‘Under the shade I flourish’:

An environmental history of northern Belize over the last three thousand five hundred years

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ABSTRACT

Environmental histories are multi-dimensional accounts of human interaction with the environment over time. They observe how and when the environment changes (material environmental histories), and the effects of human activities upon the environment (political environmental histories). Environmental histories also consider the thoughts and feelings that humans have had towards the environment (cultural/ intellectual environmental histories).

Using the methodological framework of environmental history this research, located in sub-tropical northern Belize, brings together palaeoecological records (pollen and charcoal) with archival documentary sources. This has created an interdisciplinary account which considers how the vegetation of northern Belize has changed over the last 3,500 years and, in particular, how forest resources have been used during the British Colonial period (c. AD 1800 – 1950). The palaeoecological records are derived from lake sediment cores extracted from the New River Lagoon, adjacent to the archaeological site of Lamanai. For over 3,000 years Lamanai was a Maya settlement, and then, more recently, the site of two 16th century Spanish churches and a 19th century British sugar mill. The British archival records emanate from a wide variety of sources including: 19th century import and export records, 19th century missionary letters and 19th and 20th century meteorological records and newspaper articles. The integration of these two types of record has established a temporal range of 1500 BC to the present. The palaeoecological proxies provide a low resolution record over a period of 3,500 years (c. 1500 BC – AD 2010) whereas the archival record provides annual resolution over a period of approximately 150 years (c. AD 1800 – 1950). This research also uses documentary sources to reconstruct temperature and precipitation for Belize City during the period 1865 – 2010, which is the first of its kind from Belize, and the oldest continuous record from Central America. It also provides the meteorological context for further exploration into British colonial interaction with 'tropical' climates. Perhaps because of its status as Britain's only Central American colonial outpost, Belize has remained on the periphery of research concerning European interactions with tropical climates. This environmental history draws together a new account of health, place and space in the 19th century colonial tropics, drawing out how different understandings of the aetiologies and transmission of disease developed, in particular yellow fever.

These different research strands are brought together to create an account that considers material, political and cultural aspects of environmental history. This has enabled the identification of eight phases of human interaction with the landscape at Lamanai, which are broadly indicative of general trends across northern Belize. These include the establishment of Maya field-based agriculture c. 1600 BC and a later phase of substantial Maya construction and site development c. 170 BC – AD 150. A period of active Maya management of forest, field, savanna and palm resources is also observed c. AD 500 –

1000. Polarised imaginings of the Maya as both destroyers and protectors of the tropical forest are challenged. Spanish interaction with the landscape is evident during c. AD 1500 – 1700 and this is followed by a period of substantial British colonial exploitation of timber resources, with logwood extracted c. AD 1660 – 1910 and mahogany extracted c. AD 1750 – 1945. These periods of extraction were only identifiable in the pollen record by combing the chronology from the documentary record with observed changes in the vegetation record and this demonstrates how these two contrasting methodologies can be usefully integrated. This environmental history rejects the binary opposition of benign, passive Maya landscapes and the violent, devastated European colonial landscape (Denevan, 1992). Analysis of the pollen and documentary records reveal that biodiversity is at the highest levels post AD 1950, which suggests that the forest can regrow even after multiple, diverse and prolonged periods of anthropogenic use in a matter of decades.

Published Papers

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Chapter One

Introduction

Human societies have lived and flourished in the lowland tropical forests of Central America (Fig.1.1) for thousands of years, with the Maya culture one of only a few prehistoric high cultures to develop and persist in such an ecological context across the globe. These Seasonally Dry Tropical Forests (SDTF) contain levels of biodiversity and endemism that are of global significance and contain many species of economic and cultural value (Mace et al., 2005; Hubbell et al., 2008). The apparent 'collapse' of the highly developed Maya culture in the late Classic period (c. AD 800 – 1000) has variously been attributed to climate change, environmental degradation as a result of population pressure, and social and political unrest (Hodell et al., 1995; Webster et al., 2002; Shaw, 2003; Demarest et al., 2004). Recent pressure on the remaining SDTF have led some to suggest that these forest will not survive into the next century and that this increases to the need to understand the past history of human use of tropical forest.

