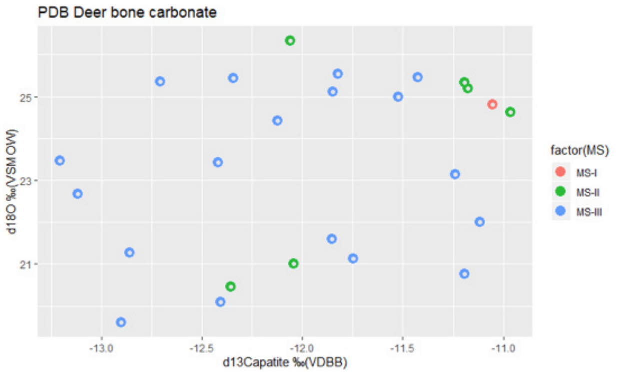

Figure 6.5. 10. PDB Deer bone $\delta^{13}C_{carbonate}$ and $\delta^{18}O$ values from Playa don Bernardo (PdB) MS-II and MS-III. We plotted one value from MS-I from data published by Sugiyama et al., (2020). C_3 plants typically have $\delta^{13}C$ values between–25 and –29‰; $\delta^{13}C$ of C_4 plants values typically ranging –12 to –16‰. CAM plant $\delta^{13}C$ values range between C_3 and C_4 plants, with greater overlap with C_4 values (O'Leary, 1988:Table 2).

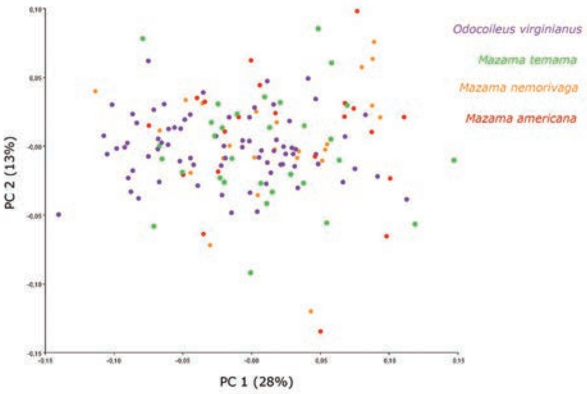

Figure 6.5. 12. Morphospace for the m3.

6.5.1.6. Geometric morphometrics

In the figure 6.5.11 it is observed that there is a greater diversity in the sizes of the deer in the MS-III than in the MS-II. There are not differences between the two occupations (Figure 6.5.11).

The PC scores of the shape of m3 shows that along PC1, the two genera are overlapping, but *Mazama* plots more towards the right side and *Odocoileus* towards the left and along PC2 could be found different *Mazama* species (Figure 6.5.12).

Canonical variate analysis (CVA) of the shape of m3 shows three groups that are significantly different. CV1 separates the two cervid genera, at the right side *Odocoileus* and in the left *Mazama* and CV2 separates the 3 *Mazama* species. The archaeological population of PDB shows a distinct morphotype, and therefore population and probably species (Figure 6.5. 13; Table 6.5.10). In the table 6.5.10 is evident that *Mazama* species are similar between them and PDB populations and *Odocoileus virginianus* are different from them. This is also evident in figure 6.5.14 where wireframe representation of the m3 shape variation and their corresponding landmarks is plotted.

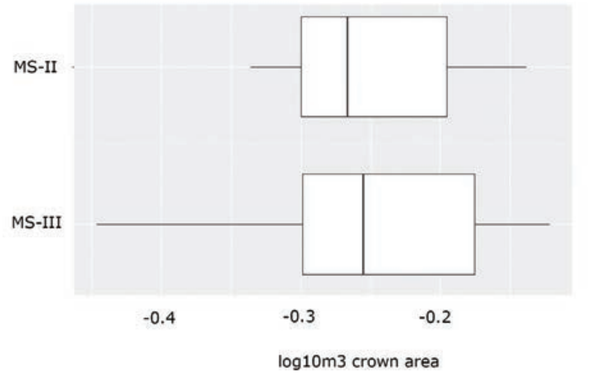

Figure 6.5. 11. Box plot log10 m3 crown area of PDB deer arranged by macrostratums.

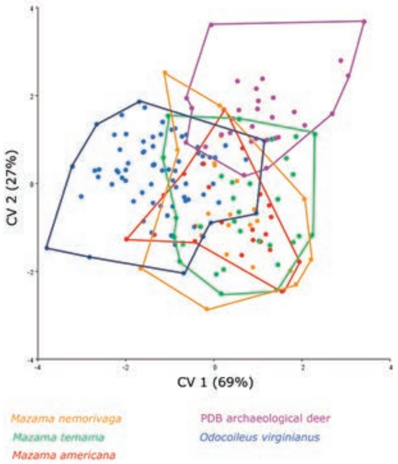

Figure 6.5. 13 .Canonical variate analysis (CVA) of m3.

Table 6.5. 10. Procrustes distance between m3 Playa don Bernardo (PdB) archaeological deer, Mazama Americana, Mazama temama, Mazama nemorivaga and Odocoileus virginianus configurations (DProcrustes), and a probability p that the observed configurations are less correlated than permuted configurations (1000 pairwise permutations).

Comparisons	$D_{Procrustes}$	**p**
Mazama nemorivaga vs Mazama americana	0.03	0.41
Mazama temama vs Mazama americana	0.02	0.80
Mazama temama vs Mazama nemorivaga	0.04	0.08
Mazama nemorivaga vs Odocoileus virginianus	0.05	0.00
Mazama americana vs Odocoileus virginianus	0.04	0.00
Mazama temama vs Odocoileus virginianus	0.04	0.00
Mazama nemorivaga vs Archarological PDB deer	0.05	0.01
Mazama americana vs Archaeological PDB deer	0.04	0.03
Mazama temama vs Arcaheological PDB deer	0.05	0.00
Odocoileus virginianus vs Archaeological PDB deer	0.05	<.0001

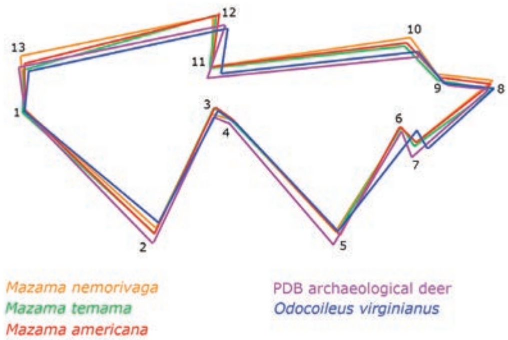

Figure 6.5.14. Wireframe representation of the m3 shape variation and their corresponding landmarks.

Table 6.5.12. Cross-validated results of the linear discriminant function for m3 Playa don Bernardo (PdB) archaeological deer (n=30) using the present-day reference sample.

	Clasification-PdB archaeological deer	
Species	**n**	**%**
Mazama americana	16.00	53.33
Mazama temama	8.00	26.67
Mazama nemorivaga	1.00	3.33
Odocoileus virginianus	5.00	16.67
Total	30.00	100.00

Table 6.5.11 shows the results of a discriminant function analysis (DFA). The 60.22% of the original cases were correctly post-classified and cross-validation tests resulted in an accuracy rate of 39.78% correctly post-classified. In table 6.5.12 the results of the cross-validated linear discriminant function for the 30 archaeological specimens from PDB using the present-day reference sample are presented. The archaeological remains were classified as *M. americana* mostly (53.33%) followed by *M. temama* (26.67%).

6.5.2. Discussion

6.5.2.1 Dwarf deer accumulation purpose

The purpose of deer accumulation at Playa don Bernardo was consumption, however deer bones and antlers were also used as

Table 6.5. 11. The results of the classification and cross-validation analyses for the discriminant function analysis (DFA) of m3 Playa don Bernardo (PdB) archaeological deer, Mazama nemorivaga, Mazama americana, Mazama temama and Odocoileus virginianus.

		Predicted group memberships								
	Group	***Mazama nemorivaga***		***Mazama americana***		***Mazama temama***		***Odocoileus virginianus***		**Total**
		n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	
Original	***Mazama nemorivaga***	15.00	42.86	5.00	16.67	1.00	2.44	3.00	4.00	24.00
	Mazama americana	8.00	22.86	16.00	53.33	13.00	31.71	7.00	9.33	44.00
	Mazama temama	3.00	8.57	4.00	13.33	22.00	53.66	9.00	12.00	38.00
	Odocoileus virginianus	9.00	25.71	5.00	16.67	5.00	12.20	56.00	74.67	75.00
	Total	35.00	100.00	30.00	100.00	41.00	100.00	75.00	100.00	181.00
Cross validated	***Mazama nemorivaga***	10.00	23.81	7.00	20.59	4.00	9.09	3.00	4.92	24.00
	Mazama americana	10.00	23.81	6.00	17.65	20.00	45.45	8.00	13.11	44.00
	Mazama temama	7.00	16.67	9.00	26.47	14.00	31.82	8.00	13.11	38.00
	Odocoileus virginianus	15.00	35.71	12.00	35.29	6.00	13.64	42.00	68.85	75.00
	Total	42.00	100.00	34.00	100.00	44.00	100.00	61.00	100.00	181.00

tools. The anatomical representation along the three macrostrata shows that the whole deer carcasses were taken to the dwellings. The highest %MAU values by macrostratum are: femur (macrostratum I), ribs (macrostratum II) and mandible (macrostratum III). In general, the deer body representation in macrostratum II and III seems equally distributed. Only the foot was under-represented in all macrostratum and hindquarter in macrostratum II and III. Underrepresentation of foot remains could be related to the manipulation of deer skins, usually, these parts remain attached to the fur. The volume density results suggest that density-mediated attrition was not responsible for the varying frequencies of skeletal parts. At Playa don Bernardo complete elements were recovered at macrostratum II and III.

