DIACHRONIC TRENDS IN LINEAR ENAMEL HYPOPLASIA AT THE MAYA

SITES OF COLHA, LA MILPA, AND DOS HOMBRES

by

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DEDICATION

In memory of Ken Riegert. For your encouragement to follow this dream from an early age and for your lessons in humility and humor that have sustained me since.

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Abbreviation	Description
LEH	Linear Enamel Hypoplasia
PfBAP	Programme for Belize Archaeological Project

I. INTRODUCTION

Health trends and deficiencies of the Maya have been linked to the pressures of a universal population boom and ecological overexploitation considered responsible for the eventual collapse of the Classic Maya world (Shaw 1999). The overarching life-history of the Maya region is addressed as a homogenous narrative of settlement, prosperity, and societal collapse. The Maya region consists of great environments differences in subsistence resources and intricate nuances that are often forgotten when talking about diachronic trends (Gerry 1997). Furthermore, health indicators have received very little attention in addressing temporal and spatial variation among the Maya. The purpose of this thesis research is to examine temporal and geographical trends in linear enamel hypoplasia (LEH), which serves as a general indicator of population stress/health in a temporal and geographical framework. To test geographical influence on LEH, this research will compare LEH prevalence among the populations of three sites: the northeast population at Colha and the more western and inland sites of La Milpa and Dos Hombres at the Programme for Belize Archaeological Project (PfBAP). Archaeological and biological data suggests these populations differ in available resources, terrain, and other variables. Temporally, the Preclassic, Classic, Terminal Classic time periods will be examined within and among each site. These temporal periods differ in agriculture intensity, population densities, and in socioeconomic structures (Table 1).

Background and Literature Review

Mayan History

The history of the Maya region is divided into six main time periods. Time periods are identified largely according to ecological and societal fluctuations summarized in Table 1.

Table 1. Chronology of the Maya region adopted from Drake (2016) and Sharer and Traxler (2006)

Time Period		Year (BC/AD)	Descriptions
Paleoindian		1200 – 8000 BC	Initial occupation by nomadic groups of hunter/ gatherers.
Archaic		8000 – 2000 BC	Small foraging groups inhabit settled villages.
Preclassic	Early	2000 – 1000 BC	The advent of complex society as agriculture emerges, population growth produces conflict over resources.
	Middle	1000 – 400 BC	Socioeconomic complexity increases.
	Late	400 BC – AD 250	Intensified agriculture, craft specialization, writing and monumental architecture mark the “initial state” defined by increased social stratification and centralized power.
Classic	Early	AD 250 – 600	Densely populated centers incorporate satellite sites and ruling elites exercise political influence (Sullivan and Valdez 2006). Expanding states promote stratification, interregional trade, dynastic rule and political instability, brought to its apex, as the major polity Calakmul incites the fall of Tikal.
	Late	AD 600 – 800	After a brief decline, the population rebounds with the stability among smaller polities. Densely populated small urban centers and hinterland sites modify landscapes, monumental construction, and intensified agriculture.
	Terminal	AD 800 – 900	Strained by a regional drought, population growth, intense resource competition, decline and site abandonment occur.

Table 1. Cont. Chronology of the Maya region adopted from Drake (2016) and Sharer and Traxler (2006)

Postclassic	AD 900 – 1502	Occasional site visitation and small-scale habitation at abandoned sites. Deemphasize on dynastic rule (Sharer and Traxler 2006)
Historic	AD 1502 +	Spanish contact.

The three temporal categories used in this thesis are an oversimplification of this timeline (Table 1) and include the Preclassic, Classic and Terminal Classic. Broad time periods were used in order to utilize sufficient sample sizes so divisions within the periods are not examined. Temporal categories designations are arbitrary categorization enabling researchers to apply a framework with which to understand and order past events. Nonetheless, it is important to justify the categorizations utilized. These represent broad sections of time with complex life histories, however, they were chosen to reflect the overall arc of the Maya occupation.

The Preclassic period (2000 BC- AD 250) encompasses the emergence and subsequent intensification of agriculture which allows for food surplus and increase in social complexity. Increased social complexity manifests as a centralization of power, social stratification, craft specialization, and the construction of monumental architecture (Drake 2016; Sharer and Traxler 2006).

The Classic period (AD 250- AD 800) is a broad designation for two phases of occupation. Initially satellite sites are incorporated into densely populated centers, promotion of interregional trade and dynastic rule which engenders political instability. In the face of instability and possibly overexploitation there is a brief site de-occupation but the population rebounds and ushers in a population boom intensifying agriculture and extensive modification of the landscape. Ideally these should be separated into Early

Classic and Late Classic periods, but the more general Classic period category is used because the sample sizes would be too small for any useful statistical analysis.

The last temporal category, the Terminal Classic (AD 800- AD 900) is much shorter but marks site abandonments occurring in the face of continued population pressures, drought, and intense resource competition. While brief, it was important to isolate this period to evaluate if the continued stressors, residual from the Classic period, affected the health of individuals the same as before site abandonment. A difference was previously observed in the expression of LEH on posterior teeth between the Late Classic and Terminal Classic at the further inland sites along the Pasion River in Guatemala (Wright 1997). Wright concluded that these results were incongruent with the ecological model. This claim contradicts much of the research suggesting that pressures of the Classic period persevered into the Terminal Classic period and the geographical influence deserved to be considered here. The idea being that Wright's (1997) results could be an isolated geographical anomaly. While generalized and therefore problematic, the chosen temporal designations provide a framework which encompasses the most notable events experienced by the Maya at large.

Overall health is likely to fluctuate in response to the Maya life history, characterized by episodes of occupation, economic success, turmoil, and collapse. The degree to which inter-site discrepancies occur depends upon varying social organization, subsistence patterns, and access to resources between sites. Understanding health and causation requires osteologists to contextualize biological data in geographical frameworks. This thesis was inspired by a study which explored the influence of status and geography on dietary privilege, a concept which emphasizes the importance of access to proteins and other food resources. Nutritional benefits include greater overall health (Gerry 1997). Conversely, decreased access to resources produce nutritional deficits. Gerry (1997) conducted an isotopic analysis of remains to directly observe dietary intake, where others had indirectly observed proxies such as height. The study found that both social class and regional affinity are correlated with differences in protein and vegetation intake.

The ecotone of a site may advantage a population and can serve to buffer environmental stressors. The efficient manipulation of available resources is vital, but the advantages do not need to be realized by initial occupiers because they will benefit nonetheless. Morse (2009) notes that advantaged by access to upland forests, riverine environments, and swamps, the Blue Creek Maya of Northwestern Belize, encountered diverse resource availability. Increased resource variation curbs the risk associated with relying on any single resource. The proximity of Blue Creek to La Milpa allows the extrapolation that the Maya at La Milpa benefited from a similar buffer to resource overdependence. Diversification can be increased through more anthropogenic means, such as engaging in trade (Morse 2009). All of these solutions are designated as adaptive strategies. Adaptive strategies are variable and can manifest as manipulation and exploitation of the local environment or the reliance on social, economic, and cultural infrastructure that bolster a community when other methods are strained.

Models of Wetland Agriculture

All three sites are in intensive wetland zones (Beach et al. 2009). The efficient exploitation of the agro-ecosystems is largely influenced by water management and soil conservation strategies. These strategies include the use of cenotes, raised fields, check dams, and agricultural terracing. Various models of wetland agriculture exist and differ on the basis of the natural processes, anthropogenic formation, and associated resources of wetland environments. The use of wetland agriculture was in large part due to the rising sea level and water table (Beach et al. 2009). Rising sea levels could have vast impacts. Exemplified at Colha, rising sea levels resulted in increased salinity in Cobweb Swamp (Luzzador-Beach and Beach 2009). An increase in saline is likely to better support taxa that flourish in saltwater but would diminish the landscapes functionality for agriculture. Natural changes in the environment had cascading repercussions for agricultural practices and resource exploitation in the Maya lowlands. More extensive research is needed to better understand the anthropogenic use of the wetlands in Northwestern Belize, but models of wetland agriculture are summarized below (Beach et al. 2009, Beach et al. 2015). These models will likely be applied to different sites based on the local environment and time period. My research utilizes these models as explanatory tools in understanding any observed patterns in LEH.

The first four models are summarized from the Beach et al. (2009) article. The first model, the Chinampas model, examines the anthropogenic origins of the wetland agriculture. Human construction is responsible for raised, drained and recessional fields. The building and ditching of sediment would have been a labor-intensive process dependent on the height of the local water table. Through these adaptive strategies, farmers create functional space out of the deep-water areas. The intensification of wetland agriculture would have been necessary during the increased rainfall between the Pleistocene and Holocene. Savannas receded at this time and environmental changes demanded new exploitative strategies. A second episode of intensified wetland agriculture is evidenced in the raised fields and canals constructed between the Preclassic and Classic periods (Beach et al. 2009). Increased production from the wetlands would serve for the larger regional subsistence.

The second model explains the patterned fields as the result of natural processes affecting the earlier Archaic horticulture and agriculture experimentation. This second model was developed by observing the wetland stratigraphy. The model holds that Archaic and Preclassic fields were submerged by increased erosion and precipitation. Aggradation is thought to be responsible for the formation of raised fields after previously dug ditches were abandoned due to the rising water table and increased salinity. These conditions would inhibit the use of this agro-ecosystem to sustain the larger region.

Model three, the Chan Cahal model, combines aspects of the first and second model, but displays a more nuanced understanding of transitions between adaptive strategies as responses to various environmental changes. It is the incremental field construction that separates this model from model two. This model frames wetland agriculture in a series of stages that begin with slash and burn agriculture. The second stage addresses the water table rise between the Archaic and Preclassic periods, but Maya agriculture was still practiced at this time. Stage three is really a Preclassic event, where the agricultural landscape was submerged by calcareous silt and sand during a large flood (Beach et al 2009, Luzzadder-Beach and Beach 2009). The exaggerated rise of water would have prevented any slash and burn agriculture. The fourth stage sees continued increase in the water table and sedimentation during the Preclassic and Classic periods.

The subsequent fifth stage characterizes the Classic period agriculture as extensive ditching and diverse agriculture. This fifth stage also suggests a heavy reliance on rainwater. Rainwater was vital for continued subsistence because the local hard water would not have sustained the maize agriculture as evidenced in pollen samples (Beach et al. 2009).

The last of the models summarized in Beach et al. (2009), model four, the Birds of Paradise model, is based off the Rio Bravo floodplain upon which both La Milpa and Dos Hombres are situated. Late / Terminal Classic ditches are patterned and regularly occur at 900m suggesting they were a preplanned project on floodplain. This area shows evidence for continual tree vegetation. Salinity was diluted by the rains and would have better supported crops, but the wetland fields were short lived as ditches were filled by aggradation (Beach et al. 2008, Luzzadder-Beach and beach 2008, Beach 2009).

After the 2009 publication, Beach et al. (2015) expanded on the archaeological evidence that produced the last four models and asked questions about the impact and interaction between human populations and ecology. Specifically, research in the Three Rivers Region resulted in the construction of an ecological model which corresponds to the Maya life history and intensified agricultural use. Three episodes of sedimentation were detected. Episodes of highest sedimentation occur during the occupation, growth, and climax of the Maya population. Through the environmental manipulation of the environment, erosion and sedimentation intensified at an accelerated rate (Beach et al. 2015). The rise seen in the Preclassic and Classic drops off in the Postclassic after widespread Maya abandonment of sites. This later model corresponds with model four and is summarized below (Table 3).

Table 2. Diachronic Model of Sedimentation at the Rio Bravo Watershed (Beach et al. 2015)

Model Stage	Diachronic Patterns	Sedimentation Rate Directionality	Time Period	Sedimentation Rates
1	Pre- Maya	Low	*Archaic – Preclassic*	*0.82mm yr*
2	Maya	High	Preclassic-Classic	*0.98-2.03 mm yr*
			Classic	*1 – 9.12 and 16.27 mm*
3	Post- Maya	Low	Postclassic	≤1 mm

Models of Maya Settlement and Adaptability

Internal community adaptations to environmental stressors are limited by the local resources and ecological constraints. Moments when needs of a community exceed its ability to meet those needs, membership in a larger exchange network can act as another adaptive buffer (Scarborough and Valdez 2009). Advantages of that larger infrastructure could alter a community's survival in times of drought or famine. The structure of the Maya community network is contested, and two models are discussed here.