This study explores human interaction with tropical environments in the past and combines palaeoecological records (pollen and charcoal) with documentary archival sources to chart how the vegetation of northern Belize, Central America has changed over the last 3,500 years. Key research questions include;

1) How have human societies interacted with tropical lowland ecosystems (particularly forests) in the past?

2) How might such an understanding of human interactions with tropical forests contribute to knowledge concerning the relative susceptibility and resilience of tropical forests to anthropogenic disturbance past, present and future?

This research has a particular focus on resource exploitation in the British colonial period (c. AD 1750 – 1950) and this focus enables the following questions to be considered;

3) Broadly speaking, how can the land-use practises and management strategies of different cultures be documented? How might these insights contribute to future management of tropical lowland environments?

4) In particular, are pre-Columbian Maya management models previously identified as 'forest garden' (Ford, 2008; Ford and Nigh, 2009) or 'managed mosaic' (Fedick, 1996) the most effective method of forest conservation?

5) How did the British colonial population interact and engage with the tropical environments they encountered?

6) How can such a case-study improve

a) our understanding of the cultural dimension of European engagement with the tropical realm during the 19th and 20th centuries?

b) our understanding of the linkages between how a society thinks about the natural world and how they use and change their environment?

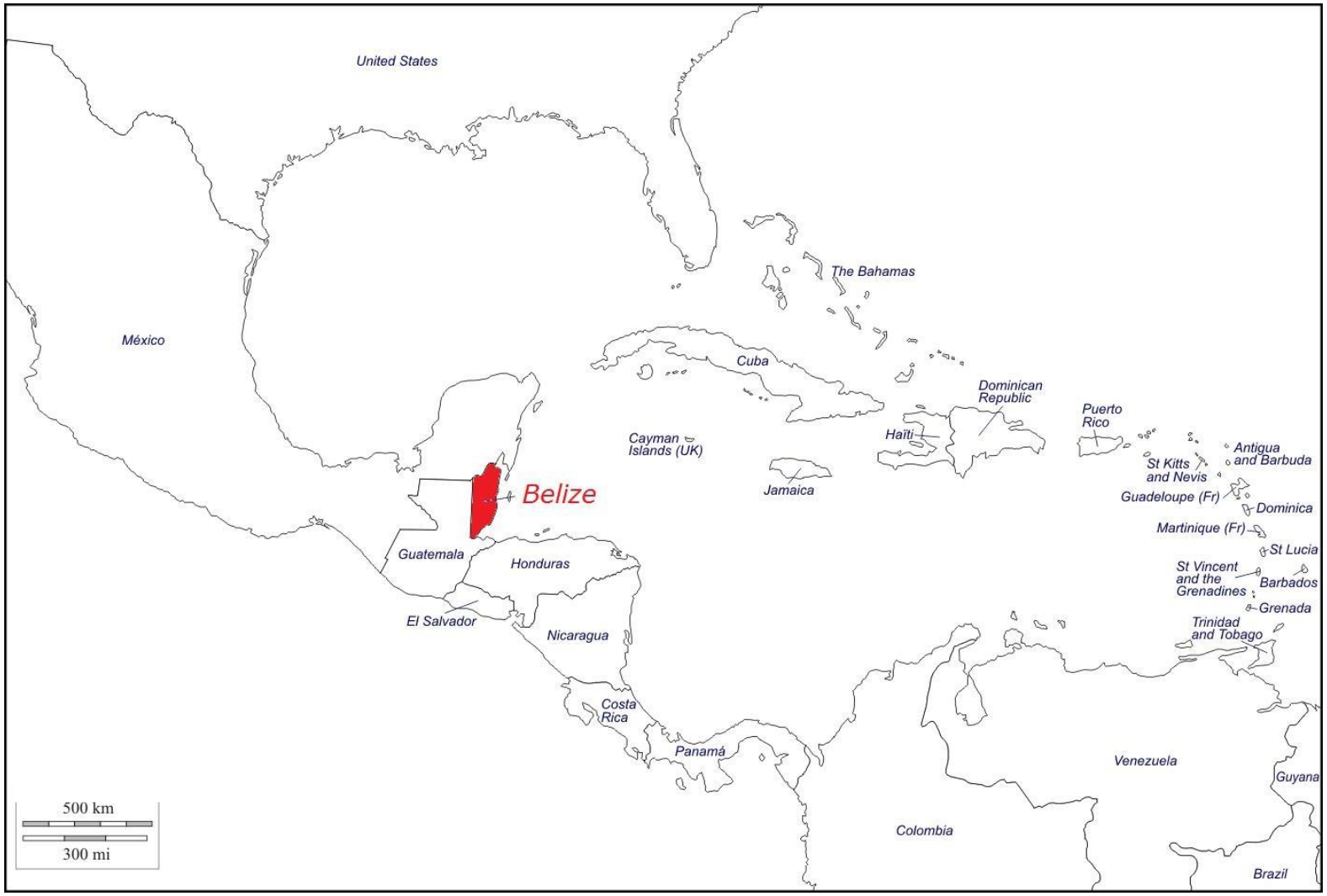

Figure 1.1 Belize in the regional context of Central America and the Caribbean (adapted from Dmaps.com)

1.1 Environmental history as a methodological framework

The first research question (p.1) asks how research should explore human interaction with tropical environments over time? The title of this thesis identifies this research as an 'environmental history' and at the outset it is important to establish what an 'environmental history' might look like, how should such a methodological framework be undertaken? (Fig.1.2) and perhaps most importantly, what significant insight and contribution can an environmental history make to the study of human interaction with tropical forests over time?

Three central components of

environmental history

1) '**Material'** environmental history (McNeill, 2003 p. 6)
- Observing environmental changes over time (Worster, 1988).
- 'Ecological sense' (Cronon, 1992, p. 1373).

2) **'Political'** environmental history (McNeill, 2003 p. 8)
- Exploring the effect of human economic, political and social activities upon the environment (Worster, 1988).

3) **'Cultural/ intellectual'** environmental history (McNeill, 2003 p. 7)