The presence of cut marks (1.3%), as well as human tooth marks (0.6%), thermal alterations (0.7%) and fracture patterns (12%) were reported at Playa don Bernardo. In this study it was found that the 41% of the cut marks on deer bones are related to the butchering process. Three types of marks show skinning (21%), two disarticulation marks (14%) and nine filleting (64%). A large percentage of the cut marks (59%) were found on antlers or on long bone fragments, indicating that deer bones were being prepared as tools or ornaments, especially in the case of macrostratum I and II. It cannot be ruled out that some of the marks on long bones are related to filleting of meat, particularly in macrostratum III.

Taking into account that no mammal predators have been recorded in archaeological sites on the Pearl Island archipelago except for small size facultatively carnivorous opossum, squirrels and monkeys targeting very small preys. Regular predation was in charge of snakes. For this reason, no carnivore tooth marks were identified. The only mammalian modification was produced by rodent gnawing. These could be related to the presence of spiny rats (*Proechimys semispinosus* and *Diplomys labilis*) in the recovered archeofaunas (Martínez-Polanco et al., 2015; Pearson et al., 2020).

6.5.2.3. Dwarf deer taxonomy

It is documented that deer morphology changes whenever animals are isolated on islands, and one of the most common change is a decrease in size (van Der Geer et al., 2006; van der Geer et al., 2010; Lyras et al., 2016). The body mass of extant San José deer is 9.2 kg while PDB deer is 5.8 kg and the average of extant *M. nemorivaga* , one of the closest relative morphotypes in South America, is 14-15.5 kg (Rossi et al., 2010; Buckley et al., 2017; Gallina et al., 2019). In the case of *M. Americana*, body mass is 30-38 kg (Gallina et al., 2019). The degree of size reduction appears to be related to the size of the islands (San José = 44 km² and Pedro Gonzalez = 14 km²) and also with the separation times between these two islands (7500-7200 uncalibrated radiocarbon years ago) (Redwood, 2020). Other isolation-induced changes are a tendency towards hypsodont teeth, more massive limbs, a reduction in the length of the autopodium relative to the body, and increases in the numbers of fusions in the foot bones (van der Geer et al., 2010). Buckley et al. (2017) documented two cases of fusion in tarsals at PDB: (1) a right cuboid fused with the internal cuneiform and (2) a lunar fused with the right cuneiform (Fig. 10.4). The results suggest that the yet unnamed species of deer that inhabited Playa don Bernardo was morphologically related to South American deer (Buckley et al., 2017).

Nowadays wild populations of *Mazama nemorivaga* are not known from the Darién province in Panama nor from the Atrato and San Juan watersheds, which geologically form part of the Isthmus of Panama. The closest wild populations in Colombia are found in the Amazonian region in tropical and subtropical broadleaf moist forests between 0-500 m a.s.l. (Rossi et al., 2010; Gallina et al., 2019). In the case of *Mazama americana*, the closest population are in Colombia, in lowland and montane tropical and subtropical forests including mature, secondary and gallery forest and savannas (Gallina et al., 2019) in different areas of the country such as the Caribean, the Pacific, the Andes, the Orinoco and Amazonian regions. In an altitudinal range between 0-1000 m a.s.l (Varela et al., 2010) however in the Sierra Nevada de Santa Marta even up to 4000 m a.s.l. (Alberico et al., 2000).

According to the geographical distribution of *Mazama*, *M. americana* is widely distributed in Northern South America while *M. nemorivaga* is more restricted to the Amazonian region. Taking into account this information, one possibility that should not be ruled out is that the deer of the San José island and PDB belong to another species of *Mazama* more related to *M. americana*. Our results of the morphometric geometrics analysis point out that PDB presents a distinctive morphotype that could be located between *M. americana* and *M. temama*. If we take a look at *Mazama* diet through mesowear scores, it is observed that brocket deer from Central America had different diet to south American brockets. In such a way that this may be another mode of showing that the island's deer are more related to those of South America.

The relevance of Playa don Bernardo dwarf deer raised over the Great American Biotic Interchange, an event that includes the migration of cervids to South America. Two scenarios could be plausible, Is PDB deer a dwarf form of *Mazama* Americana? Or Is it a different species? if it is another species how much time takes the speciation process? Could be traced to its origin? However, with the data that we have right now is not possible to solve none of these questions. The best way to know, this is would be by conducting genetic studies of current and archaeological populations, although it is worth mentioning that collagen conservation is quite poor in PDB samples as we previously explained for the isotope analysis. We hope that in the near future the development of new techniques gives us more insights about this fascinating dwarf deer story.

6.5.3. Conclusion

Human intervention at PDB included anthropogenic burning of vegetative cover, significant burning and landscape clearance, a novel set of introduced plants and heavy impacts on terrestrial mammals including insular extirpation of the dwarf deer between 5700 and 2300 cal yr BP. The diet of the *Mazama* deer was initially based exclusively on C_3 plants, but human arrival induced changes. At the onset of human occupation represented by Macrostratum III, dwarf deer diet was more diversified than in later occupations. In Macrostratum II, diet shifted towards herbaceous vegetation with a high proportion of abrasive plants. Scratch variability evidenced a change in the durations of the occupations at the site, from a long occupation in Macrostratum III to a short seasonal occupation in Macrostratum II. A more sporadic human presence enabled the island terrestrial fauna to stabilize and even increase slightly. But the dwarf brocket did not survive on Pedro González Island and disappeared at some moment between 5775-2300 cal yr BP when a pottery-using wave of immigrants arrived and stayed for a long period.

6.6. Data summary

Almost 10000 deer remains, collected within a long sequence of occupation at Parita Bay and Pearl Island Archipelago, were analyzed in this thesis. These samples contain 116 individuals; most of them were adults (76.72%); the sex determination was difficult, none of the innominate specimens were suitable for sexing, so the only criterion available was the presence or absence of antler pedicles. There are very few cranial bones in the collections. The principal purpose of these accumulations was consumption. In the assemblages, the meatiest elements are the most frequent (Table 6.6.1). The volume density results suggest that density-mediated attrition was not responsible for the varying frequencies of skeletal parts in none of the samples (Table 6.6.1). Although the consumption of the animals was the origin of the accumulations, each one of them exhibits differentiating characteristics, as can be seen in the results of skeletal completeness and long bone representation (Table 6.6.1). At Playa don Bernardo (PDB), deer body representation seems equally distributed, and only the foot is under-represented. In the other archaeological sites, such as Cerro Mangote (AG-1) and Sitio Sierra (AG-3) forefoot and foot are under-represented (Table 6.6.1). The axial skeleton is underrepresented at Cerro Juan Díaz (LS-3) (Table 6.6.1). In terms of long bone representation, 26.65% of the Cerro Mangote sample were long bones, at Cerro Juan Díaz 16.61%, Sitio Sierra 3 8.47%, and Playa don Bernardo 6.47%.

Figura 6.6. 1. Examples of skulls. a. Cerro Mangote: male; b. Playa don Bernardo: male; c. Cerro Juan Díaz: female, males.

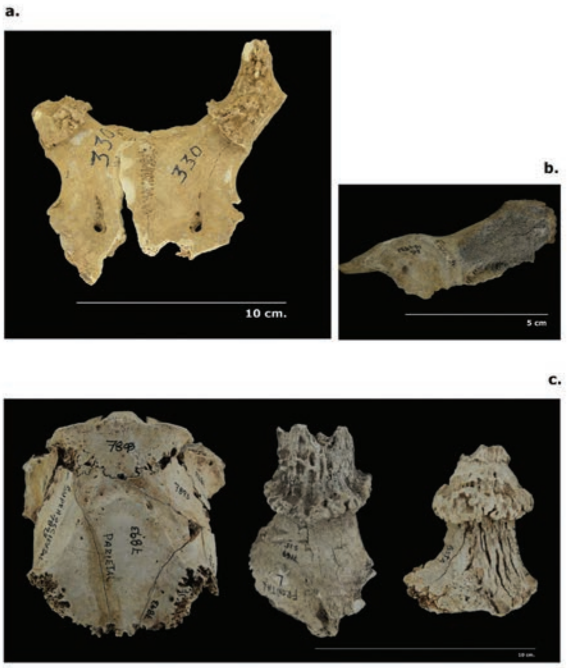

Figura 6.6. 2. Examples of cut marks. a. Playa don Bernardo; b. Cerro Mangote; c. Cerro Juan Díaz; d. Sitio Sierra.