The hierarchical dependency model frames a social network made up of isolated communities which are centered around and pay tribute to a large centralized polity (Scarborough and Valdez 2009). Under a hierarchical framework, an elite class (from the large centralized polity) would rule a labor force and install the hegemonic systems of the

Maya world. Hegemonic value systems would reverberate in the architecture and iconography of the subservient communities. This concept also falls within the model of the segmentary state. The segmentary state is structured with a centralized power and ruled towns mimicking that power dynamic. When surrounding communities grew to a substantial population size, they began to directly resemble the elite polity. Scarborough and Valdez (2009) identify this pattern as a cultural homogenization which innately inhibits complex society. Unlike isolated bodies, the Maya area was largely dispersed settlements and densely populated secondary centers. This settlement pattern is inconsistent with the presence of a hierarchical social structure and subservient labor force (Scarborough and Valdez 2009).

More recent understandings of Maya settlement and economy approach the Maya as a nuanced network of moderately autonomous entities simultaneously interdependent on regional networks (Dunning et al. 2003; Scarborough 2005b, Scarborough 2008; Scarborough and Valdez 2009). This alternative model, the resource specialized community model, frames the Maya world as a series of heterarchical networks through which specialized production allows flexible adaptations in times of environmental or sociopolitical stressors (Scarborough and Valdez 2009). Exchange systems would exploit variations in resources depending on community needs. This model works well in the Maya lowlands for a couple reasons. First, while salting and preserving food occurred, overall storage of food in the tropical climate can be difficult. Just like other resources, food was used as a commodity which served communities that may have otherwise starved under less than preferential environmental fluctuations (Scarborough et al. 1999' Scarborough et al. 2003; Scarborough and Valdez 2009). Infrastructure between the dispersed communities allowed the accelerated exchange of these goods. Secondly, the rainy and dry seasons cause annual droughts and water logging which would have affected agriculture and access to potable water. Ninety percent of rainfall occurs during the rainy season (Beach et al. 2015). Annually, precipitation reaches 1500 mm and results in waterlogging during the rainy season. The perennial nature of the Tropical climate is characterizing an extended dry season and period of drought. The intensity of drought changes based on moisture availability, culture change as well as global and local climatic changes (Morse 2009). Intense episodes of drought have been detected in the Late Preclassic, Late to Terminal Classic, and Postclassic periods in the Rio Bravo area (Beach et al. 2015; Dunning et al. 2012). Two sites in the Three Rivers Region, Medicinal Trail and Rio Bravo, contain tanks which can contain enough water for their communities and one additional community for an entire drought season (Scarborough and Valdez 2009). A network that is operating with the larger network in mind, benefits when conditions would otherwise cause extreme hardship. This experience, however, may not have been as severe for all Maya communities. While there is evidence for episodes of drought at Cobweb Swamp, the investigations showed the presence of a forest that flourished in the absence of a drought (Jones 1991). Likewise, evidence of agriculture and forest clearance exists at Cobweb Swamp and indicates the area did not experience the same evidence of drought experienced further to the west (Jones 1991; Morse 2009). They may have served as the source of needed good for other communities experiencing severe drought at that time. In the fickle and sometimes harsh environment of Northern Belize, an adaptive interdependent regional approach affords a reliable sense of security likely not experienced under a distant and hierarchical elite rule.

Sociopolitical Turmoil and Maya Collapse

The Classic Maya collapse in the Terminal Classic has been attributed to other environmental factors such as hurricanes and earthquakes. Sociopolitical factors include warfare, internal revolution, and invasion (Coe 2005). Warfare is the opposition of organized group that may be religiously, politically, or economically motivated (Webster 1993). Acts of warfare include personal violence, but also the destruction of physical property (Barrett and Sharer 2005). Destructive acts seen at Colha suggest social turmoil or tension. Turmoil is most evident in the skull pit excavation which included the remains of thirty decapitated crania. This interment is thought to be associated with the collapse and abandonment at Colha (Eaton 1980b; Massey and Steele 1997; Barrett and Sharer 2005) and highlights the internal conflict taking place near the end of the Classic period. Turmoil was confounded or even influenced by the massive overpopulation and subsequent competition for resources. Ultimately, overpopulation, overexploitation of the agro-ecosystem, and internal warfare are considered to be the key elements that led to the Classic Maya collapse (Coe 2005).

Burial practices

Maya burial practices are complex and reflect an embodied identity aligned with spatial and temporal cultural realities (Drake 2016). Mortuary practices vary between and within sites, burial position, head position, and interment context. No singular predominant practice is observed, but most often simple burials, commonly encountered burial positions include individuals situated in a supine extended, flexed, or seated position. This practice is typical of burials from Tikal, Kaminaljuyu, and Colha (Thompson 2005; Drake 2016). However, burials within the PfBAP area are distinctly variable and include primary interments, secondary interments, multiple burials, cremains, and burials as human offering within variable contexts. The region's trends in burial practice have been explored by Dr. Drake (2016) and Geller (2004) will be referenced upon the results and interpretation of this thesis.

Linear Enamel Hypoplasia

Teeth reliably retain the evidence of malnutrition as well as a plethora of possible insults to the body. Linear enamel hypoplasia is one example of preserved evidence of health during childhood development. Enamel hypoplasia is the resultant arrest line formed in the disruption of amelogenesis. During dental development, enamel is laid down from the occlusal surface working towards what will become the cement-enamel conjunction. Decreased health or insult during amelogenesis reduces enamel secretion and manifests as a hypoplasia or abnormality macroscopically observable in the enamel surface (Goodman and Rose 1990; Cucina 2013). The interruption of the secretion process provides data on health but also on the age of insult.

The location of the arrest line indicates age by delineating where an individual was in their dental development during the stress event (Goodman and Armelagos 1985). Affected teeth, in theory, should correspond to where an individual is in their dental development. It has been hypothesized that crown development related risk of hypoplastic reaction should indiscriminately affect the teeth that develop at the same time. While theoretically it is logical that a systemic reaction would affect all developing crowns, research has shown that anterior dentition exhibits three times the risk of LEH in comparison to their distal counterparts (Goodman and Armelagos 1985). The research conducted by Goodman and Armelagos (1985) provided a frequency of LEH by tooth type. Their results are as follows: highest frequencies of LEH presented in maxillary central incisors, second highest LEH frequencies occurred in maxillary lateral incisors, mandibular incisors, and all canines; subsequently the first premolar and first molars and finally the second premolars and second molars presented the lowest rates of LEH. While this pattern encourages the primary focus be placed on the anterior teeth, all dentition warrants examination (Hillson 2014). In order to incorporate as much data as possible anterior and distal dentition were included in the presence/absence scoring reported here.

Factors causing enamel hypoplasia include trauma, congenital disorders, hormonal changes, systemic metabolic responses, and psychological stress (Kreshover and Clough 1953; Al-Shorman et al. 2014; Goodman and Armelagos 1985; Pinborg 1970). Hypoplasia is more likely attributed to malnutrition if hypoplasia presents in multiple individuals younger than 40 (Ortner 2012). Systemic attack rarely produces a differential diagnosis, however examination of distributions and incidence of LEH may narrow theories surrounding pathogenesis. In order to best explore patterns in health it is necessary to observe the environmental and cultural factors that stimulate LEH causative agents.

Project Goals

It is hypothesized that patterns of LEH prevalence will correspond to temporal fluctuations in the life history of the Maya due to increased use of agriculture, population fluctuations and the effects of an overexploited ecology. Likewise, it is hypothesized that costal populations may have less LEH prevalence because of access to more diverse food resources. It is also thought that these trends will not be significantly affected by age and sex but may be influenced by other factors such as burial and grave type that reflect cultural and social identity, status, or occupation. At this point, however, there has not been standardization of data collection protocol or a determination of how many skeletons with teeth are present for each geographical region/site or temporal period within each site. Therefore, this project sought to standardize the data collected for skeletal remains at each site and to examine and describe the patterns of LEH among the Maya within a temporal and spatial context. Available demographic and archaeological information (e.g., burial and grave type) will also be examined to evaluate relationships with LEH. Ultimately the goal is to develop hypotheses about diachronic aspects that can be tested.

Hypotheses

Hypothesis 1: Patterns of LEH prevalence will correspond to temporal and geographical fluctuations in the life history of the Maya Region State.

I will explore geographical and temporal trends in Linear Enamel Hypoplasia between Colha, La Milpa, and Dos Hombres.

Hypothesis 2: Trends in LEH will not be significantly affected by age or sex but may be influenced by other factors such as burial or grave type.

I will establish if significant relationships exist between age, sex, and mortuary practices in respect to LEH presence.

II. MATERIALS AND METHODS

Materials

This research is a part of a larger ongoing effort to study the skeletal collection at the PfBAP. Additional ongoing research explores dental histological methods for the Belize area and targets inter-site differences within the Rio Bravo Conservation Area (Koutlias personal correspondence 2018). Data reported are a compilation of my own reports and dental data collection, as well as the dissertations, theses, and professional reports conducted for the excavations at Colha, La Milpa, and Dos Hombres (Figure 1). Below is a brief description of these sites.

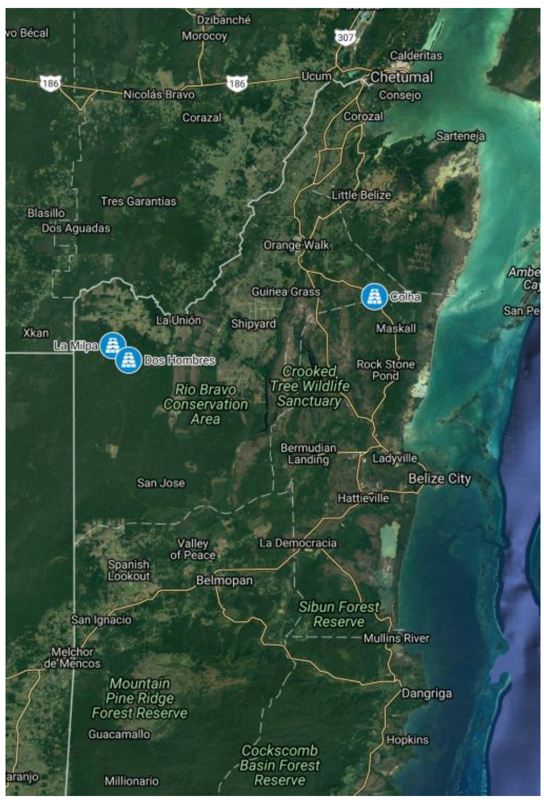

Figure 1. Map of Belize Indicating the Location of Colha, La Milpa, and Dos Hombres.

Archaeological Sites

Colha

Colha is a centrally situated Maya site in Northern Belize. Cobweb Swamp serves as the northern site border, eastern site border, and repository for the drainage of Rancho Creek which bisects the site. The current delineated area covers six square kilometers, but the extent of the site is not fully ascertained (Hester and Shafer 1984). Consisting of four courtyards, Mayanists consider the site a “moderate sized community” occupied between the Middle Preclassic through the Late/Terminal Classic (Hester and Shafer 1984). The site was characterized by extensive craft specialization encompassing production of both utilitarian and prestige goods and was extensively entwined in the regional trade network. With access to quality chert, prosperity was rooted in the site’s role as a major lithic production site that supplied much of Northern Belize (Valdez 1987). Other resources such as maize, cotton, and chile peppers were cultivated among wetland raised fields (Morse 2009). Terminal Classic site instability is evident in the interment of an elite 30 decapitated individuals deemed the “skull pit” (Massey 1989).

La Milpa:

La Milpa is the largest urban center in northwest Belize, and the third largest Maya site in Belize (Geller 2004, Trein 2016, Drake 2016). With connections to other polities in Belize and major Maya sites in the Peten of Guatemala, La Milpa exercised its influence as early as the Late Preclassic and as late as the Early Postclassic (Robichaux 1995). A major ceremonial center with variable monumental architecture, La Milpa was an area for public ceremony and elite residence centered on multiple adjacent plazas

(Bullard 1960; Geller 2004; Drake 2016). On a smaller scale, La Milpa is the largest of the major ceremonial centers in the Three Rivers Region, the Belize area bordering Mexico and Guatemala. North and South plazas at La Milpa are connected by a sacbe and there are two areas thought to serve as a quarry or water reservoirs (Robichaux 1995; Houk 2010). Within the La Lucha Uplands ecozone, La Milpa sits elevated on the upland area between the Rio Bravo and Rio Azul. The Uplands tend to contain shallow yet fertile soil. The Upland soil tends to be well-draining clay mollisols and/or rendzinas (Beach et al 2015). Generally, the Three Rivers Region experience a diet that was about 50% maize based and 50% plant based (Knisely 2013). La Milpa's meat source mainly consisted of terrestrial Herbivores. Reflecting the unique topographical and ecological diversity within the RBCMA, La Milpa is variably dispersed" over hills, seasonal swamps, and incised drainages" which limited the available farmland (Rose 2000).