- Understanding the thoughts and feelings humans have had about the environment (Worster, 1988).
- Stories about nature (Cronon, 1992).

ASPECTS TO INTEGRATE

1) TEMPORAL SCALES:
Millenial
centennial
decadal
annual
sub-annual
daily
sub-daily

2) SPATIAL SCALES:
Global
Regional
National
Sub-national
Ecosystems
Species
City
Settlement

3) SOCIETAL SCALES:
Global trend/ organisation
Political/ cultural movement
Civilisation
National government
Regional leadership
Individual leadership
Individual thought/action

Drawing together different spatial, temporal and societal scales to create **an integrated environmental history.**

Figure 1.2. Summary conceptual framework of environmental history

In his collection *The Ends of the Earth* (1988), Donald Worster sets out how one might write an environmental history. Worster asks the researcher to deepen 'our understanding of how humans have been affected by their natural environment through time and conversely, how they have affected that environment, and with what results' (p.289). This endeavour is a reflection of the ambition driving this thesis and is set out in the six research questions highlighted (p.1-2); how have humans interacted with tropical environments over time? How has such an interaction affected different societies? What impacts has this had upon the tropical forests? What is perhaps only implied by Worster's statement, but is integral to this thesis is; how can such an understanding of past interaction inform future management? (Research Questions 3, 4 and 5, p.1). According to Worster, environmental histories should pursue three aims that crucially, are components of an integrated study. These three lines of inquiry are as follows: 1) to understand nature itself and the changes it exhibits over time; 2) to understand how human economic activities and political and social organisation affect their environment, and 3) to understand the thoughts and feelings that humanity and their societies have had about their environment. McNeill (2003) divides environmental histories into three varieties; material, political, and cultural/ intellectual. Material environmental histories consider changes in the physical and biological environment and are closely related to the first aspect of Worster's environmental history (Fig.1.2). Cultural/intelectuall environmental histories are mainly concerned with the relative impacts of societies upon their environment, with the key contribution concerning, 'the impact of specific ideas or sets of ideas…how…ideas fit into new contexts, socially, politically and ecologically' (McNeill, 2003 p.8). McNeill (2003) suggests that political environmental histories are most closely related to the discipline of History, where environmental historians use 'the nation-state as their unit of analysis' (p.8). Of the three varieties, Mc Neill (2003) suggests that material environmental histories are the most difficult to integrate as:

> 'it offers the unwelcome message that historians need to pay attention not only to more things, but to very different kinds of things…That means not only developing the skills to make technical matters comprehensive and interesting, but building real intellectual bridges to the territories of specialities' (p.9).

Cronon (1992) has emphasised the narrative element of environmental histories that is, that histories are stories about humans and nature and human ideas of nature. Furthermore, for an environmental history these stories must make ecological sense, the environmental historian must understand the ecology of the time and place about which the story is told. Interdisciplinary approaches are central to environmental history research, as McNeill (2003) notes, environmental history is 'about as interdisciplinary as intellectual pursuits can get' (p.9). Powell (1995) maintains that environmental history is not a sub-discipline of history but is a distinct interdisciplinary methodology. Figure 1.2 highlights the three central components of environmental history and categorises the types of information gathered into three further groups; temporal, spatial and societal. Within these three groups there are multiple scales and perspective and these are outlined in Figure 1.2.

An integrated environmental history seeks to draw information from across these central components and across these categories and scales to build an account that can encompass ecosystem change over millennia, document the impact of human activity over a season, lifetime and society. Such an integrated account also considers the role that individual ideas and thoughts may play in creating a cultural narrative about the natural world. How this multiplicity of information is to be drawn together is not explicitly set out by Worster (1988) or McNeill (2003), and this raises some important questions for this research. These include; what are the rules for the integration of sources? How do you bring together contrasting sources of information? What happens when different sources provide accounts that differ or are inconsistent? Which data types and sources take priority? How do you identify gaps in knowledge? How do you address gaps in knowledge? These questions along with the research questions identified previously (p.1-2) will be returned to throughout the course of this thesis and particularly in Chapter 8. This research seeks not only to create an account of the environmental history of northern Belize over the last 3,500 years, but to contribute insights as to how, why and with that opportunities and challenges such environmental histories may encounter (Chapter 8).

It is the ideas and frameworks of Worster (1988), Cronon (1992), Powell (1995) and McNeill (2003) that have shaped the course of my research, building an environmental history founded on a long-term palaeoecological record that is informed and illuminated by shorter-term documentary archival sources. Although such an academic approach has been long proposed, until recently, few environmental histories incorporated both sedimentary and documentary record within the same body of research. Lawson (1974) reconstructed the climate of the western interior United States during the first fifty years of the 19th century using dendrochronologies, meteorological records and documentary sources. Butzer and Hegren (2005) combine 19th century travelogues with pollen and charcoal records to explore vegetation and land-use change in New South Wales, Australia during the period AD 1820 – 1920. Butzer and Helgren (2005) also used lake sediment derived pollen profiles alongside archaeological investigations and ethnographic analysis to explore the causes and effects of land degradation and soil erosion in the Mediterranean since c. 4,000 BC. Metcalfe et al. (2010) have compared sedimentary records from Laguna Juanacatlán, Mexio with tree ring records and Spanish colonial and post-independence archival sources to demonstrate that the sedimentary record (specifically the titanium elemental record) is a proxy for summer monsoonal rainfall across the north monsoon region over the last 2,000 years. Dugmore and Vesteinsson (2012) compared documentary accounts with tephrochronologies to explore how volcanic hazards affected pre-industrial Iceland and suggest that each volcanic event needs to be considered ‘within its landscape and historical context’ (p.68). The same could be said for any examination of an aspect of environmental or landscape change. All of these approaches (to a greater or lesser extent) seek to compare or combine narrative accounts of environmental change within the context of a temporally extended sedimentary (physical) record, in order to

better assess the nature, causes and impacts of the changes and events observed.