Table 6.6. 1. Summary of the zooarchaeological analysis. NISP (Number of Identified Specimens); MNI (Minimal Number of Individuals); %MAU (Minimal Animal Units); VD (Volume density).

Site	Zooarchaeological analysis									
			Sex		Age					
	NISP	MNI	Fem	Mal	Sub-adults	Adults	%MAU	VD	Skeletal completeness	Long bone representation
Cerro Mangote (AG-1)	2082	45	0	14	0	45	Femur-humerus	insignificant and significant negative correlation	Forefoot and foot under-represented, hindfoot well represented	555 remains were long bones, the most represented zone was the distal, followed by the proximal, and lastly the medial
Playa don Bernardo (PDB)	2502	22	0	6	5	17	Femur-Ribs-Mandible	insignificant and significant negative correlation	In general, the deer body representation in macrostratum II and III seems equally distributed except for the foot that is under-represented	162 remains were long bones, the most represented zone was distal followed by proximal, medial and whole.
Sitio Sierra (AG-3)	2973	38			22	16	Mandible-femur-humerus	Non significant negative correlation	Head, forefoot, hind foot, and foot under-represented forequarter and hindquarter over-represented	252 remains were long bones; the most represented zone was the distal, followed by proximal, whole and medial
Cerro Juan Díaz (LS-3)	1517	11	1	7	2	9	Femur-tibia-mandible	insignificant negative correlation	Axial skeleton under-represented forequarter over-represented	252 remains were long bones; the most represented zone was the proximal, follow by distal, medial and whole
Total	9074	116	1	27	29	87				

Table 6.6. 2. Summary of the taphonomical analysis: anthropic modifications.

Site	Anthropic modifications			
	Bone fracture patterns	Cut marks	Burning damage	Tooth marks
Cerro Mangote (AG-1)	Deer remains show the characteristic fracture pattern of fresh breakage. Percussion marks were observed on 160 (62.25%) elements. Also identified were: percussion cones (n=43;16.73%), negative cortical flakes (n=17; 6.61%) and medular flakes (n=43; 16.73%).	66 cut marks were identified on 36 elements representing 1.72% of the total sample. These marks are fairly superficial and have 1) straight incisions (69.70%), 2) superficial scraping (25.76%) and 3) deeper hack marks (4.55%). The position of the cut marks infers 1) defleshing (63.41%), 2) skinning (29.27%), and 3) disarticulation (7.32%).	138 (6.62%) elements show thermal alteration. Color grades grade 2 and 3 were the most frequent.	Ribs were peeled clean with the teeth, as we identified in three elements with cortex loss (0.14 %).
Playa don Bernardo (PDB)	12% of the sample presents anthropic fractures. Percussion cones (82%) were the most commons, follow by flakes (9%), negative cortical flakes (7%) and percussion marks (2%).	112 cut marks were identified on 34 elements (1.3%). 77% were fairly deep straight incisions, 20% superficial scraping and 3% deeper hack marks.	17 (0.7%) elements presents thermal alteration.	At MS-III, 16 cases were identified (0,6%). These are characterized by cortex loss and cortical lift. Most of the cases were observed on ribs and on some long bones.
Sitio Sierra (AG-3)	Deer remains show the characteristic fracture pattern of fresh breakage.	769 cut marks were identified on 187 elements representing 6.28% of the total sample. These marks are characterized as fairly deep and straight incisions (64.23%), superficial scraping (27.43%) and deeper hack marks (8.32%). The position of the cut marks infers defleshing (59.69%), skinning (31.51%), and disarticulation (8.78%).	285 elements show thermal alteration representing 9.58% of the sample.	Two elements (0.32 %) in unit A2/1-A2/2 show evidence of human tooth marks: a long bone with cortex loss, and a rib showing peeling.
Cerro Juan Díaz (LS-3)	63 (4.15%) deer remains in Op-1/1B show percussion marks, cortical flake negatives and medular flakes.	195 cut marks were identified on 45 elements representing 2.96% of the total sample. Cut marks are notable for being fairly deep straight incisions (61.53%). Superficial scraping (36.41%) and deeper hack marks (2.05%) were also observed. The position of the cut marks infers skinning (35.55%) more than other activities such as defleshing (33.33%) and disarticulation (17.77%) The remaining 13.33% are cut marks identified on antlers that could not be assigned to any of the former activities.	Eighty-four elements show thermal alteration representing 5.53 % of the sample. The majority shows double colour (40.48%) and colour grade 3 (39.29%).	We did not identify human tooth marks in the sample from Op.-1/1B.

The taphonomical analysis evidences that humans modified directly deer bones in all the archaeological sites. Fresh breakage was identified in the four assemblages (Table 6.6.2). Bone marrow was a resource used in all the sites, but bones were used also to produce artifacts or tools. The cut marks identified are related to the processing of the deer carcasses (Table 6.6.2; Figure 6.6.1). All the butchering sequence was identified in the four collections (skinning, defleshing, disarticulation) (Table 6.6.2). At Cerro Juan Díaz many of the cut marks present on bones and antlers are clearly related to non-subsistence activities. Burning damage was observed in the four collections, however Sitio Sierra was the one with more remains showing this kind of modifications (Table 6.6.2). Direct consumption of deer meat was observed at Cerro Mangote, Playa don Bernardo, and Sitio Sierra where cortex loss and cortical lift were identified on ribs as a product of peeling, at Cerro Juan Díaz human tooth marks were not identified (Table 6.6.2).

Post-depositional modifications such as manganese stains, concretions, and root damage were frequent at all archaeological sites. These modifications could be related to the humidity present in the surrounding environment at the sites (Table 6.6.3). Modifications for the bird of prey or carnivores (even dogs) were not identified in any of the assemblages analyzed. The only animal modification found was rodent gnawing and on a few occasions and in major quantity at Cerro Juan Díaz (Table 6.6.3).

Table 6.6. 3. Taphonomical analysis summary: Post-depositional modifications

Site	**Post-depositional modifications**	
	Environmental modifications	**Rodents**
Cerro Mangote (AG-1)	Post-depositional modifications were identified on 686 remains (32.94%), the most prevalent being concretions (31.65%) followed by root damage (0.72%), manganese stains (0.48%).	2 remains present rodent gnawing (0.09%).
Playa don Bernardo (PDB)	In general, the modifications found are related to the humidity and are present on 14% of the specimens. 77% corresponds to concretions, 11% to manganese stains, 9% to the action of the roots and the remaining 3% to long exposure to the environment (weathering).	19 remains (0.7%) present rodents marks.
Sitio Sierra (AG-3)	Post-depositional modifications were identified in 1156 remains (39%), and the concretions (18.83%) and manganese stains (17.92%) were the most prevalent	Only eight (0.26 %) remains indicate gnawing
Cerro Juan Díaz (LS-3)	Post-depositional modifications were identified on 92 remains (6.06%): concretions (47.83%), root damage (27.17%), and manganese stains (2.17%) were the most prevalent.	21 remains present rodent-gnawing (1.38%).

7. Discussion

7.1. White-tailed deer as an environmental indicator

In Panama there is evidence of human perturbation of local vegetation that was intensified after 7000 BP with the advent of swidden farming (e.g. Piperno, 1984; 2011; Piperno and Jones, 2003). White-tailed deer is an optimal proxy to document gradations of landscape alteration in Neotropical environments. Crops planted in fields or garden plots increase the white-tailed deer population because deer prefer second-growth vegetation, and would thus have benefitted from the disturbance of primary forest cover for opening garden plots and fields (Smith, 1991; Teer, 1994; Geist, 2000; Gallina et al., 2010; Cherry et al., 2018). Anthropogenic diets are reflected in the isotopic record of the fauna and could be distinguished in different C_4 plants variation in a wide chronological and also local or regional level. C_4 diets in animals are produced by regular and intentional feed (Sugiyama et al., 2015; Somerville et al., 2016; 2017; Thornton et al., 2016; Sugiyama and Somerville, 2017).

At the Maya area, many researchers used various stable isotope signatures (i.e. carbon, nitrogen, oxygen, and strontium) to study deer populations (Carr, 1996; Emery et al., 2000; White et al., 2001; 2004; Emery and Thornton, 2008; Thornton, 2011; Rivera-Araya and Pilaar Birch, 2018; Freiwald et al., 2019). White et al. (2004) demonstrated that discrete levels of anthropogenic impact on animal populations can be distinguished. They performed an isotopic analysis of deer from Maya sites of Lagartero, Tikal and Copan. They separated isotopically animals with "wild" signatures (almost all C_3–natural diet) from those whose values were consistent with occasional crop grazing (mixed C_3-C_4 diet), and finally from others with predominant C_4 signatures indicating that their diets were purposefully and abundantly complemented with maize.