Dos Hombres:

Twelve Km southeast of La Milpa, Dos Hombres is the smaller of the two major ceremonial centers in the Three Rivers Region. The site is situated along the Rio Bravo Escarpment and mainly consists of bajo and poorly draining terrain (Buttles 2002, Trachman 2007). This area is marked by swamp forest, diminutive trees, and shrubs (Beach et al. 2015). Dos Hombres is also a part of the Three Rivers Region and therefore shares the same regional diet as La Milpa, sharing about a 50% reliance on maize and a meat diet of terrestrial herbivores (Knisely 2013). A Sacbe connects the two main site components encompassing four courtyard groups (Houk 1996). Recovered material culture is largely from the Late and Terminal Classic occupation, but group A includes two Late Preclassic structures and burials (Saul and Saul 1995 as reported in Houk 1996; Drake 2016). Burials have also been recovered from surrounding household groups (Lohse 2001; Trachman and Valdez 2006; and Trachman 2007).

Dental Samples

Skeletal remains from Colha, La Milpa, and Dos Hombres are differentially preserved. Preservation at Colha is remarkably better compared to its' nearby counterparts. Remains from the 2017 excavations show Middle Preclassic deposits at Colha characterized by better preservation than skeletal material than the Classic and Late Classic deposits at the inland sites. Due to this disparity in preservation conditions, comparisons in health are best undertaken by looking at the better-preserved dentition. Dentition is the only reliable material that is consistently preserved at both the inland and coastal sites. All three sites are marked by assemblages with well-preserved dentition. Therefore, LEH are scored for any skeleton with preserved teeth. However, LEH will be recorded as present if it occurs on any tooth for the individual. The position of the LEH and the number of LEH will not be recorded. Why? or something more?

Methods

My original analyses included basic inventories and biological profiles with an emphasis on any observable pathology, sex, and age indicators. The poor preservation requires osteologists to utilize a broader set of methods to form the biological profile. Table 3.1 shows the data that will be collected, and Appendix A provides a description of each. Table 3.2 is a summary of how these data categories were collected.

Table 3.1 Data Collection Categories and Descriptions.

Data Category	Description
Site Name	Colha, La Milpa, or Dos Hombres
Burial ID	Skeletal ID number
Time Period	Preclassic, Classic, or Postclassic
Burial Type	Primary or Secondary
Grave Type	Simple, Complex, or Disturbed
Teeth Present	Maxillary: I1, I2, C, PM1, PM2, M1, M2, M3 Mandibular: I1, I2, C, PM1, PM2, M1, M2, M3
LEH	Present or absent on any tooth
Age Category	Adolescent, Child, Young Adult, Middle Adult, Older Adult
Dental score	Dental score for molars
Sex	Male, Female, or Undetermined

Table 3.2. Summary of Applied Methodology.

Data Category	Method
Time Period	Data is collected from excavation records. Time periods are estimations based on relative dating and radiocarbon dating. The method varies by burial.

Table 3.2. Cont. Summary of Applied Methodology.

Burial Type and Grave Type	Data is collected from excavation records. Definitions of burial and grave categories are based off those laid out by Geller (2004).
Teeth Present	A basic inventory of all present elements is recorded both visually and as a summary table. Previous reports vary on how comprehensive inventories are recorded.
LEH	LEH is recorded on a visual recording form. LEH is defined in accordance with the definition by (Goodman and Armelagos 1985). If possible, distance from the cementoenamel junction (CEJ) is measured (Mayhall 1992; Buikstra and Ubelaker 1994)). Though these measurements were recorded when possible, interpretations in this thesis are based on absence or presence of LEH. Restricting analysis to the absence or presence of LEH facilitated a larger study sample because it includes previous cases that only report on the absence or presence of pathologies.
Age Category	Age estimation is conducted through the analysis of morphological changes occurring in skeletal development and degeneration (Todd 1921; Lovejoy et al. 1985; Brooks and Suchey 1990). Age estimates reported here are largely based on dental development, degenerative changes, and dental wear scores.

Table 3.2. Cont. Summary of Applied Methodology.

	Juvenile age estimation is based on ossification centers (Sheuer and Black 2000), epiphyseal union (Scheuer and Black 2000), measurements of long bone length (Schaefer et al. 2009), and dental development (Ubelaker 1989a)
	Adult age estimation observes morphological changes seen in the pubic symphysis (Brooks and Suchey 1990), auricular surface (Lovejoy et al. 1985), alteration of the fourth and first sternal rib Iscan et al. 1984a,b, Digangi et al. 2009), and cranial suture closures (Meindl and Lovejoy 1985). It should be noted that the extensive degradation from the tropical environment prohibits the use of histology and limits the use of the above-mentioned age estimates.
	Dental wear scores are scored according to Scott (1979) and are used to obtain more precise age categories for poorly preserved remains.
Dental score	The maize based diet, common among the Maya, significantly degrades the occlusal surface over time. Because teeth do not repair and the damage increases with time, bioarchaeologists are able to use the degree of dental wear as a proxy for age (Uhl 2013). This seriation method is limited because it is diet based and less predictable than other degenerative processes.

Table 2.2. Cont. Summary of Applied Methodology.

Sex	Sex assesment is based off methods outlined in (Buikstra and Ubelaker 1994; Digangi and Moore 2013) These methods largely look at a gradient of morphological characteristics that are sexually dimorphic. Sex is not assessed for subadults (Buikstra and Ubelaker 1994; Moore 2013). Spradley and Jantz (2011) clarify the difference in sex estimation and sex assessment. Sex estimation relies on metric analysis and produces error rates. Taphonomic damage to the three samples largely prevents me from applying a metric analysis. Instead, sex is largely assessed through visual non-metric methods assessing fragmented os coxae and cranial morphology (Krogman and Iscan 1986; Bass 1987; Buikstra and Ubelaker 1994; Walker 2008; and White et al. 2012).

My own osteological analyses addressed individuals from burials I had excavated, burials from previous excavations, burials excavated from the 2017 field season at Colha, and re-analysis of La Milpa burials located at the Center for Archaeological & Tropical Studies (CATS), and the PfBAP field lab. The La Milpa burials were only re-analyzed if the age, sex, or dental data excluded pertinent information. For previously analyzed burials, reports are the primary source for data collection. The reliance on previous reports avoids the further handling of friable remains.

Reports augmenting my own analysis are reports and research by Potter (1984), Wright (1989), Sullivan (1991), Anthony and Black (1994), Shaw and Mangan (1994), Young (1994), Buttles (2002), Thompson (2005), Trachman (2007), and Drake (2016). These publications consistently report basic biological profiles, burial context and associated cultural material. Additional data (Appendix B) is collected when reports excluded pertinent information for my analyses. The only data consistently absent were dental wear scores and detailed information on dental pathology. Dental wear is scored to provide age categories to individuals assigned broad age categories such as adult or subadult (Scott1979). The dental pathology data is collected to corroborate the LEH data referenced in reports. When reports are accessible, but the physical remains are not, data is incorporated only if dental data, dental pathology, MNI, and discrete age categories are published. Occasionally, multiple publications are referenced to obtain all necessary data for each individual. Individuals were excluded from the sample if analyses could not distinguish individuals from commingled burials. To reconcile all available data from both records and my own collections, analyses are archived in a new database targeting the three sites: Colha, La Milpa, and Dos Hombres. Databases by Geller (2004) and Drake (2016) will be referenced for the organization and prioritization of information.

Frequencies, Quantitative, and Matrix Analysis

Methodologically, data are analyzed as exploratory data analysis. Various relationships between demographic information and LEH occurrence are presented in frequency tables. Frequency tables present data by providing percentages of a whole demographic. Frequency tables better present population level information because individuals with no LEH will still be a part of the overall count of individuals. Therefore, the data will be understood through a temporal and site-specific framework. This method enables the population comparison at specific time periods.

An exploratory approach isolates trends and facilitates new hypotheses. This approach ideally directs future research towards more robust statistical analysis. The data presented in this thesis is intended to explore temporal and geographical trends that may be applied a larger area encompassing the Lowland region. Geographical trends from the larger Maya region is beyond the scope of this thesis, but future research should include greater geographical variability with site specific environments.

III. RESULTS

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A total of 100 individuals were sampled for this thesis. However, due to the limitations of the data set there are gaps in information for various individuals. Data are absent in cases where the skeletal material was not preserved or for cases lacking accessible excavation reports detailing burial position, grave type, or associated dating for time period. Due to the limitations of a small sample size, all burials were included in the analysis despite the pitfalls of missing data. For this reason, it is suggested that future research acquire a larger sample which would allow the exclusion of burials with significant data. Frequency analysis was utilized to determine the statistical significance of various trends. Further analysis focused on relationships between variables, a chi-squared determines the likelihood these relationships are a random occurrence. Instances of statistical significance will be further explored in the following discussion.

Burials by Site

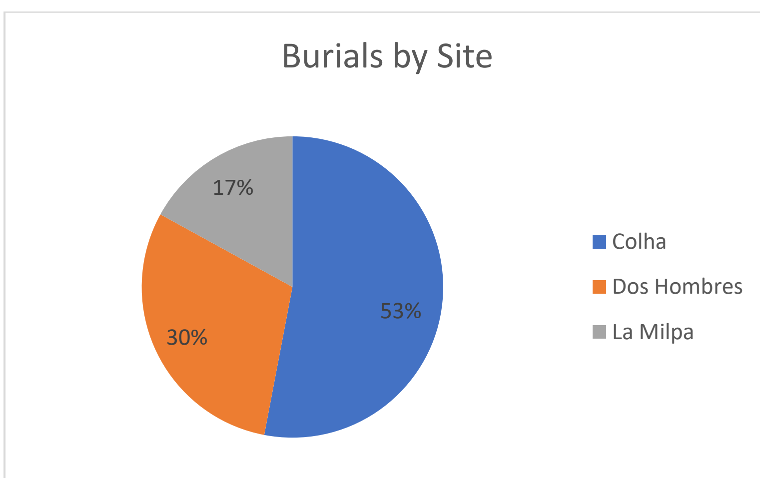

Figure 2. Pie Chart of the Site Distribution of All Sites.

Burials from Colha make up just over half the sample analyzed (Figure 2). The smallest sample is from La Milpa with 17 individuals. Samples from La Milpa and Dos

Hombres will at times be analyzed together as a comparison to the more eastern site Colha.

Table 4. Distribution and % of individuals exhibiting LEH by site

Site	LEH Score: 1	LEH Score: 0	% of Individuals with LEH
Colha	22	31	41.5%
La Milpa	8	9	40.0%
Dos Hombres	12	18	47.06%
Dos Hombres and La Milpa Combined	20	27	42.55%
All Sites Combined	42	58	42.0%

Overall, Colha had the most individuals with LEH (41.5%, n=22), however Dos Hombres had a larger percentage of individuals with LEH (47.06%, n=12). All sites exhibited an LEH frequency in the 40 percentiles (Table 4). These differences were not deemed statistically significant according to a chi-squared test. The 41.5%, 40 %, and 47% occurrence of LEH at Colha, La Milpa, and Dos Hombres respectfully differ from a previous study (Wright 1997) which found a 59% prevalence of LEH further inland along the Pasion River in Guatemala. Similarly, a study carried out at nearby site of K'axob, slightly northeast of Colha, found an overall 78.9% prevalence of LEH (Vance 2014). Therefore, the data does not support the original hypothesis that geographic differences between Colha, La Milpa, and Dos Hombres would be reflected as a difference in LEH presence. In fact, the similar presence of LEH (Figure 3) across sites supports the idea that these sites represent a regional experience and that the hypoplasias were experienced at a lower prevalence in this region than in other parts of the Maya world (Wright 1997, Vance 2014). In future research it may be appropriate to treat these sites as a regional aggregate in order to test this same hypothesis on a larger scale. However, a larger sample size expanding to a larger region is necessary to further test this hypothesis. My results will further be compared to this study in the following sections.