Having explored what an environmental history might look like (Fig.1.2), a summary of the specific contexts for environmental history of northern Belize will be outlined, including the different methodologies used. As has been previously outlined in the research questions (p.1-2) this research is focused upon the linkages and relationships between humans and their environment in the context of the lowland topics. The ecologically diverse vegetation of northern Belize is the present day context for substantial Maya archaeological settlements. Much recent research has rejected the idea that the pre-Columbian Americas were an unspoiled wilderness, inhabited by small populations whose interaction with the landscape exemplified environmental harmony and ecological balance. This was articulated by Denevan (1992) as 'the pristine myth' however, the relative impacts of the indigenous and European populations remain poorly understood. This research seeks to explore these relative impacts as outlined in research questions 2, 4, 5 and 6 (p.1-2). This thesis uses pollen and charcoal records from a lake site, the New River Lagoon, adjacent to the Maya site of Lamanai. These records, extracted from two separate cores, together reconstruct vegetation change from 1500 BC to the present. The long core (Lamanai I 1999) captures the period 1500 BC – AD 1500, with the short core (Lamanai II 2010) providing a higher resolution record of the period AD 700 to the present. These sedimentary derived palaeoecological records provide the long-term context of ecological change, the history of the environment *per se*, the first line of inquiry in an environmental history.

The British established a permanent settlement in northern Belize by the mid-17th century, initially cutting logwood along the northern coast of Belize, establishing the only British colonial presence in the Yucatán Peninsula, indeed in all of Central America. This period of governance has produced substantial collections of archival documents which give further insight to the land-use and resource extraction practises of the colonial population. Belize, therefore, provides an opportunity to extend research concerning the changing nature of tropical forests, as well as exploring the land-use practises and management strategies of the distinct Maya and colonial populations, as revealed by both the palaeoecological records and documentary archives. Here the first two lines of enquiry of an environmental history are integrated, and, when viewed as a whole, they have the potential to imrove out understanding of the relative susceptibility and resilience of tropical forests to anthropogenic disturbance as identified in research questions 1- 6 (p.1-2).

At the beginning of the 19th century, Belize was a small British settlement, with a population mainly located in Belize City, who were almost completely concerned with the cutting and exporting of logwood and mahogany. The vast majority of the European populations resident in Belize City were British, and it is this population that provided the vast majority of the documentary archival sources and materials. A central aspect of this documentary reconstruction is the 145 year record of temperature and precipitation, comprised of

predominantly daily instrumental observations (Chapter 5). This reconstruction provides a record of historical climatology that is in keeping with the first line of enquiry in an environmental history, as it presents an account of the weather (as opposed to the environment) over time. As the palaeoecological record provides the long-term context of vegetation change over which the British archival records provide detail as to the specific timber extraction methods during the colonial period, the meteorological reconstructions provide a frame of reference for the nature of temperature and precipitation variability upon both timber extraction across the 19th century, the incidents of mosquito borne disease such as yellow fever. The archival documentary records from the British population also provide the final aspect of an environmental history of Belize, which explores the ideas, thoughts, feelings and cultural narratives that have emerged from the resident population c. AD 1820 – 1910. The location of Belize, on the periphery of 19th century British Empire, neither part of the Caribbean holding and isolated in Central America has meant that thus far, little attention has been paid to the experiences of this British population in a tropical region. The 19th century colonial population in Belize offer a new opportunity to further understanding of British colonial interaction with tropical climates, both actual and perceived, including an understanding of the nature, causes and relative susceptibilities of European populations to disease in the tropics. The different aspects of an environmental history of northern Belize are now summarised in a statement of the thesis aims. The research questions (p.1-2) that are most closely related to these stated operational aims are identified in brackets alongside each aim.