Deer isotope distribution at Parita Bay evidences that the introduction of maize agriculture impacted these landscapes differently, as deer consumed a mixed C_3/C_4 (Sugiyama et al., 2020). In the case of Cerro Mangote, maize use is documented by the large number of grinding implements found in the kitchen midden (some with maize phytoliths incrusted on them) is consistent with constant maize use, and the existence of nearby fields (McGimsey, 1956; Ranere, 1979; Piperno, 2011a). Deer diet at this site is consisting of C_4 resources corroborating the paleobotanical evidence of large-scale forest burning and garden hunting strategy (Sugiyama et al., 2020) and also microwear and mesowear patterns that suggest a low abrasive diet. By the village agriculture period, deer diet presents varying fractions of C_4 consumption which correspond to occasional or even habitual garden raiding patterns, as can be seen at Sitio Sierra and Cerro Juan Díaz (Sugiyama et al., 2020).

7.2. White-tailed deer hunting and seasonality at Parita Bay

The microwear analysis evidences a low scratch and pit variation in the samples from Cerro Mangote and Cerro Juan Díaz suggesting that white-tailed deer were more likely to have been hunted at these sites during the rainy season (May-December) when the deer were more selective about their diet, and focused on the young leaves of particular shrub and vine taxa (Sánchez-Rojas et al., 1997; Bello et al., 2001; 2004; Arceo et al., 2005). On the other hand, at Sitio Sierra, deer were likely hunted mostly during the dry season because scratch and pit frequencies have a higher variability in these samples than in those from Cerro Mangote and Cerro Juan Diaz. A wide diversity of available plant species and plant parts (e.g. fruits, seeds, leaves and woody forage) from several taxa of shrubs and trees, are conducive to a more variable white-tailed deer diet during the dry months (Sánchez-Rojas et al., 1997; Bello et al., 2001; 2004; Arceo et al., 2005).

The detailed zooarchaeological and taphonomical study of the white-tailed deer at Sitio Sierra describes a communal feasting event at which deer meat was consumed in large quantity. Socially, holding communal feasts of this nature is more practical and appealing between late December and late April as suggested by tooth microwear, than during the rainy and stormy months. Dry season is the time of year when the Ngäbe communities of the Pacific side held their stick-throwing competitions – the krun (Ngäbere) or balsería

(Spanish) – which were attended by many people from dispersed hamlets scattered over the landscape, and which offered great prestige to the individual or kin group that had been able to accrue sufficient food and fermented maize beverages - known as do kwaga in Ngäbere and chicha fuerte in Panamanian Spanish) - for feeding a throng of guests (Young, 1976).

In the case of Cerro Mangote, the variability of white-tailed deer diet -- evidenced by tooth wear at the moment they were hunted -— points towards the wet season feeding. This makes sense in a garden hunting scenario because maize and manioc planted nearby would have been tender and leafy in the wet season. However at this early stage of development, of course, maize would not have yet attained the foliage density and kernel-size of later varieties maize would have been far less productive than varieties used at Panamanian villages until about 2300 cal yr BP (Galinat, 1980; Cooke, 1984; Norr, 1995; Dickau, 2010; Piperno, 2011b). Even though the maize planted at Cerro Mangote favored deer population. The isotope analysis of Sugiyama et al. (2020) shows a substantial fraction of the deer diet consisting of *C4* resources, supporting the results from the microwear analysis. It is interesting to point out that even at the early stage of maize production it produces a clear low abrasive signal in deer tooth that is observed through microwear and mesowear analysis.

At Cerro Juan Díaz, seasonality for deer hunting could not be evidenced from the microwear analysis because the type of occupation could not be distinguished with any certitude because its position on the heat map was not significant and this is not due to the sample size (n=70). Two alternatives stand out: firstly, Cerro Juan Díaz represents a village occupied all year round, and secondly, because we used samples from different excavation units or "operations," which could belong to different occupational events. Taking into account other evidences such as: several funerary precincts spanning at least 1800 calendar years, some of which show evidence for discrete burial groups with connotations of kinship relationships and ancestor-worship (Cooke and Sánchez Herrera, 1997; Cooke et al., 1998; 2000; Díaz, 1999) the most plausible hypothesis is the long-term sedentary occupation.

The microwear and mesowear analysis of these archaeological sites evidences that deer was hunting all year; at dry season in Sitio Sierra and at wet season in Cerro Mangote and Cerro Juan Díaz. However, their consumption was related to social events as in the case of Sitio Sierra where deer probably was consumed in feastings. Ritual hunt of deer by Moche society in Peru were celebrated at the beginning of the humid season (Bourget, 2001). According to Bourget (2001), it would have been an annual ritual for agricultural renewal and fertility.
In the Maya area, at Seibal (Guatemala), Pohl (1990) suggested deer hunting all year round. Taking into account that hunting is productive in dry season when animals tends to congregate near to water sources but also in wet season during rutting seasons males join females and fawns, and the group makes an easy target. The availability of resources such as fruits in wet season and the beginning of the maize cultivation at the end of the dry season also favors the hunting of deer.

7.3. Insular dwarf deer populations

Human impacts in islands are easier to observe than on the mainland due to the fragility of island ecosystems. Any human group entering a new territory will cause devastation (Grayson, 2001; Rick et al., 2013). Archaeological records on islands show that foragers rarely cause extinctions whereas farmers with a very different relation to the natural world often have a severe ecological impact. Island agriculturalists habitually brought 'transported landscapes' along with them, including a suite of domesticated plants and animals (Takamiya, 2006; Fitzpatrick and Keegan, 2007; Giovas et al., 2012; Fitzpatrick, 2015; Laffoon et al., 2015; Hofman and Rick, 2018). In the case of Playa don Bernardo ancient colonizers brought with them maize *(Zea mays)* and unidentified root crops.

Maize consumption by deer is documented at Cerro Mangote, Sitio Sierra and Cerro Juan Díaz. Taking into account that *O. virginianus* is attracted to maize fields it is reasonable to propose that maize was part of their diet (Sánchez, 1995; Cooke and Sánchez, 2004; Cooke et al., 2007; 2008; Cooke, 2016). The isotopic analysis performed by Sugiyama et al. (2020) shows variable patterns of maize consumption at the Parita Bay archaeological sites. At Playa don Bernardo, it was expected that, if *O. virginianus* were present there, stable isotopes and microwear and mesowear analyses would show this, given the fact that maize phytoliths were found at the site. However, our results do not demonstrate this. The evidence points to a Playa don Bernardo dwarf deer diet based mainly on C_3 plants and highly abrasive plants.

Mesowear analysis allows the study of the diet of animals over a long period of time of their life-history and reflects their average diet over few months/ years before death (Fortelius and Solounias, 2000; Rivals et al., 2013; 2017; Amano et al., 2016; Ackermans et al., 2020). The mesowear scores for the ancient Pearl Island deer point to considerable differences from the diets of ancient white-tailed deer in mainland archaeological sites and also from modern populations living on Coiba Island and the Florida Keys. Detailed mesowear analyses shows that the Playa don Bernardo deer changed their diet at the time humans arrived on the island. Playa don Bernardo dwarf deer did not immediate shifted its diet to consume the maize that the new settlers brought with them, as *O. virginianus* would have done. The microwear data of white-tailed deer from Cerro Mangote, Sitio Sierra and Cerro Juan Díaz in mainland anthropogenic savannas shows that the presence of maize in the environment is reflected on deer teeth even though the stage of maize's evolution 8000-4500 cal yr BP would not have been as productive at Cerro Mangote as varieties used at the later villages (Sitio Sierra and Cerro Juan Díaz) (Martínez-Polanco et al., 2019).

The results show that the dwarf deer preferred to consume other plants like grasses, which are more abrasive than maize. Tooth microwear, mesowear and stable isotopes results show that at the beginning of human occupation 6.3 cal yr BP, the dwarf deer had a more diversified diet than later during the preceramic occupation. This also infers that people exerted an increasing impact on the island environment by clearing and burning the natural forest. These activities stimulated herbaceous cover that the dwarf deer had to eat. The island archaeological record shows that a similar set of anthropogenic factors including intensive hunting led to the extirpation of some animal species on Pedro González including the dwarf deer itself. Scratch variability in Macrostratum III suggests an occupation event that lasted longer than a season. In Macrostratum II, however, the island population had responded to a seasonal or a shorter event. These results coincide with the analysis of the faunal remains of the salvage project concluded in 2015. The abundance of faunal remains of 2015 field season reveals that dwarf deer bones are common at the beginning of the occupation. This situation points towards instant human impact on this species although not extirpation since, after a gradual fall-off (levels 36 and 20 –Macrostratum III-) a slight recovery occurred (levels 18-11 –Macrostratum II-). The second and third most abundant mammals in the Pedro González midden -- agouti and opossum -- show an increase in frequency after the cervids began to diminish (Pearson et al., 2020). Pearson et al. (2020) ruled out two hypotheses: 1. PDB may have been a seasonal encampment periodically abandoned when groups settled other parts of PG or moved to other islands in the archipelago during the year; 2. The declines in the quantity of faunal remains are associated with an increase in agricultural activities and a shift in diet. According to the results present here the more plausible hypothesis is the first one. This situation evokes the hypothesis that, when people first arrived on Pedro González island, they quickly exhausted the local resources and then left. When they returned, the island animal populations had had time to recover. The dwarf deer were still hanging on about 5775 cal yr BP by which time the islanders were consuming more and more coastal mollusks. Soon after, the Late Preceramic people left. By the time people returned they had been using pottery for at least 2000 years. The dwarf deer had gone from Pedro González. The hiatus between Pre-ceramic and Ceramic occupation could be related to the increase in El Niño events and it is conceivable that this influenced the site's abandonment (Cooke et al., 2016).