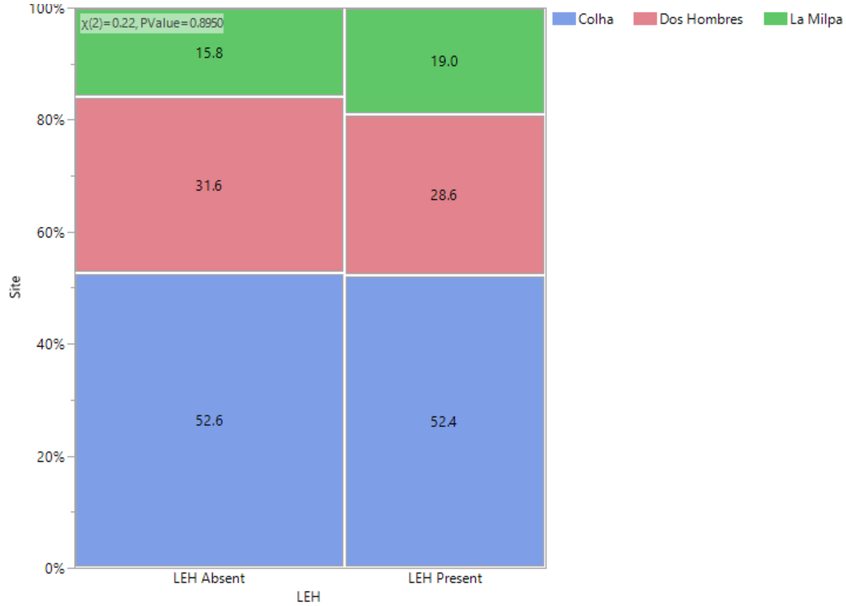

Figure 3. Mosaic of LEH Scores and % by Site.

Time Period

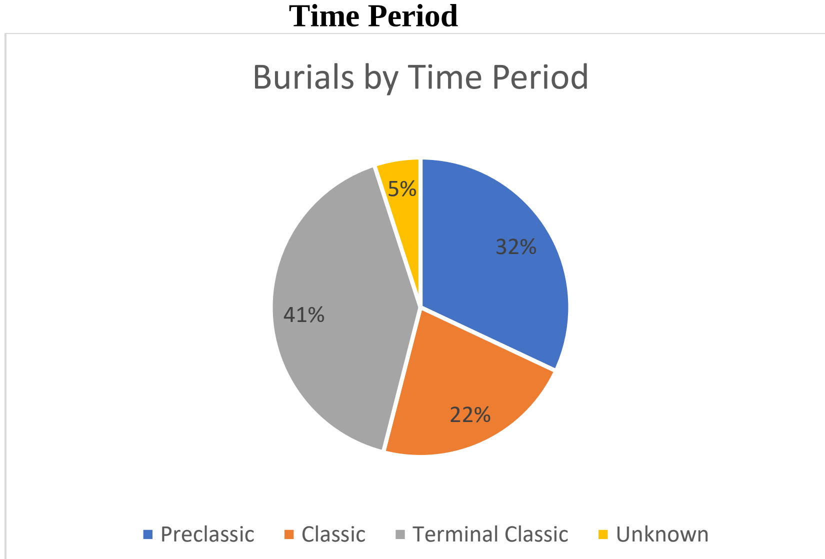

Figure 4. Pie Chart of Burial Distribution by Time Period.

Three temporal categories were utilized to encompass the arcs of the Maya life history. However, these are wide expanses of time and are used as an initial investigation for temporal trends in LEH. Temporal categories were chosen to compare trends observed at (Wright 1997). Due to limitations of the sample, no burial information for the Classic period at Colha was available. Sample bias may obstruct some questions addressing changes between the Classic and Terminal Classic at Colha but temporal trends between the Preclassic and Terminal Classic are investigated.

Table 5. Total Counts for Each LEH Category by Time Period

Time Period	**N Rows**	**N (LEH 0)**	**N (LEH 1)**
Preclassic	30	18	12
Classic	21	10	11
Terminal Classic	38	26	11
Unknown	11	3	8

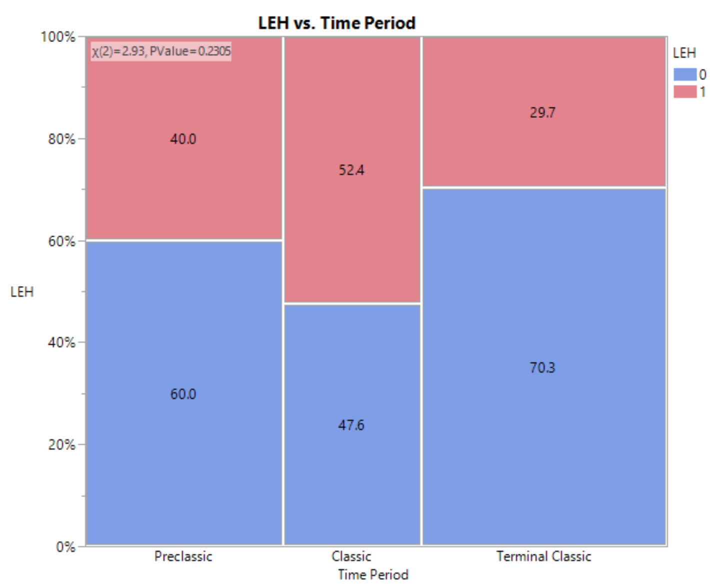

Figure 5. Chronological Trends in LEH.

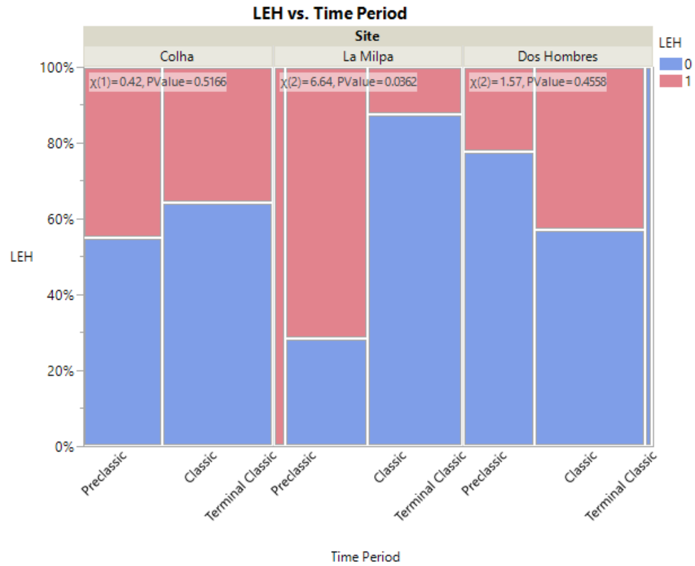

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Figure 6. Chronological Trends in LEH by Site.

Chronological trends (Figure 6) in LEH overtime were only found to be significant between the Classic and Terminal Classic periods at La Milpa. At La Milpa, 71.4% of individuals present with LEH in the Classic period, but by the Terminal Classic only 12.5% of the population show LEH (Figure 7). The small sample size from the Preclassic at La Milpa (one individual) possibly shows a more drastic decline of LEH prevalence than occurred (Figure 8).

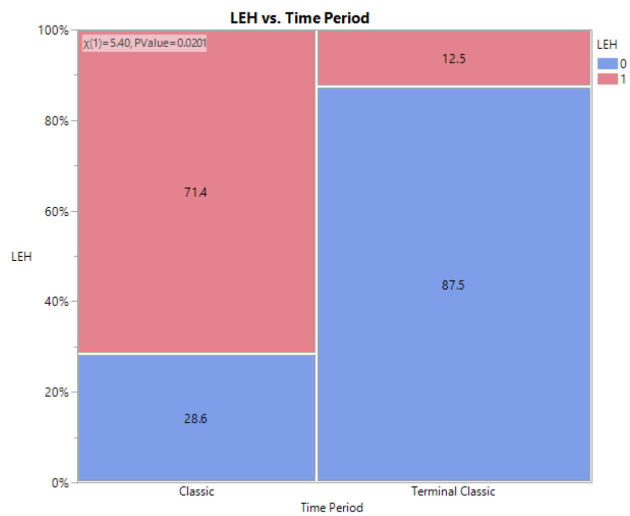

Figure 7. LEH from the Classic to Terminal Classic at La Milpa.

An overall trend of decline in LEH between the Preclassic to the Terminal Classic is apparent at all three sites. The recurring trends between sites again reflects regional similarity and supports future research to treat them as belonging to the same regional experience. Absent of significant fluctuations, chronological trends seen in the sites overall show a general stability over time at Colha and Dos Hombres with a slight decline in the Terminal Classic. The chronological pattern seen in this research again reflects patterns seen at Pasión in Guatemala that saw overall stability of stress events through time but with an increase in LEH for posterior teeth between the Late Classic and Terminal Classic (Wright 1997). This was interpreted as a shift in onset of stress from later to earlier periods in childhood, contradicting the ecological model which posits continued nutritional stress into the Terminal Classic Period. The data collected at Colha, La Milpa, and Dos Hombres further substantiates the findings by Wright (1997) by illustrating the influx of LEH incidence in the Classic period, a time of massive population growth, but levels of stress seem to decline in the Terminal Classic contradicting a model of sustained population stress substantial enough to maintain high LEH incidence (Figure 8).

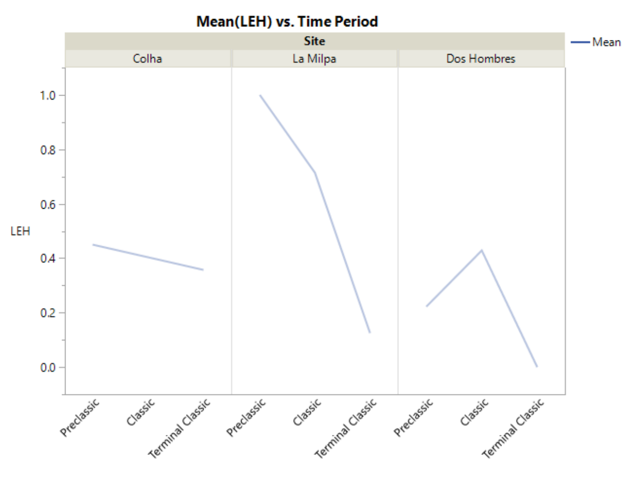

Figure 8. Chronological Trends by Site.

Burial Type

Primary and secondary burials were similarly prevalent at all sites (Figure 9), however, when broken down by site, the distribution of burial types becomes starkly different (Figure 10). Colha had mostly secondary burials (56% n= 30). Primary burials are overwhelmingly dominant at La Milpa (88% n=15) and similarly prominent at Dos Hombres (75% n=6) (Figure 10, Figure 11). While both secondary and primary burials appear at all three sites, Colha's prevalence of secondary burials is juxtaposed geographically to the preference of primary burials at the inland sites. Geographical trends in burial type were found to be statistically significant using a Pearson Correlation ((X^2 = 28.44, p=<.0001)(Figure 10). To further compare Colha to the more inland sites the same discrepancy between burial types was present ($X^{2=}$*24.92, p=<.0001*) (Figure 7).

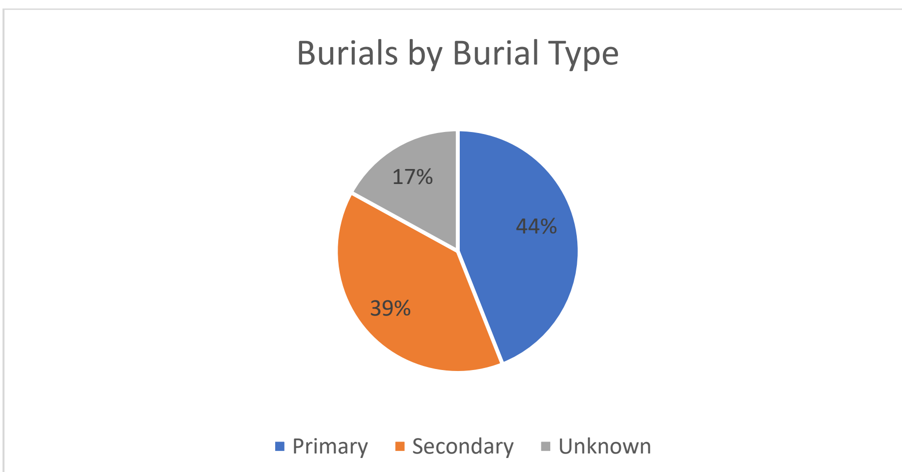

Figure 9. Pie Chart of Burial Type Distributions Across All Sites.

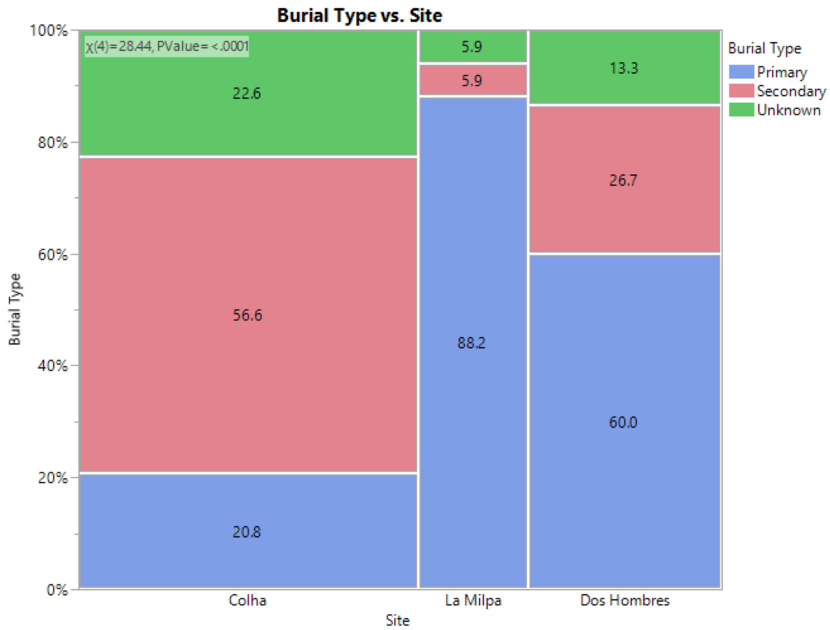

Figure 10. Mosaic of Burial Type Distributions by Site. Counts of burial types are displayed in the Mosaic.

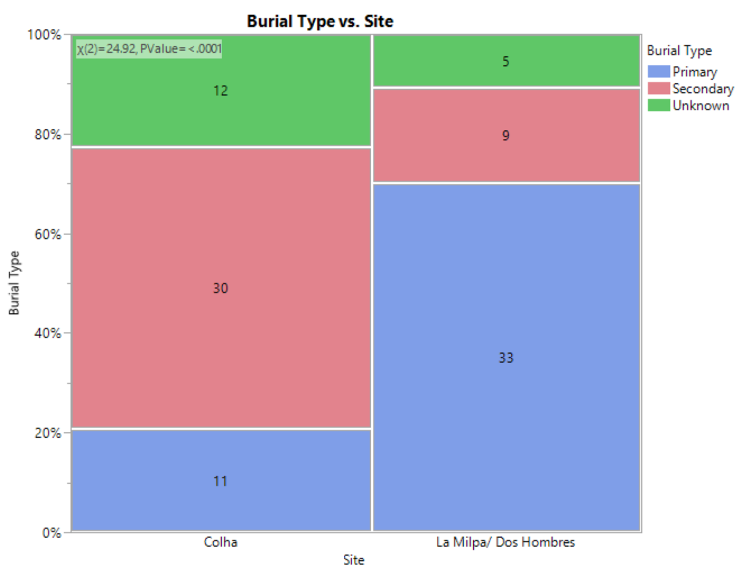

Figure 11. Mosaic of Burial Type Distributions Comparing Colha to La Milpa and Dos Hombres.

Temporal trends in burial type revealed the variability of the Preclassic, prevalence of primary interments in the Classic, and the surge of secondary burials in the Terminal Classic (Figure 12). This trend is likely influenced by the fact that many of the Colha burials were from the Terminal Classic (Figure 12). The absence of secondary burials in the Classic period is speculated to be the result of sample bias as Colha is not represented in this period. However, a shift in practices and other variables between the Classic and Terminal Classic is a common theme throughout this analysis.

Table 6. Total Counts for Each LEH Category by Burial Type.

Burial Type	N Rows	N (LEH 0)	N (LEH 1)
Primary	44	26	18
Secondary	39	25	13
Unknown	17	6	11

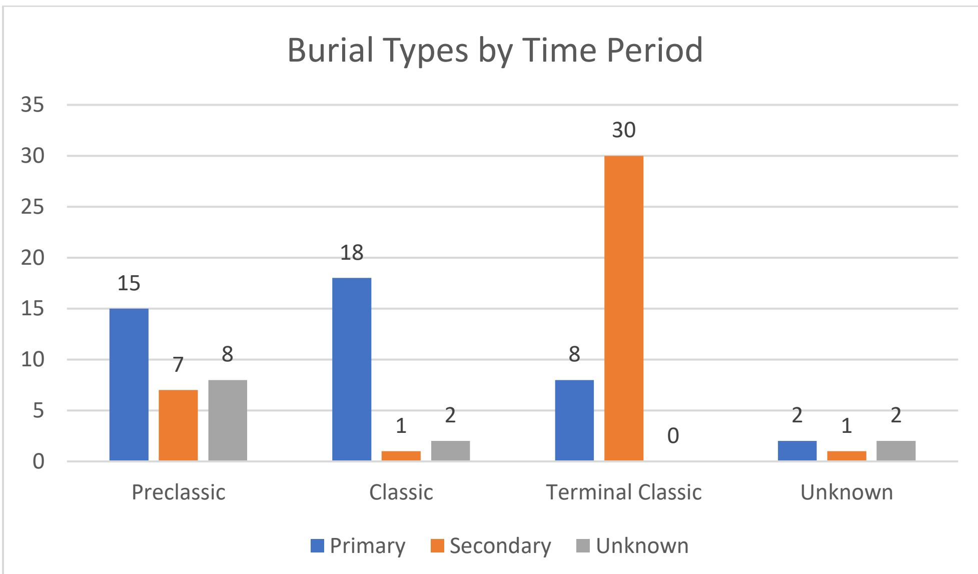

Figure 12. Bar Graph Plotting Burial Type by Time Period.

LEH and Burial Type

No significant relationship between LEH and burial type was found (X^2*=4.55, p=0.1030*). Primary burials especially exhibit approximately the same frequencies of LEH (42.86%) for all sites as well as for each individual site (Figure 13). LEH and burial type were analyzed within separate sites (X^2 and *p* values are summarized in figure 13). While no significant relationship exists between burial type and LEH, the variation between site burial types is again apparent (figure 13 right).

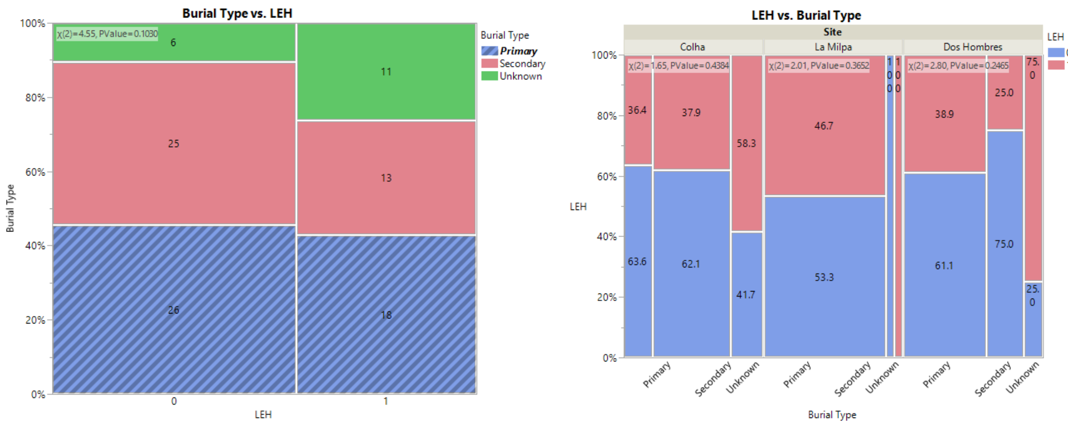

Figure 13. (Left) Mosaic and Chi-Squared of LEH and Burial Type (Right) Mosaic and Chi-Squared of LEH and Burial Type by Site.

Grave Type

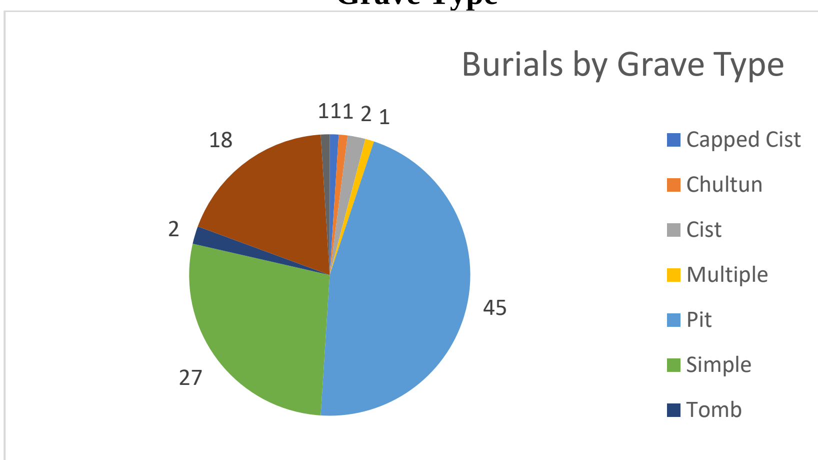

Figure 14. Grave Type Frequencies

Pit graves and Simple burials are the most prominent burial types at all sites. All other grave types are significantly absent across sites and through time (Figure 14 and 15). A t-test was used due to the small sample size of the more formalized burials. The more formal nature of these grave types including capped cists, chultuns, cists, multiple individuals, and tombs, is consistent with the observed diminished frequencies. The frequency analysis found a significant relationship (*p*= *.0426*), the less frequent grave types are treated as outliers (Table 5) when exploring the relationships between site, LEH, and grave type.

Table 7. Probabilities and Confidence Intervals for Grave Type Distribution Analysis

Level	Count	Prob	Lower CI	Upper CI	1-Alpha
Capped Cist	1	0.01020	0.001804	0.055555	0.950
Chultun	1	0.01020	0.001804	0.055555	0.950
Cist	2	0.02041	0.005615	0.071382	0.950
Multiple	1	0.01020	0.001804	0.055555	0.950
Pit	45	0.45918	0.363927	0.55752	0.950
Simple	27	0.27551	0.196796	0.37116	0.950
Tomb	2	0.02041	0.005615	0.071382	0.950
Unknown	18	0.18367	0.119461	0.27175	0.950
Vessel	1	0.01020	0.001804	0.055555	0.950

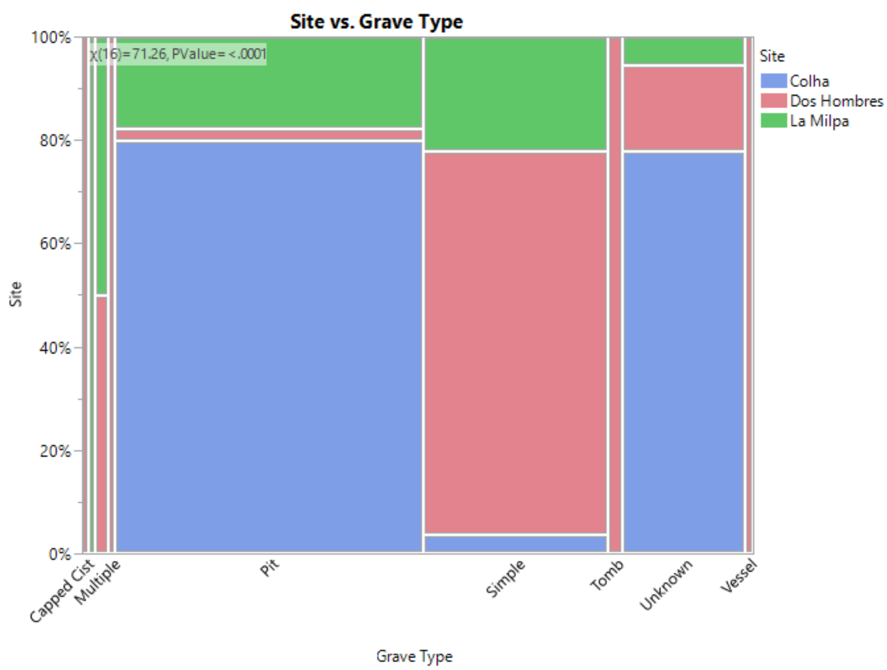

Figure 15. Mosaic of All Grave Types by Site.

To elaborate on the relationship between the most prominent grave types and site differences an additional mosaic was used to further investigate differences between pit and simple graves, reducing the influence outliers may have in the frequency analysis (Figure 16). The relationship between site and burial type was found to be highly significant (X^2*=49.16, p=0001*). Statistical significance is likely driven by the high prevalence of pit burials at Colha and high prevalence of simple burials at Dos Hombres ($X^2 = 49.16$, $p = <.0001$) (Figure 16) but the small sample size may also be biasing results.