Pedro Gonzalez island is located in an area where annual and multiannual climate variability are driven by the interaction of the intertropical convergence zone (ITCZ) and the El Niño Southern Oscillation (ENSO). During years of strong north-to-south winds, upwelling is especially strong around PG, and sea surface temperatures can drop to 15º C (Toth et al., 2012). The variation in the d^{180} could be related to El Niño warm events, La Niña cool events, and normal conditions (Andrus et al., 2008). Taking into account that there is a negative correlation between ^{18}O and temperature; as water temperatures rise, ^{18}O values fall (Grossman and Ku, 1986). This could be reflected in our data evidencing that human occupations in both periods occurred at the two moments (El Niño and La Niña). And if we linked these results to the scratch variability at Macrostratum III where it is observed an occupation pattern longer than a single season, persistently warm and dry conditions occurred and it could be observed in the isotope data. This is in contrast with Macrostratum II where a seasonal pattern is observed the distribution of the isotope data suggest two different moments which could be one El Niño and one La Niña.

At Cerro Mangote hill-top hamlet-dwellers hunted white-tailed deer throughout the Late Preceramic occupation. Maize grown near this site would have been an attractant to deer and would have heightened hunting success. However, at this site, hunters focused on adult deer thus alluding to human management of deer stocks. Cultural management allowed the maintenance of the deer population and its permanence in the area through time. Management was not put into practice on Pedro González Island owing probably to the small size of the island and the fragility of the dwarf deer population. This study also illuminates different strategies to which white-tailed deer could resort for adapting and responding to human intervention. The white-tailed deer is plastic and adaptable, an opportunistic feeder that could respond quickly to environmental changes by shifting its diet. On the other hand, *Mazama* species appear everywhere to be more sensitive to changes in forest cover and clearly also to overhunting. In fact, the International Union for the Conservation of Nature (IUCN) considers that habitat destruction is the main threat to the Amazonian brown brocket in South America (Rossi and Duarte, 2016; Gallina et al., 2019a)

7.4. Cervid accumulations purposes

The Late Preceramic inhabitants of Cerro Mangote used a single strategy for exploiting and managing white-tailed deer during the formation of the red zone and brown zone occupations. The deer accumulation responds to a nutritional purpose as can be deduced by: 1. Bone marrow process evidence; 2. The sequence of carcass processing through cut marks analysis (i.e., defleshing, skinning, and disarticulation); 3. The consumption of cooked meat judged from the patterns of burning coloration identified on some elements; and 4. Presence of the meatiest elements in the assemblage. The inhabitants of Cerro Mangote also took advantage of deer skins as can be deduced from the good representation of the hindfoot.

In the case of Playa don Bernardo, the purpose of deer accumulation was also consumption. It can be inferred by 1. The anatomical representation of deer evidence that the whole deer were taken to the dwellings and people consumed all the deer; 2. the cut marks on deer bones are related to the butchering process; 3. The direct consumption of deer meet was evident for the presence of human tooth marks; 4. The consumption of cooked meat was also revealed by the different patterns of thermal alteration. However, the ancient inhabitants of Playa don Bernardo also used bone and antlers to prepare tools and ornaments, especially in the case of Macrostrata I and II (Martínez-Polanco et al., 2015a).

The archaeological record of Sabana de Bogotá evidences also the consumption of deer in preceramic sites coeval to Cerro Mangote and Playa don Bernardo (Peña and Pinto, 1996; Peña and Rincón-Rodríguez, 2020). An example, is Aguazuque (5,025 ± 40 BP [5895-5660 cal BP] to 2,725 ± 35 BP [2880-2760 cal BP]) where is observed at a ca 3000-year occupation and sustained consumption of deer along occupation time (Correal, 1990; Martínez-Polanco, 2018). Also at Checua where a human occupation begins at 9470-8969 cal BP (2σ), and ended at 5190-5052 cal BP (2σ) (Groot, 1992; Archila et al., 2020).

Some authors pointed out that the presence of deer in the Maya world cannot be related quickly with a feasting or a ritual context but also with elite or non-elite settlement (Emery, 2007a; Montero-Lopez, 2009; Manin and Lefèvre, 2016). Taking into account that white-tailed deer is a multi-purpose animal, its importance is related to its symbolic connotations with the concepts of fertility and regeneration. It is also one of the largest mammals in the area and its importance as a source of proteins and raw materials makes deer difficult to use as indication of the type of archaeological context (Emery, 2007a; Montero-Lopez, 2009; Manin and Lefèvre, 2016). This observation could be also translated to other parts of Central and South America.

At Sitio Sierra, deer accumulation was related to consumption however in a non every day meat consumption context. White-tailed deer meat was clearly the most important animal food in the feasts. This can be inferred by the following evidences: 1. deer were brought back to the site where they were processed in situ; 2. there is a special focus on body parts with high meat values, such as femur; 3. Complete and articulated deer remains represented that implies that the elements were deposited quickly and for a short time; 4. All the process of butchering is reflected in the cut marks analysis; 5. Cooked meat was consumed according to the burning coloration patterns identified; 6. The age pattern of hunted deer showed a high number of juveniles. Their meat could be preferred over adult deer meat.

During the Maya Late Classic Period at Chinikihá (Mexico), enormous amounts of deer remains have been found in what appear to have been massive feasts (Montero López and Varela Scherrer, 2017). These authors suggest that the increase in meat consumption during the Late Classic period, possibly as a consequence of an increase in political interaction between sites in the region (Montero López and Varela Scherrer, 2017). In this site, there are evidences for hindquarters preference which probably should have played an important role in the banquets (Montero López and Varela Scherrer, 2017).

White-tailed deer remains that were deposited between 500 and 700 CE in the midden at Cerro Juan Díaz named Op. 1/1B were placed there partly for nutritional purposes. This idea receives support from 1. the deposition of bones with high meat values such as the femur and tibia and 2. cut marks related to skinning, de-fleshing and disarticulation. The under-representation of elements belonging to the deer axial skeleton and the over-representation of the forequarter suggest that only certain body parts were brought back to the site where they were processed.

However, nutrition was not the only goal. Many of the cut marks in op. 1/1B are clearly related to non-subsistence activities. The refuse feature in operation 1/1B at Cerro Jun Díaz clearly represents the waste of a deer bone and antler workshop. The choice of materials for the crafting of tools was predicated upon availability, mechanics, the shape of the final product and traditional practice. Long bones (humerus, radius, metacarpal, femur, tibia, and metatarsal) were selected to produce bone tubes and elements of young adult individuals were preferred. Non finished deer bone tubes were found in Op. 1/1B but what were found are the proximal and distal portions of bones that had been cut to make tubes. This workshop appears only to have prepared tubes fashioned from white-tailed long bones.

White-tailed deer antlers and bones served as raw materials from which to craft artifacts and ornaments throughout their distribution. For instances, in Canada (Gates St-Pierre, 2010; Gates St-Pierre et al., 2016; Gates St-Pierre et al., 2016), United States of America (Martin, 1976), Mexico (Pérez Róldan, 2005; Valentín and Pérez Roldán, 2010; Pérez Roldán, 2013; Blasco Martín et al., 2019), Guatemala (Emery and Aoyamab, 2007; Emery, 2008; 2009), Belize (Boileau and Stanchly, 2020), Panama (Cooke, 2004b; Cooke and Jiménez-Acosta, 2010), Colombia (Correal, 1990; Groot, 1992) and Ecuador (Stahl and Athens, 2002).

It is feasible that the deer bone and antler artisans who worked in Op.1 / 1B in Cerro Juan Díaz belong to the same social group of specialists and the knowledge of bone and antler making techniques passed from one generation to another. Another support for the hypothesis of a specialization in the bone industry is related to the fact that all the evidence of manufacturing was found in the same place Cerro Juan Diaz (southwest of the settlement), both the shell workshop (Op. 8) and the deer bone antler workshop (Op.1/1B).