Table 8. Contingency Table of Site and Grave Type for Simple and Pit Burials (associated with figure 16)

Count Total% Col % Row % Cell Chi^2	**Colha**	**La Milpa**	**Dos Hombres**	**Total**
Pit	36 50.00 97.30 80.00 71.682	8 11.11 57.14 17.78 0.0643	1 1.39 4.76 2.22 11.2012	45 62.50
Simple	1 1.39 2.70 3.70 11.9471	6 8.33 42.86 22.22 0.1071	20 27.78 95.24 74.07 18.667	27 37.50
Total	37 51.39	21 29.17	14 19.44	72

LEH by Grave Type

When considering only the two main grave types, the relationship between LEH prevalence and grave type was found to be significant and across sites, pit burials had about 20% more individuals with LEH ($X^2 = 4.55$, $p = 0.0329$)(Figure 17). Because not all three sites have abundant pit burials, the relationship between LEH and grave type was further analyzed by site. Grave types were subsequently grouped by site. A significant relationship was still found at Dos Hombres ($X^2 = 4.46$ $p = 0.0346$) (Figure 18). This relationship is thought to be the result of sample bias because only one individual was recovered from a pit burial at Dos Hombres.

Table 9. LEH Scores by Grave Category.

Grave Type	N Rows	N (LEH 0)	N (LEH 1)
Unknown	2	2	0
Capped Cist	1	0	1
Chultun	1	1	0
Cist	2	0	2
Multiple	1	0	1
Pit	45	25	19
Simple	27	22	5
Tomb	2	0	2
Unknown	18	7	11
Vessel	1	0	1

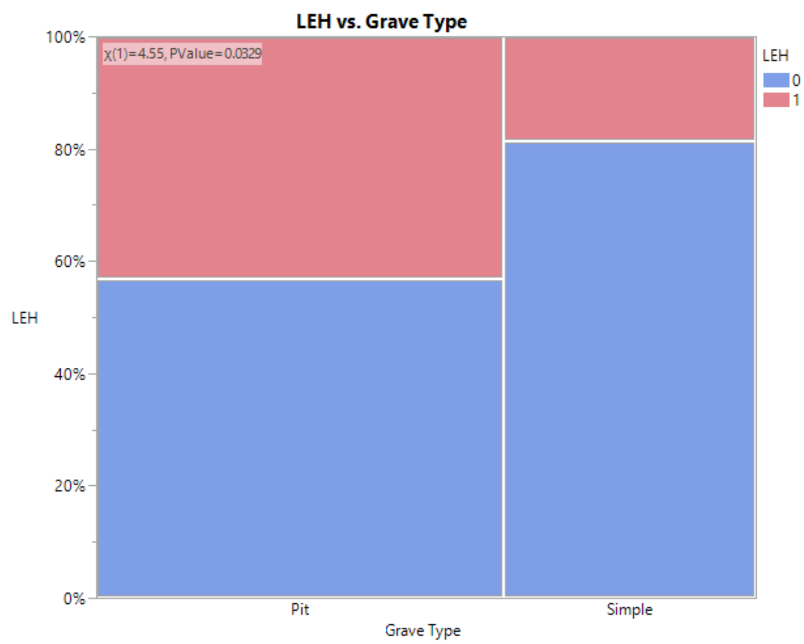

Figure 16. Mosaic of LEH by Grave Type for Pit and Simple Grave Types.

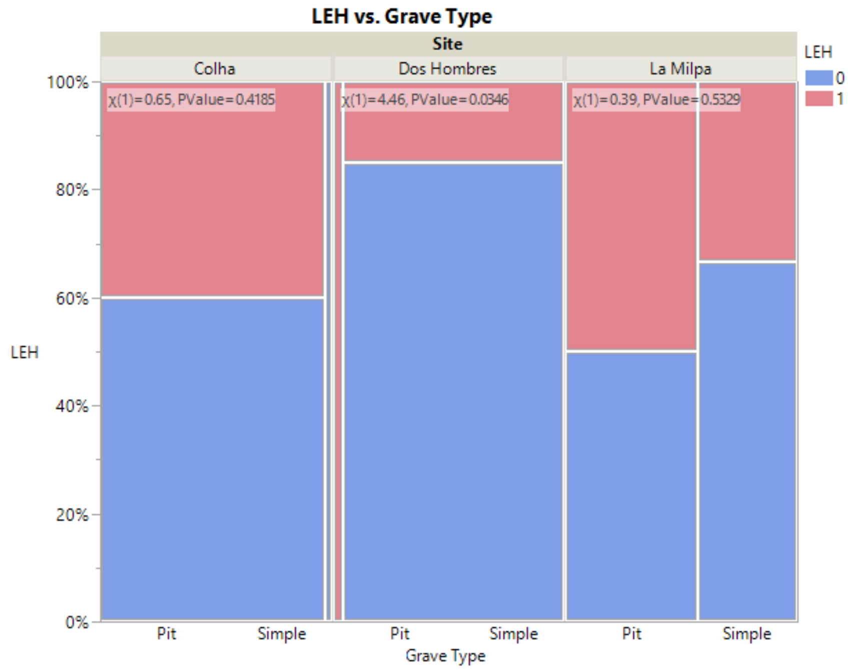

Figure 17. Mosaic of LEH by Grave Type by Site.

Age Category

Young adults were the most prominent age group at all sites (Figure 19). A more representative age distribution is present at Colha with an equal presence of children, middle adults, and old adults (Figure 20). Children and Middle Adults are far less represented at La Milpa and Dos Hombres while Old Adults are not represented at all (Figure 21).

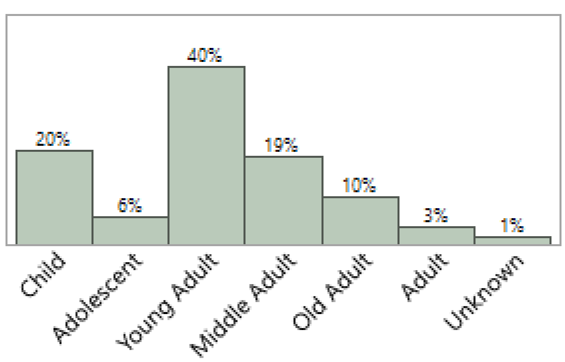

Figure 18. Age Category Distribution.

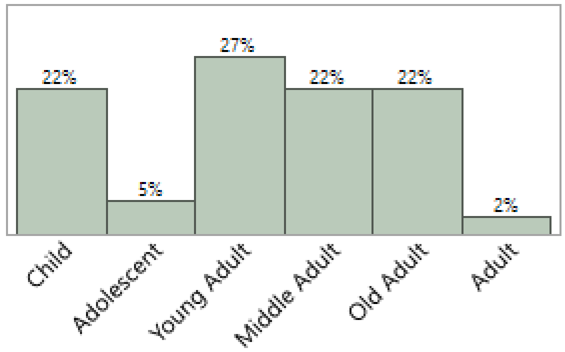

Figure 19. Age Distribution at Colha.

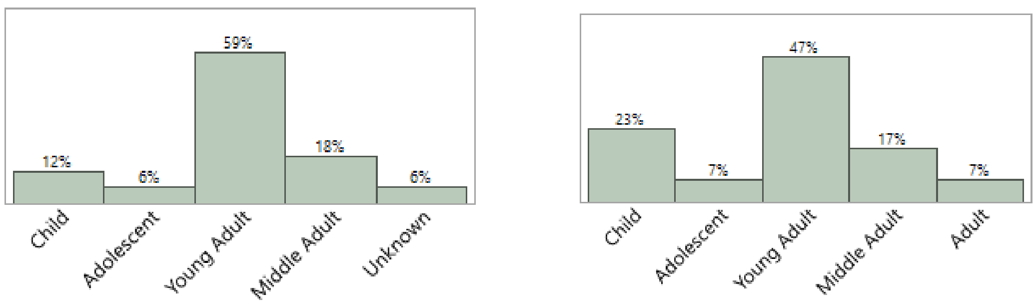

Figure 20. (Left) Age Distribution at La Milpa (Right) Age Distribution at Dos Hombres.

Trends in LEH across age groups showed no significant relationships, but an apparent pattern showed increased LEH in the young adult age group for all sites (Figure 22). This pattern was observed again when broken down by age (Figure 23) but was only found to be significant for the Dos Hombres assemblage. An increased LEH prevalence in young adults is suspected to be the result of increased numbers of young adults in the age distribution as a whole (Figure 19).

Table 10. Total Counts for Each LEH Category by Age Category

Age Category	**N Rows**	**N (LEH 0)**	**N(LEH 1)**
Child	18	14	4
Adolescent	5	4	1
Young Adult	35	15	20
Middle Adult	17	9	8
Old Adult	9	5	3

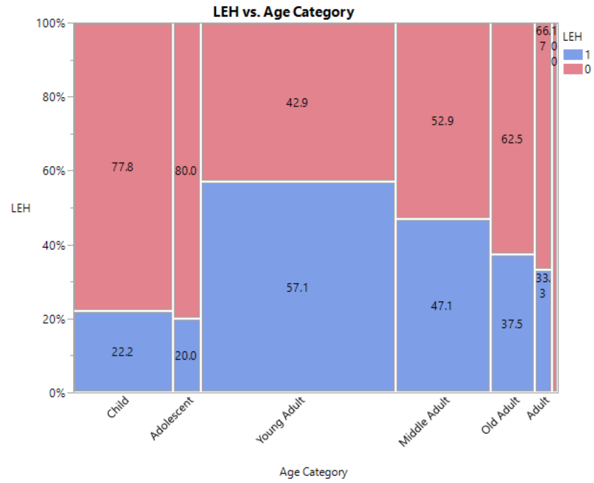

Figure 21. Mosaic of LEH Presence and Age Categories.

Sex

Many of the individuals sampled were unable to be sexed but male presence was almost double the female presence for those that underwent sex estimation (Figure 24). LEH for all sites were present at relatively the same frequencies and no significant relationship between LEH and sex was detected (Figure 25). It should be noted that due to the substantial number of individuals with unknown sex that this analysis is highly limited, and interpretations should really be reserved for future studies with more complete sex estimation data.

Table 11. Total Counts for Each LEH Category by Sex

Sex	N Rows	N (LEH 0)	N (LEH 1)
F	18	11	7
M	33	17	15
Unknown	49	29	20

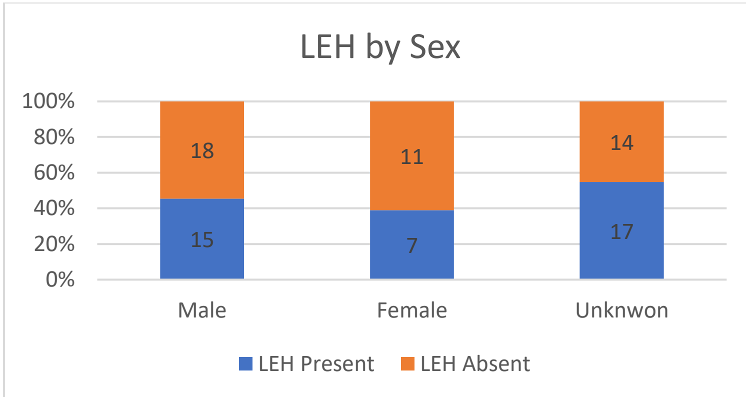

Figure 22. Bar Graph of LEH Presence by Sex Across Sites.

IV. DISCUSSION

Geographical Trends

Hypothesis 1: Patterns of LEH prevalence will correspond to temporal and geographical fluctuations in the life history of the Maya Region State.

Geographical trends between sites were not found to be substantial in LEH differences. The similar riverine environments and agricultural use of the landscape as well as engagement in trade networks may have created similar enough dietary conditions and access to resources. However, while the experienced prevalence of LEH is similar at all three sites, the causation for these levels are a combination of a multitude of variables and may differ by site. Beyond overall regional similarity, what is notable is the comparison of LEH prevalence at these three sites of Belize to other sites of the area.