However, this is not the case for example, in the Iroquoian sites of Mailhot-Curran and McDonald where there are no concentration of remains that could be associated with bone workshops. In these sites manufacturing debris are equally distributed in each family space of the longhouses. That implies that the existence of the sharing of technical knowledge about bone tool production between families and also between households. It is possible that anyone in the household was able to make bone objects (Gates St-Pierre et al. 2016; Gates St-Pierre, Boisvert, and Chapdelaine 2016). At La Montesita site (Aguascalientes, Mexico), that dating back approximately to the Epiclassic period (600-900 AD), a specialized area devoted to the bone and antler work was identified. According to the authors, this area reflects an ideal working space, with access to light, comfortable space, tools, and raw materials (Blasco Martín et al. 2019). The Classic Maya site of Aguateca (Guatemala) shows an interesting pattern of bone crafting production. In this site, there is evidence that all the members of Maya nobility were also artisans, and they produced bone artifacts. This site also describes that certain parts of the bone crafting process were carried out in certain households and in separate areas of each structure. The zooarchaeological evidence found in this site pointed out that the Maya women are directly involved in crafting activities, particularly in those related to food and textile areas (Emery and Aoyamab 2007). In these archaeological sites, deer bone workshops respond to a particular social and economic organization and in some cases also it could be linked to a symbolic and ritual world.

Although it is true that all the deer remains found in these archaeological sites are related to food, it is important to note that other uses of the by-products could also be inferred, such as the use of skins (Cerro Mangote), and the elaboration of ornaments or artifacts in bone or antlers (Playa don Bernardo and Cerro Juan Díaz).

7.5. White-tailed deer management

Cultivation of crops near the settlement at Cerro Mangote would have favored deer population density, taking into account that deer prefer second-growth vegetation enabled by the anthropogenic disturbance of primary forest cover by the expansion of agricultural fields (cf. Smith, 1991; Gallina et al., 2010; Cherry et al., 2018). Animals that approached the crops were targeted in the manner of garden hunting described by Linares (1976). At Cerro Mangote, such a hunting strategy in which no fawns or young were killed thus ensured that these animals reached adulthood and reproduced, guaranteeing a stable and long-term top-rank meat supply. The proximity of Albinas -a large salt flats- would have facilitated the storage of dried and salted carcasses.

In the case of Sitio Sierra, the slightly higher number of young individuals may suggest that people took fawns, and fed them before the feastings. Deer isotope analysis evidences an elevated $\delta^{13}C_{bioapatite}$. Sugiyama et al. (2020) proposed that the deer diet was constituted by a mixed pattern of garden browsing complemented with purposeful feeding by villagers.

The early sixteenth century CE chroniclers, Pascual de Andagoya [1514] and Gaspar de Espinosa [1517] observed that hunting deer and other mammals was forbidden in chief Parita's territory – located to the south of Sitio Sierra -- but not in neighbouring territories (Andagoya, 1994; Espinosa, 1994). The most logical explanation for the Spaniards' observations is that they came across a temporary proscription in forcé in this particular territory, which was not being enforced at that time in other chiefdoms. But there are other reasons, Cooke and Ranere (1992) suggested a deer proscription along totemic lines (i.e. for a high-ranked deer clan). Such is the ubiquity of animal images on the art objects of Greater Coclé, that some form of totemism probably played an important role in human-animal relations. That is reflected at Cerro Juan Díaz were bone of deer was used to produce wealth items that could be employed for a special part of the society and in non-quotidian context, complete and finished elements were found in burials and associated with high ranked people. The use of this management strategy was successful and it is demonstrated by the fact that large white-tailed deer populations survived in the wooded savannas of central Pacific Panama until the Spanish conquest. White-tailed deer populations held on during the Republica eras (1821-2020) until recently when motorized hunting with powerful firearms led to a dramatic crash. But today, these deer are increasingly being penned up for provisioning restaurants and wealthy homes.

The archaeological record of the Maya World (Guatemala, Honduras, Belize, and Mexico) evidences nearly 4000 years of continuous exploitation of faunal resources in particular white-tailed deer. Nevertheless, hunting, forest clearance and landscape modifications there is no evidence of extinctions or local extirpation of any species as in other parts of the world (Emery, 2007b).

Emery (2007b) performed a long term study of the proportions of large mammals, in particular white-tailed deer in the Maya area. The aim of this study was to evaluate resource depression caused by hunting pressure. It is expected that the reduction in hunting efficiency increase the presence of small species. The result of this study evidences complex temporal changes. There is an increase in hunting efficiency between the Preclassic and Early classic for large game, and an increase between the Preclassic and Late Classic for white-tailed deer. Then it is observed a dramatic decline between the Late Classic and the Terminal/Postclassic periods, and increases again for the Colonial period (Emery, 2007b).

Emery (2007b) signals that the replacement of high forests with scrub forests, savannahs, and grasslands during the Classic period has important implications for the availability of deer. Deer was proportionally more frequent in Late Classic – the period characterized by the largest human population, greatest political activity and highest proportion of elites in the population, largest extent of forest clearance, and greatest climatic stability-assemblages than in Terminal Classic/Postclassic assemblages. Hunters in these periods responded to resource depression by exploiting more diverse and smaller game (Emery, 2007b). The presence of white-tailed deer in Late classic period reflects a social management of this species, for example: protected forest reserves, trade from distant resource areas and/or management of captive deer herds to ensure continued availability (Emery, 2007b).

An indirect practice for managing a wild animal population is simultaneously to manage its food sources (Ojasti, 2000). In the Neotropics, Linares (1976) proposed the concept of "garden hunting", which refers to the hunting and consumption of animals that are attracted to plants that grow in gardens. This kind of practice is evidenced in Maya lownlands sites such as Chichén Itzá, Dzibilchaltún, and Sihó (México) throughout the Classic and Postclassic (Götz, 2014) and Seibal, Altar de Sacrificios, Tikal, Macanche and Flores (Guatemala) (Pohl, 1990).

The archaeological record evidence the avoidance of killing fawns. Only for special occasion younger deer were hunted. If the killing did at a time when they are raising fawns. It implies that fawns could not survive unless the hunters could locate them and bring them home as pets (Carr, 1996). Later the women took the deer to designated places in the forest where they kept them (Pohl, 1990). This could be the beginning of deer herds. However at Mayapán (Mexico), it is suggested that the presence of infra-structural features are suitable for game confinement, in the form of pens and corrals that are located adjacent to domestic houselot walls (Masson and Peraza Lope, 2008). In this site the exceptionally high proportion of older subadult white-tailed deer causes the authors to infer that deer were raised and probably bred in captivity. Alternatively, a sophisticated form of forest game management was in place (Masson and Peraza Lope, 2008). The authors proposed that deer-raising or management was a major production industry for the site, and deer provided a staple food source for the city's residents and surplus meat and bone products for exchange (Masson and Peraza Lope, 2008).

Another way to manage deer in Maya times was the restriction of their consumption. For example, the consumption of meat, specifically white-tailed deer, was controlled by the Chinikihá (México) Late Classic elite, who used the preparation and consumption of banquets as a mechanism of social control towards the lower classes, but also as a means of displaying their power (Montero López and Varela Scherrer, 2017). According to the authors the increase in meat consumption during the Late Classic period was a consequence of an increase in political interaction between sites in the region (Montero López and Varela Scherrer, 2017).

Nowadays, white-tailed deer is the most appreciated species for subsistence hunters and is the subject of several cultural traditions among the Mayan hunters (Reyna-Hurtado and Sanchez-Pinzón, 2019). The current Maya from Yucatec and Campeche obtain most of the fauna prey in the gardens and in the horticultural fields adjacent to the settlements, as well as in the patches of secondary vegetation that are formed as a result of the rotating system of slash, grave and burn (Barrera-Bassols and Toledo, 2005; Retana-Guiascón and Padilla Paz, 2018).

In the archaeological record of the Sabana de Bogota, Colombia, at a ca 3000-year occupation at Aguazuque (5025 ± 40 BP [5895-5660 cal BP] to 2725 ± 35 BP [2880-2760 cal BP] an intensification of venison consumption was observed in the last two occupation periods, compared to the older period (Martínez-Polanco, 2011). However, the hunting of the white-tailed deer in Aguazuque was apparently sustainable, because no evidence was found that indicated changes in the proportion of ages or a reduction in the size of individuals over time (Martínez-Polanco, 2011); these results suggest that people managed white tailed-deer hunting by targeting adult animals of both sexes (Martínez-Polanco et al., 2015b). Ancient settlers of Aguazuque also chose mixed subsistence strategies, where vegetables played an important role, as well as the presence of smaller animals such as guinea pigs (Martínez-Polanco et al., 2020).