The rates of LEH were lower than other studies conducted in the Maya region (Wright 1997, Saul and Saul 1997, Vance 2014). Geographically, the closest site K'axob exceeds the highest prevalence at La Milpa by over 30% (Vance 2014) while LEH prevalence at Cuello and the Pasión River region of the Peten presented rates of LEH around 59% (Saul and Saul 1997 and Wright 1997). Originally, this research took the perspective that geographical differences would influence access to dietary resources and would ultimately affect the prevalence of LEH. However, the lower rates of LEH in this region suggest while geography seems to have an influence on a larger scale across Mesoamerica, the specific role the environment plays needs to be further explored. Due to the inland location of the Peten, it was speculated that the highest rates of overall LEH prevalence would be expected at the Peten region of Guatemala not K'axob to the East in Belize. The abundance of dietary resources at K'axob confounded deductions about the existence of such high rates of LEH at the site. Environmental factors important to this are likely less related to diet and more related to other factors responsible for LEH expression. Vance (2014) suggested parasite presence as a possible contributor to the observed high LEH prevalence. Decreased LEH prevalence at Colha, La Milpa, and Dos Hombres may indicate an absence of stressors such as parasitic load or local environments were somehow advantageous. Ecological studies at Cobweb Swamp and the Three Rivers Region reveal various factors that may have bolstered the population's resilience to stressors that are in some way related to LEH expression. While droughts were experienced at Colha, Cobweb Swamp experienced droughts to a lesser degree compared to Maya to the West and the area around Colha continued to sustain a flourishing forest between episodic drought (Jones 1991, Morse 2009). As previously discussed, adaptability in a community is equally important in the creation of a resilient community. The network of sites around La Milpa and Dos Hombres possibly enabled access to the water reservoirs at Medicinal Trail and Rio Bravo (Scarborough and Valdez 2009). In accordance with the resource specialized community model (Scarborough and Valdez 2009), it is possible that these advantages enabled preferable conditions compared to surrounding sites with higher rates of LEH. Yet, currently it is difficult to truly speculate on the relatively lower rates of LEH reported in this study. Whether it be disadvantages such as parasitic loads or advantages such as drought resistant infrastructure, adequate answers to what these environmental factors may truly be are intriguing but exceed the scope of this thesis. Instead, I digress with the discussion of further unique trends detected temporally for all three sites.

Temporal Trends

An overall gradual diachronic trend was detected and suggest a shared large-scale experience over the span of Maya occupation. The overall decline, with peaks in the Classic, likely reflect environmental conditions experienced during this time period. The overall pattern of decline in prevalence of LEH is inconsistent with the ecological model. Ecological models highlight the relationships between the population and ecology. The ecological model holds that that environmental stressors of the Late Classic, resulting in the collapse of Maya cities and de-population continued into the Terminal Classic (Santley et al. 1986 and Culbert 1988). The Classic Maya collapse is framed as the result of intense rainy/dry seasons and environmental stressors brought on by overexploitation and population growth. These stressors such as evidence of episodic drought in the Rio Bravo area are shown to endure into the Terminal / Post Classic (Beach et al 2015; Dunning et al 2012). Logically, according to the ecological model, physical representations of this stress should continue to be expressed into the Terminal / Post Classic periods. The Classic period peak of LEH seen at La Milpa and Dos Hombres likely reflects the population boom and subsequent stressors experienced during the Late Classic. Contrary to the ecological model, this peak in LEH and lingering stressor is not evident in the Terminal Classic sample from any of the three sites tested here. However, because the Early and Late Classic burials were grouped together, a larger history of temporary de-occupation and re-occupation are encompassed in this timeline group. Nonetheless, either the evidence produced in this thesis does not overtly support this ecological model or the environmental challenges we know continued into the Terminal Classic (Beach et al. 2015; Dunning et al 2012) were not drivers of LEH prevalence. These results are like those found by Wright (1998) at the Pasión Region. In

Wright's study stressors appeared to be constant through time, though a shift in the onset of weaning between the Late Classic and Terminal Classic was detected. This shift was seen in the differential expression between anterior and posterior teeth. Posterior teeth expressed LEH when weaning occurred later in childhood during posterior teeth development. Weaning was thought to occur later in childhood in times of food shortage and heavier maize reliance would be accompanied by increased total LEH prevalence (Santley et al. 1986; and Wright 1997). In this instance LEH would present at later ages in accordance with weaning. A pattern of delayed weaning as seen in differential proportional LEH expression on posterior teeth, was detected in the Pasión region in the Late Classic. Yet, the Terminal Classic sample showed decreased LEH in posterior teeth and suggests a return to previous weaning practices. The adaptive weaning practices hypothesized suggest that the population pressures of the Late Classic subsided into the Terminal Classic (Wright 1997). It is possible that the decline in LEH, significantly different between the Classic and Terminal Classic at La Milpa, represent similar changes in weaning practices and/or subsistence strategies. This study lacks a robust enough sample size to detect more discreet temporal changes in weaning practices. However, through the incorporation of future recovered skeletal remains and the analysis of as a regional whole instead of three separate sites may enable more sensitive investigation into weaning practices. While Wright (1997) concludes that her results are inconsistent with the ecological model, I propose that region specific models such as those proposed by Beach et al. (2015) may hold some explanatory power. Wright (1997) discusses the connection between weaning and agriculture, a concept that would pair well with the wetland ecological models which show the processes such as erosion/sedimentation which affect wetland agriculture. These processes were accelerated in the Classic with intensified agriculture. Yet, the Terminal Classic showed evidence of continued tree vegetation and decreased rates of erosion/sedimentation are observed in the Postclassic (Beach et al. 2015). The environment may in fact have the capacity to rebound. All models discussed include factors influencing a population's ability to not just survive, but to flourish healthily. These are the contextual frameworks in which episodes of stress can alter the physiological functioning of the body and are used in this study to explain observed patterns in the expression of LEH.

Deterioration of dietary variability, drought, accelerated erosion/sedimentation affecting agricultural ditching (Beach et al. 2015) and an increased reliance on maize during the Late Classic could be responsible for the extreme of approximately 80% LEH prevalence at La Milpa and the overall 54% high of LEH across sites seen for the Classic category. However, the extreme almost 70% decline at La Milpa and over 20% decline in LEH prevalence across sites is not likely due to a sudden decreased reliance of maize or spontaneous advancement in health conditions. Currently, what may be said for Colha, La Milpa, and Dos Hombres, is that despite increasingly challenging environmental conditions and evidence of violent conflict (Massey and Steele 1997; Eaton 1980b; Barrett and Sharer 2005), all three populations experienced decreased pressures responsible for the expression of LEH.

This conclusion is contradictory to much of what we know of Maya history. Models have been discussed to address questions which arise as to what scenarios could discourage either the expression or the detection of LEH. If detection not expression is inhibited, the decline seen in the Terminal Classic may not reflect increased health or environmental conditions, but in fact increased mortality before the time of weaning, as weaning is thought to be significantly tied to the expression of LEH (Wright 1997). Increased conflict as seen at Colha (Eaton 1980b) and decreased health conditions could lead to greater mortality among the most vulnerable including infants. Increases in childhood morbidity were observed in the Maya region during the Late/Terminal Classic (Culbert 1988 and Saul 1973). If pre-weaned individuals were dying at greater rates, less of the population would have experienced one of the main drivers of LEH expression and could appear as decreased LEH prevalence in the archaeological record (Wright 1997). Children (1-11 years old) are consistently represented through time but the Terminal Classic sample has a decreased representation of adolescents (Figure 26).

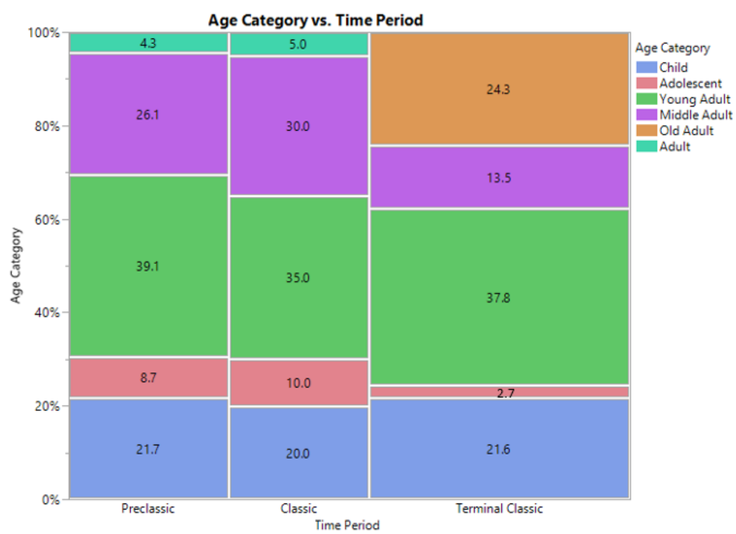

Figure 23. Mosaic of Age Distributions Between Time Periods.

Additionally, the decrease in LEH overtime may represent a change in cultural practices and not a reflection actual LEH prevalence. Burial practices are largely responsible for what survives in the archaeological record especially in the harsh environment of the Belizean forest. What influences burial practices is complicated as these practices are often a reflection of a myriad variables of identity including socioeconomic status and subsequently access to resources (Gillespie 2001, Agarwall and Glencross 2011, Geller 2012). Therefore, what survives is the product of burial context. This fact begs questions such as what if anything were they interred in, and what was the quality of the surrounding materials. The population most likely to be preserved are those with access to these elite spaces and resources but they are also the most likely to have access to resources in life. Therefore, it is logical to hypothesize that these are also the most likely to be the healthiest subset of the population. It is likely that the population most susceptible to stressors and subsequent LEH expression may not have had or decreasingly had membership to groups practicing interment rituals that would preserve remains to the present day (Valdez personal communication 2018). This decrease in LEH overtime then could reflect decreasing access to quality construction material or access to elite space for increasing portions of the population. According to current understandings of the present environmental challenges and political conflict of the Terminal Classic, I propose that the latter of the two interpretations are more plausible and consistent with current models of Maya collapse.

Hypothesis 2: Trends in LEH will not be significantly affected by age or sex but may be influenced by other factors such as burial or grave type.

Burial Trends and Mortuary Practices

Mortuary practices were juxtaposed between Colha and the PfBAP sites of La Milpa and Dos Hombres. Findings at La Milpa and Dos Hombres corroborated those explored by Drake (2016) and Geller (2004). These burials often include simple primary interments (Drake 2016, Geller 2004). Primary interments however were present at only 39% compared to the 44% presence of secondary burials (Figure 9). This increase in overall prevalence of secondary burials was driven by the 56.6% presence of secondary burials at Colha. The amount of primary burials at La Milpa and Dos Hombres far exceed those at Colha. Only 20.8% of burials at Colha were primary interments compared to 88.2 % at La Milpa and 60% at Dos Hombres, a disparity that a chi-squared proved to be significant (Figure 10). The secondary burials that are at La Milpa and Dos Hombres are reported as grave offerings (Drake 2016) whereas the secondary remains at Colha are largely those of a violent pit interment.

Differences in grave type additional contrast the mortuary practices of Colha and the PfBAP sites. Simple burials have been observed predominantly throughout the Maya world from Honduras, Guatemala, Mexico and Belize (Welsh 1988). Colha predominantly had pit burials. Pit burials and simple burials were approximately split at La Milpa, but simple burials dominated the mortuary practice at Dos Hombres (Figure 15 and Figure 16). Generally, the burial practices at La Milpa and Dos Hombres are consistent with the more typical simple primary mortuary practices of the region while Colha seems to be somewhat of an anomaly amidst typical Northwest Belize burial practice. The peak of pit burials occurs in the Terminal Classic (Figure 12) and at Colha is largely the product of the violent interment of 30 decapitated individuals (Eaton 1980b). The anomaly seen at Colha may in fact reflect the sociopolitical turmoil experienced at the site in the Terminal Classic.

Here, it is important to note the role of agency in the burial process. The prevalence of a certain mortuary practice may reflect the social or political environment of the time. Beyond evidence obtained in the biological profile, burial analysis reflects not only the life of those interred but the agency of those individuals whom acted out the burial practice of the deceased (Agarwall and Glencross 2011; Crandall and Martin 2014). The interment practice at Colha is remarkable as it reflects the agency of the living in the creation of deviant burials marked not only by violence but anomalous mortuary practices beyond regional norms.

While a geographical distinction in mortuary practice exists, no relationship between LEH and mortuary practices were detected. Additional relationships between LEH and mortuary practices including cranial direction, body alignment, and burial orientation were not explored in this thesis but may be in the future.

Age and Sex

The overall sex distribution including a decreased females to males' ratio corroborates previous findings at the PfBAP (Drake 2016). LEH was common among the largest group of young adults but, neither age nor sex was found to have a significant relationship to LEH expression. Relationships between sex and LEH are proposed to be further explored such as was done at Cuello where females expressed an increase in LEH (Saul and Saul 1997). It is possible larger sample sizes may elucidate sex or age differences not detected in this research project.