Three agro-pottery and pre-Hispanic periods for the Sabana de Bogotá has been describe: Herrera (400 BC–200 AD), Early Muisca (200 AD–1000 AD), and Late Muisca (1000 AD–1600 AD) (González, 2017). In the agro-pottery periods at Sabana de Bogotá, increased consumption of venison was expected. However, the zooarchaeological evidence of Herrera and Muisca sites at the Sabana de Bogotá does not show a high number of individuals being hunted. For example, in the Las Delicias site (1180±70 DC and 1010±60 DC), 548 remains were identified to be of the *Odocoileus* and *Mazama* species and represented by 14 individuals. Of these, 59.5% were adults and 40.5% were juveniles (Enciso, 1996). Another case in the San Carlos site showed the frequencies *O. virginianus* corresponded to Herrera (MNI: 4; two juveniles and two adults) and Late Muisca (MNI: 7; three juveniles and four adults) (Rincón-Rodríguez, 2020). However, this is not at trend, at the Nueva Esperanza site, a detailed studied of deer age shows high numbers of deer hunted: at Herrera period: Infantile MNI=4; juvenile MNI=4; adult=37; at Early Muisca: Infantile MNI=11; juvenile MNI=16; adult=74 and at Late Muisca: Infantile MNI=4; juvenile MNI=9; adult=39. In this site there are differences between the Early Muisca period and the Late Muisca and Herrera periods. However, in all periods the adult category contained higher frequencies, which is an indicator of sustainable management of the resources available in the area (Castro et al., 2020).

Later, in colonial times, the chroniclers make reference to the abundance of this species in the area (Simón, 1981[1625]; Fernández de Piedrahita, 1987 [1688]). According to the chroniclers, the Muisca caciques had undeniable privileges: their position was hereditary, passed down from uncle to nephew through the mother; according to some authors, they were the only people who could eat venison (Castellanos, 1955); and they could also determine what everyone else ate, especially meat (Friede, 1976). For this reason, the consumption of venison was seen by a local archaeologist as an indication of higher rank in Muisca society (Boada, 2007). However, the zooarchaeological studies of the Muisca period not cover this aspect. Except, Boada (2007) who studied the deer patterns of spatial distribution. She found that settlement hierarchies were related to the consumption and to the access to the best parts of deer. The distribution of venison during the Late Herrera period indicated a pattern of sharing venison in which the best parts were exclusively delivered to a certain place in the settlement. This pattern is stronger in later periods, and this residential unit is the only ward that exhibits the best-quality cuts, while the rest of the wards only had cuts with poor meat content. Control over consumption of meat played a more important role in social hierarchy during the Early Muisca and Late Muisca periods (Boada, 2007).

Determining who can eat an animal and when this can happen is a conservation strategy that allows sustainable exploitation of a resource over time (Sinclair et al., 2006) and it was the strategy used by Muisca elite according to Boada (2007).

Nowadays, white-tailed deer is locally extinct in the Sabana de Bogotá area (Martínez-Polanco, 2008). The main causes that affect and threaten wild populations of deer are fragmentation, destruction and habitat degradation; interaction with domestic species and overexploitation derived from the indiscriminated use of rural communities and hunting (López Arévalo et al., 2020).

The white-tailed deer is considered to be of Least Concern according to The IUCN (International Union for Conservation of Nature) Red List of Threatened Species. This publication adduces that the present-day status of this species is stable in light of its adaptability. This view is based primarily on the fact that this species increased considerably in North America during the last century. On the other hand, white-tailed deer populations in Central America and northern South America are small and in decline (Gallina and López Arévalo, 2016). The interaction process between communities and deer population varies between regions. In the case of Mexico, the subspecies *O. v. texanus* has been introduced outside its distribution area because it is greatly appreciated as a trophy. However, this action put in risk the genetic diversity of the other subspecies (Gallina et al., 2019b). The situation in Panama is different because today white-tailed deer population are still preserved even in urban areas. However, population studies will be needed in order to propose conservation strategies. In the case of Colombia, the species presents different conservation status according to their distribution along the country. López-Arévalo and González-Hernández (2006) suggested different threatened categories according to the subspecies of CR (Critically Endangered) for *O. v. tropicalis*, DD (Deficient Data) for subspecies *O. v. goudotti* and *O. v. ustus*, and LC (Least Concern) for *O .v. apurensis*. The population of white-tailed deer is related to protected areas (10% of the country) and the major challenges in the protection of this species are the populations outside this areas because of the ongoing transformation of these landscapes (Montenegro et al., 2019).

The data provided by the archaeological record could be used as predictors for modeling the effects of modern activities and their impact in white-tailed deer populations. By studding the relationships between ancient human populations and their environment as result of direct exploitation and modification of forest could provide elements that conservationist and managers could employed to plane conservation strategies.

7.6. White-tailed deer hunting as a subsistence strategy at Parita Bay: Much more than meat alone

In central Pacific Panama, white-tailed deer were hunted during the Preceramic agricultural period (8000-4500 BP), and the subsequent Early Ceramic agricultural period (4500-2500 BP) (Cooke et al., 2008). During this long time period, exogenous plant domesticates such as maize *(Zea mays)*, manioc (*Manihot esculenta*) and squash (*Cucurbita moschata*) entered Greater Coclé subsistence systems from Central America and South America (Piperno, 2011b). Subsistence activities and their relative importance varied greatly across a landscape full of multiple ecological niches (Piperno, 2011a).

The white-tailed deer was dietarily and culturally by far the most important mammal at Late Preceramic Cerro Mangote between ca 7900 and 4600 BP. This is predictable since disturbance of primary dry forest cover by the expansion of agricultural fields and their crops is well known to have been beneficial to white-tailed deer populations. They continued to consume the same kinds of fish as well, and the fact that they took quite large fish 50 meters up to the hill top makes it likely that their dwellings were there (Cooke and Ranere, 1999). The fact that the manner of deer exploitation followed the same pattern in the two occupations identified at the site (one less intense [red zone], and the other more intense [brown zone]) indicates that a social group with the same traditions occupied the site throughout the Late Preceramic. The Greater Coclé semiotic system cannot be identified objectively until bi- and tri-chrome pottery began to be manufactured between about 2500 and 1700 BP (Cooke, 2011). During and after this time period, settlements on the Pacific watershed nucleated, and clustered mostly along major rivers with intervals between them averaging about 2 km in the lower and flatter reaches of the rivers (Cooke, 1979; Isaza Aizpurua, 2007; Cooke et al., 2013). The thousands of painted and modeled clay vessels that were unearthed from Sitio Conte and El Caño, have allowed anthropological interpretations of the zoomorphic images of the Greater Coclé Semiotic Tradition, which includes abstract representations of the white-tailed deer (Cooke et al., 2008). Whether complete animals or synecdoches – i.e. fragments that symbolize the whole animal --, images clearly depict branched antlers, and thus exclude brocket deer (*Mazama* sp.) taxa as models (Cooke et al., 2008: Figure 6-6 a-e). Cooke and Ranere (1992:285) argued that many Greater Coclé images that combine anthropomorphic and animal elements may represent mythical figures (i.e., cultural heroes or cosmological actors), and/or corporate group eponyms, whose symbolism could only be understood by members of the social unit. Shamanic transformation involving the most feared animals (sharks, crocodiles and jaguars) is likely also to be involved (Labbe, 1995; Cooke, 2004a).

At Sitio Sierra several characteristics of feasting according to the literature were identified (Masson, 1999; DeBoer, 2001; Dietler and Hayden, 2001; Hayden, 2001; Vega-Centeno Sara-Lafosse, 2007; Twiss, 2008; Montero-Lopez, 2009; 2012; Montero López and Varela Scherrer, 2017) such as: 1. large quantities of vessels used for preparing and serving food, which include unusual types, sizes, quality or materials, 2. high frequency of carcass-processing, 3. high frequency of young animals, 4. low frequency of post-depositional modifications, and 5. wanton discard of edible material (i.e. articulated joints, and unprocessed bone). Offering roast deer meat in a feast – an animal with restricted access because of its polysemic ritual significance – would have been an honor for the guests, and proof of the provider's status in an essentially a low status village. The cut marks are located at identical positions on several elements that could be explained for the similar anatomy of the deer and the sharing of traditional practices through generations. Adult males of Sitio Sierra and its social environs could perhaps only hunt and gorge themselves on deer after a prior ritual preparation: deer hunting was mediated by ritual activities linked to special occasions.

It is not straightforward to interpret the hypothetical feasts, and feasible explanations are multiple, i.e., ancestor worship (bearing in mind the presence at Sitio Sierra of two cemeteries), rites of passage like the modern Guna chicherías, celebrations of cultural awareness and group oral history -- similar to the Ngäbe balsería –, and political gatherings designed to enhance the reputation of the provider. In the last case, the providers at Sitio Sierra did not reward the invitees with sumptuous goods as in the potlaches of the American northwest or, one assumes, at feasts at high status Sitio Conte and El Caño. Speculating, perhaps the feast represented by context A2-1-1/A2-1-2 was of the "minimally distinctive" kind (Hayden, 2001) -- a small-scale household and moderate-sized lineage solidarity feast, which took place in and around the cane and palm thatch residence. Another possibility is an end-of-fast feast in honor of males who were forbidden deer meat for diverse reasons, and when the taboo was over, gorged themselves on deer meat from storage houses (Cooke and Ranere, 1989; 1992b).

The intensification of elite-sponsored artisanal production is one of the markers of political development because through the production, exhibition, and distribution of wealth, leaders define their own social states and those of others, thus defining the rights and obligations through the use of articles of wealth (Johnson and Earle, 2000). Specialized production of luxury goods is related to the intervention of the elite in order to legitimize their hegemony (Johnson and Earle, 2000). Cooke (2004b) and Cooke and Ranere (1992) pointed out that 'Gran Coclé' society may have been organized into ranked and named clans, which would have used animal and plant identifiers. Probably, genealogy and ancestry were determinants of rank and the chiefs come only from certain social groups. It is possible that the same pattern occurs in crafters, that artisans belong to a determinate social group. (Cooke and Jiménez-Acosta (2010) signaled that the great number of carved bone artifacts in grave 32 at Sitio Conte (i.e. the carved vertebrae, the bone box, and spear-thrower guards) exhibit unusual crafting skills. In this grave, three adult males were found. These findings evidence that probably these individuals belonged to a lineage of specialist bone carvers. The evidence found at Cerro Juan Díaz strongly suggest a specialization, where wealth items made on deer bone and antler were produced. Knowledge of bone industry techniques and methods may have been passed down from generation to generation within a family nucleus. Following the model proposed the social status of the craftsman was inherited; the birth within a certain family group and their condition determined the trade and status of the new members of the group.

The zooarchaeological record of Parita Bay evidences that human groups did not rely exclusively upon white-tailed deer, they had a broad-spectrum diet, composed mostly by fish and reptiles (i.e. Cooke and Ranere, 1989; 1992a; Cooke, 1992; Jiménez-Acosta, 1999; Cooke et al., 2007; 2013; Cooke and Jiménez-Acosta, 2008). The deer consumption of C_4 products increased through time however it seems that represented a supplement in their diets (Sugiyama et al. 2020). The study of white-tailed deer in the archaeological record of this area did not evidence an intensification in deer hunting, the presence of deer is constant along the human occupation sequence at Parita Bay. With the passage of time it is observed that the role of the deer changes and appears not only associated with dietary contexts but also in others such as artisans workshops. The role of white-tailed deer was an important element in Great Coclé culture and before too.

8. Conclusions and outlook

Microwear and mesowear analyses allowed to address the issue of the times of the year when deer hunting was practiced at three sites bordering Parita Bay in the strongly seasonal dry crescent of Pacific Panama: Cerro Mangote, Cerro Juan Díaz, and Sitio Sierra. At two sites located in two different watersheds with markedly different calibrated radiocarbon ages, and very different population sizes -- Cerro Mangote and Cerro Juan Díaz --, the tooth wear data infer that the ubiquitous white-tailed deer were likely hunted mostly during the wet season (May to November). On the contrary, results from Sitio Sierra show that white-tailed deer were hunted preferentially during the early dry season (December to April) when productive varieties of maize would have been nearing collection or already harvested, and rapidly consumed during seasonal festivities evinced by our taphonomic studies.

•Human intervention at Playa don Bernardo included anthropogenic burning of vegetative cover, significant burning and landscape clearance, a novel set of introduced plants and heavy impacts on terrestrial mammals including insular extirpation of the dwarf deer between 5700 and 2300 cal yr BP. The diet of the *Mazama* deer was initially based exclusively on C_3 plants, but human arrival induced changes. At the onset of human occupation represented by Macrostratum III, dwarf deer diet was more diversified than in later occupations. A more sporadic human presence enabled the island terrestrial fauna to stabilize and even increase slightly. But the dwarf brocket did not survive on Pedro González Island and disappeared when a pottery-using wave of immigrants arrived they didn't find any deer on the island.

•The white-tailed deer was dietarily and culturally by far the most important mammal at Late Preceramic Cerro Mangote between ca 7900 and 4600 BP. This is predictable since disturbance of primary dry forest cover by the expansion of agricultural fields and their crops is well known to have been beneficial to white-tailed deer populations. The fact that the manner of deer exploitation followed the same pattern in the two occupations identified at the site (one less intense [red zone], and the other more intense [brown zone]) indicates that a social group with the same traditions occupied the site throughout the Late Preceramic. This is not at all surprising in a region where multiple lines of evidence have stressed strong population and cultural continuity since the early Holocene or even earlier.

•By studying, the deer sample from Sitio Sierra in conjunction with the evidences of the ceramic and the cooking, it can be concluded that ritual activities mediated the feasts that are inferred by the zooarchaeological, taphonomical and archaeological evidence at Sitio Sierra. White-tailed deer meat was clearly the most important animal food in the feasts which likely served guests large quantities of fermented maize chicha. This special menu contrasts with the everyday meals at Sitio Sierra whose remains were widely scattered around houses, and comprised foods such as marine and river fish, iguanas, and small turtles. Offering roast deer meat in a feast would have been an honor for the guests, and proof of the provider's status in an essentially a low status village.

•The refuse feature in Operation 1/1B at Cerro Juan Díaz clearly represents the waste of a deer bone and antler workshop. In this operation, the excavation did not recovered the kinds of final products that were used at the elite graveyards such as Sitio Conte. This workshop appears only to have prepared tubes fashioned from white-tailed long bones. Knowledge of bone industry techniques and methods may have been passed down within families from generation to generation. Following the model proposed, the social status of the craftsman was inherited; the birth within a certain family group determined the status of the new members of the group.

•Detailed taphonomic evidences demonstrated that the Cerro Mangote hunters were managing deer populations in a more positive way (by preferentially culling adults) than in later ceramic-using periods when larger regional populations and more densely occupied villages likely exerted growing pressure on the environment, making earlier adult-focused conservationist strategies more difficult to maintain. Besides in these villages another kind of management came to the fore: the control of access to deer hunting by certain privileged persons of the community and at certain moments of t he year.

•The study of deer bone and antler permits an understanding of different human behaviors related to social and economic organization but also it could be linked to a symbolic and ritual world. The white-tailed deer was an animal with restricted access because of its polysemic ritual significance at Parita Bay in particular within Greater Coclé semiotic system.

•The zooarchaeological record of Parita Bay evidences that human groups did not rely upon white-tailed deer, they had a broad-spectrum diet. The study of white-tailed deer in the archaeological record of this area did not evidence an intensification in deer hunting, the presence of deer is constant along the human occupation sequence and even modern times.

One of the major contributions of this thesis is that through the study of a single species (*Odocoileus virginianus* in the mainland and *Mazama* sp. in the island) many aspects of ancient societies of Panama can be understood. For example, through the study of animal diets it was possible to infer environmental aspects related to human occupations and the introduction of swidden farming and garden hunting as consequence. Through the analysis of deer remains aspects related to social organization and even symbolic aspects important for these human populations were evidenced.

The long term study of one species also allows understand the different ways in which humans interacted with this species and whether they used or not wildlife management strategies. In the case of white-tailed deer they have been successful to the extent that the species survives today even in Panama City. In the case of dwarf deer, the impact of human hunting but not less important the impact in the island environment led to the extinction of the species on the islands.

At a methodological level, several aspects should be mentioned: 1. A multiproxy approach allowed the interaction between proxies and the better understanding of the same problematic from different scales of analysis; 2. In the case of the zooarchaeological and taphonomical analysis a standardization of the method allowed a comparison between sites; 3. The inclusion of cutting edge techniques such as microwear, mesowear, isotope stable analysis and geometric morphometrics.

While it is true, that individual articles are presented this thesis, it was tried to maintain a unity and to answer the research questions planed at the beginning of the volume. At the same time, it is expected that the reading of this thesis has been fluid.

Despite all the work done for this PhD thesis, this is only the tip of the iceberg of a number of research possibilities, below I present some of them and hope that in the near future I will be able to carry them out.

•Zooarchaeology & Taphonomy: It would be interesting to study other contexts at Cerro Juan Díaz in order to evaluate differences between them and also between time periods. Other interesting point will be the study of the bone industry of Cerro Mangote. And in both cases the use wear analysis to better know the deer bone industry and their manufacture process.

•Mesowear & Microwear: I had the opportunity to visit the mammal collection of the American Museum of Natural History in New York (A MNH), Smithsonian National Museum of Natural History in Washington D.C. (NMNH) and Instituto de Investigación de Recursos Biológicos Alexander von Humboldt in Villa de Leiva, Colombia (IAvHM). In these collections I made cast of cervids of the study area (a total of 300 samples casted). The next step will be to analyze all these samples in order to study the dietary ecology of these species.

•Isotope analysis: I already sampled deer teeth and bones from Cerro Juan Díaz, Cerro Mangote and Sitio Sierra. The next step will be to analyze these data and to publish them.

•Geometric morphometrics: It would be interesting to extend this type of analysis to other bones in order to better understand the changes in size and shape that the dwarf deer suffered on the island.
·The Playa don Bernardo chapter will be formatted in a paper to publish these results.
Although it seems that the work has been completed, the truth is that several lines of work have been started that have great potential and that in the near future may be extended to other species, other chronologies and geographical areas.

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