V. CONCLUSION

This thesis sought to explore relationships between geography, time, and indicators of health at the Northern Belize sites of Colha, La Milpa, and Dos Hombres. While thehypothesized geographic differences in LEH was not substantiated, a most notable trend was detected in a diachronic decline of LEH across sites and peak instances of LEH consistent with the population boom and stressors experienced in the Classic Periods. While beyond the scope of this thesis, additional data on Classic period burials at Colha and Preclassic burials at La Milpa are needed to verify and expand on these findings. Overall, general diachronic trends in LEH expression were observed through the initial and superficial grouping of individuals into three broad temporal categories, Preclassic, Classic, and Terminal Classic periods. A general decline in LEH prevalence was observed over the period of Maya occupation, but it is vital that further research incorporate more sensitive temporal designations to observe the extensively more nuanced influence of a complicated and eventful Maya occupation. While geographical similarities between sites were found, the rate of LEH presence was diminished compared to other research in the area (Saul and Saul 1997; Wright 1998; and Vance 2014). Additionally, despite time, geography, and varied mortuary practices, a resemblance in the trajectory of LEH expression was seen between Colha, La Milpa, and Dos Hombres. Similar patterns of LEH decline are observed at all three sites though more dramatic at the western-most situated PfBAP sites. Diachronic trends in LEH detected at Colha, La Milpa, and Dos Hombres, while needing further study, provide evidence contrary to the vast studies of environmental challenges and sociopolitical turmoil at the culmination of the span of Maya occupation. The lack of adherence to this model raises further questions of regional and temporal trends in health over the Maya life history.

APPENDIX SECTION

APPENDIX A

Site Name: Site names include Colha, La Milpa, and Dos Hombres. These will be used as the geographic designations where Colha is the coastal site and La Milpa and Dos Hombres are inland sites.

Burial ID: Colha skeletal ID numbers follow the SOP established at PfBAP (Drake 2016) in which each burial or individual is initially demarcated by the year of excavation followed by a number sequence denoting order of analysis or excavation (i.e. if the first burial of 2017 was being labeled, the remains would be labeled as 2017-1). This labeling system is also retroactively applied to previously analyzed remains for cohesion purposes.

Time Period: In order to attain evenly distributed sample sizes, temporal designations were collapsed into three main time period categories: Preclassic, Classic, and Postclassic.

Burial Type: Burial type distinguishes from primary and secondary burials. Primary interments are those which are situated in the original deposition location. Secondary interments are those which have been moved from the original deposition context. Often the secondary burials serve as human offerings to other primary burials.

- **Primary:** A burial in which the initial location of interment is undisturbed, and the individual often resides in articulation.
- **Secondary:** A burial in which the burial was disturbed either the intrusion of another individual, architecture, or object or disturbed and reinterred in a different location from the initial interment.

Grave Type: Grave type consists of categorical descriptors of grave construction.

- **Cache/ Capped Cist:** Remains are interred within a container, often a ceramic vessel or material. These are more often secondary burials but not exclusively.
- **Multiple:**
- **Chultun**: Artificial or arguable natural chambers carved into bedrock or soil. Cist Stone lines the sides and/ or floor of the grave. Cists may be capped but more often are not.
- **Tomb**: Often in proximity to monumental architecture or elite spaces, a tomb is a large sealed space either cut from rock or stone lined and is often characterized by ornate preparations and formal construction.
- **Simple:** The category "simple", is defined by are those within soil or cobble that have no further evidence of grave construction. The grave itself is indistinguishable from the surrounding matrix and is often a hole situated beneath constructions such as a floor or wall. Drake combines this category with pit burials, but they will be separated in this thesis.
- **Pit**: A carved out space where the burial fill often consists of construction fill distinguishable from the surrounding matrix but where formal construction materials delineating the grave are absent. Like simple burials, pit burials may also be situated beneath construction such as benches, floors, or walls.

LEH: Preservation biasing dental arcade's observable elements prevents a detailed analysis encompassing number of affected teeth or age at stress incident. Therefore, LEH is scored on an absence "0" or presence "1" basis.

Age: discrete age estimations will be allocated into appropriate age categories. Age will be divided into three age cohorts: adult (young, middle, older), adolescent, juvenile, and infant.

Child1-11 year **Adolescent** 12-20 years **Young Adult** 20-35 years

Middle Adult 35-50 years **Old Adult** 50 + years

Dental Attrition Score: Dental attrition will be scored following Scott (1979). Dental attrition will be more increased due to the use of grinding slabs for processing maize (Teaford 1996).

Sex- biological sex categories include M (male) and F (female) and NA for remains that were insufficient for sex estimation.

APPENDIX B

Table. 12 Condensed Dataset

Site	**Time Period**	**Burial Type**	**Grave Type**	**LEH**	**Age Category**	**Sex**
Colha	Preclassic	Unknown	Unknown	1	Middle Adult	Unknown
Colha	Preclassic	Unknown	Unknown	1	Middle Adult	Unknown
Colha	Preclassic	Unknown	Unknown	0	Middle Adult	Unknown
Colha	Preclassic	Secondary	Pit	1	Young Adult	M
Colha	Preclassic	Primary	Pit	1	Young Adult	F
Colha	Unknown	Unknown		0	Unknown	Unknown
Colha	Unknown	Unknown	Unknown	1	Unknown	Unknown
Colha	Unknown	Unknown	Unknown	1	Unknown	Unknown
Colha	Unknown	Unknown	Unknown	1	Unknown	Unknown
Colha	Preclassic	Primary	Pit	1	Middle Adult	Unknown
Colha	Preclassic	Primary	Pit	1	Young Adult	M
Colha	Preclassic	Unknown	Unknown	1	Unknown	F
Colha	Preclassic	Unknown	Unknown	1	Unknown	Unknown
Colha	Preclassic	Primary	Unknown	0	Unknown	Unknown
Colha	Preclassic	Primary	Unknown	0	Unknown	Unknown
Colha	Preclassic	Primary	Unknown	0	Unknown	Unknown
Colha	Preclassic	Primary	Unknown	0	Unknown	Unknown
Colha	Preclassic	Primary	Unknown	0	Adolescent	Unknown
Colha	Preclassic	Primary	Unknown	1	Adult	Unknown
Colha	Terminal Classic	Secondary	Pit	0	Child	Unknown
Colha	Terminal Classic	Secondary	Pit	0	Child	Unknown
Colha	Terminal Classic	Secondary	Pit	1	Child	Unknown
Colha	Terminal Classic	Secondary	Pit	0	Child	Unknown
Colha	Terminal Classic	Secondary	Pit	0	Unknown	Unknown
Colha	Terminal Classic	Secondary	Pit	0	Child	Unknown

Colha	Terminal Classic	Secondary	Pit	0	Child	Unknown
Colha	Terminal Classic	Secondary	Pit	1	Child	Unknown
Colha	Terminal Classic	Secondary	Pit	1	Child	Unknown
Colha	Preclassic	Unknown	Unknown	0	Unknown	Unknown
Colha	Preclassic	Unknown	Simple	0	Child	Unknown
Colha	Preclassic	Primary	Pit	0	Adolescen t	M
Colha	Preclassic	Primary	Pit	0	Middle Adult	M
Colha	Preclassic	Unknown	Pit	0	Young Adult	M
Colha	Terminal Classic	Secondary	Pit	0	Old Adult	F
Colha	Terminal Classic	Secondary	Pit	1	Old Adult	F
Colha	Terminal Classic	Secondary	Pit	0	Young Adult	M
Colha	Terminal Classic	Secondary	Pit	1	Young Adult	M
Colha	Terminal Classic	Secondary	Pit	0	Young Adult	F
Colha	Terminal Classic	Secondary	Pit	1	Old Adult	M
Colha	Terminal Classic	Secondary	Pit	0	Middle Adult	M
Colha	Terminal Classic	Secondary	Pit	1	Old Adult	F
Colha	Terminal Classic	Secondary	Pit	0	Old Adult	F
Colha	Terminal Classic	Secondary	Pit	0	Young Adult	M
Colha	Terminal Classic	Secondary	Pit	0	Middle Adult	F
Colha	Terminal Classic	Secondary	Pit	0	Old Adult	F
Colha	Terminal Classic	Secondary	Pit	0	Young Adult	M
Colha	Terminal Classic	Secondary	Pit	0	Old Adult	F
Colha	Terminal Classic	Secondary	Pit	1	Young Adult	Unknown

Colha	Terminal Classic	Secondary	Pit	1	Middle Adult	F
Colha	Terminal Classic	Secondary	Pit		Old Adult	M
Colha	Terminal Classic	Secondary	Pit	1	Young Adult	F
Colha	Terminal Classic	Secondary	Pit	0	Old Adult	Unknown
Colha	Terminal Classic	Secondary	Pit	0	Middle Adult	M
La Milpa	Terminal Classic	Primary	Pit	1	Young Adult	M
La Milpa	Classic	Primary	Chultun	0	Unknown	Unknown
La Milpa	Preclassic	Primary	Simple	1	Young Adult	M
La Milpa	Classic	Primary	Simple	1	Young Adult	M
La Milpa		Unknown	Unknown	1	Child	Unknown
La Milpa	Classic	Primary	Simple	0	Child	Unknown
La Milpa	Classic	Primary	Cist	1	Middle Adult	M
La Milpa	Classic	Primary	Pit	1	Young Adult	M
La Milpa	Classic	Primary	Pit	1	Young Adult	M
La Milpa	Classic	Primary	Pit	1	Middle Adult	Unknown
La Milpa	Terminal Classic	Primary	Pit	0	Young Adult	M
La Milpa	Terminal Classic	Primary	Pit	0	Middle Adult	M
La Milpa	Terminal Classic	Primary	Simple	0	Young Adult	F
La Milpa	Terminal Classic	Primary	Pit	0	Young Adult	M
La Milpa	Terminal Classic	Primary	Simple	0	Adolescent	M
La Milpa	Terminal Classic	Secondary	Simple	0	Young Adult	M
La Milpa	Terminal Classic	Primary	Pit	0	Young Adult	M
Dos Hombres	Classic	Primary	Unknown	1	Adolescent	Unknown
Dos Hombres	Classic	Unknown	Simple	1	Middle Adult	Unknown

Dos Hombres	Classic	Secondary	Simple	0	Middle Adult	F
Dos Hombres	Unknown	Primary	Simple	0	Adult	F
Dos Hombres	Classic	Primary	Multiple	1	Young Adult	M
Dos Hombres	Classic	Primary	Simple	0	Middle Adult	M
Dos Hombres	Classic	Primary	Simple	0	Young Adult	Unknown
Dos Hombres	Classic	Primary	Simple	0	Child	Unknown
Dos Hombres	Classic	Primary	Capped Cist	1	Young Adult	M
Dos Hombres	Terminal Classic	Primary	Simple	0	Young Adult	M
Dos Hombres	Classic	Primary	Pit	1	Young Adult	M
Dos Hombres	Classic	Primary	Simple	0	Child	Unknown
Dos Hombres	Unknown	Unknown	Tomb	1	Young Adult	M
Dos Hombres	Unknown	Unknown	Tomb	1	Young Adult	Unknown
Dos Hombres	Classic	Unknown	Simple	0	Child	Unknown
Dos Hombres	Classic	Primary	Simple	0	Adolescent	F
Dos Hombres	Preclassic	Primary	Simple	1	Young Adult	F
Dos Hombres	Preclassic	Secondary	Simple	1	Young Adult	M
Dos Hombres	Preclassic	Secondary	Simple	0	Middle Adult	M
Dos Hombres	Preclassic	Primary	Simple	0	Child	Unknown
Dos Hombres	Preclassic	Primary	Simple	0	Young Adult	Unknown
Dos Hombres	Preclassic	Secondary	Simple	0	Child	Unknown
Dos Hombres	Preclassic	Secondary	Simple	0	Young Adult	Unknown
Dos Hombres	Preclassic	Secondary	Simple	0	Child	Unknown
Dos Hombres	Preclassic	Secondary	Simple	0	Child	Unknown

Dos Hombres	Classic	Primary	Cist	1	Middle Adult	Unknown
Dos Hombres	Classic	Primary	Simple	0	Adult	F
Dos Hombres	Unknown	Primary	Unknown	0	Young Adult	Unknown
Dos Hombres	Unknown	Secondary	Vessel	1	Young Adult	Unknown
Dos Hombres	Unknown	Primary	Unknown	1	Young Adult	Unknown

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