1.2 Thesis aims

1. To document how vegetation, particularly the seasonally dry tropical forest (SDTF) has changed in northern Belize during the post-Columbian period, in the context of change over c. the last 3,500 years. (Research questions one, three and four).

2. To use documentary sources to give greater insight into resource exploitation and vegetation change in the British colonial period c. 1800 – 1950. (Research questions one and three).

3. To use documentary sources to reconstruct a record of temperature and precipitation from Belize City for the period 1865 – 2010. (Research question five).

4. To use documentary sources to explore British colonial interaction with a ‘tropical’ climate, both actual and perceived, during the 19th and early 20th centuries. (Research questions five and six).

5. To draw together the longer term palaeoecological record, with the 19th and 20th century documentary reconstructions, creating the first integrated environmental history of the region. (Research questions one, two, three, four, five and six).

Having identified the exploration of human – environment relationships in lowland tropical forests over time as critically important in order to manage the globally important economic and cultural resource in the future, the methodological framework of environmental history has been established as an interdisciplinary approach that draws together information from both palaeoecological and documentary archival resources. Unlike quaternary science approaches that, broadly speaking, seek to reconstruct physical changes in past environments, environmental histories seek to explain what has changed, how and by whom and can contribute to future management of resources derived from the natural world. This environmental history is located in northern Belize, which forms part of the Yucatán Peninsula, lying at the heart of the tropical Americas (also called the Neotropics). The Yucatán Peninsula comprises the southern Mexican states of Campeché, Yucatán and Quintana Roo, the El Petén department of Guatemala, and Belize (Fig. 1.1). A general introduction to the Yucatán Peninsula and palaeoenvironmental research undertaken in this region now follows.

1.3 An introduction to the Yucatán Peninsula

The Yucatán Peninsula (<215 masl) is low-lying (approximately 181,200 km^2) and separates the Gulf of Mexico from the Caribbean Sea (Correa-Metrio et al., 2011) (Fig.1.1). The peninsula is underlain by Tertiary and Cretaceous carbonates (Correa-Metrio et al., 2011) and limestone covers much of the region to a depth in excess of hundreds of metres (Wilson, 1980). Unconsolidated calcareous beach sands are found in the north at low elevations (0 – 10 masl) and igneous and metamorphic rocks form the southern Maya mountains that stretch across the El Petén department of Guatemala (100 - <400 masl) (Beach et al., 2009; Correa-Metrio et al., 2011). The Yucatán Peninsula is a distinct biological region, with approximately 10% of plant species endemics (Correa-Metrio et al., 2011). In general terms vegetation varies according to precipitation levels, with a 'northward gradient from the tropical rainforest to scrub forest, with intermediate stages of seasonal, semi-deciduous and deciduous forest' (Correa-Metrio et al., 2011, p. 683).

Inter-annual climate variability in the Yucatán Peninsula is defined by differences in precipitation rather than temperature, which is uniformly warm (annual average 24 – 26˚C) (Correa-Metrio et al., 2011). Rainfall varies along a north – south gradient from approximately 1000 – 3000 mm mean annual precipitation. The migration of the Inter Tropical Convergence Zone (ITCZ) is the predominant driver of the climate of the Yucatán Peninsula, as this movement produces clearly defined 'rainy' and 'dry' seasons. The rainy season occurs during May – December when the ITCZ (usually located at the equator) and the Azores-Bermuda high pressure system (centred in the mid-latitude North Atlantic) move north (Carillo-Bastos et al., 2010). When this movement combines with higher Sea Surface Temperatures (SSTs) in the tropical/subtropical North Atlantic and Caribbean there is increased moisture

availability for precipitation (Brenner et al., 2001). Dry conditions prevail from December – April when the ITCZ and Azores-Bermuda high pressure systems migrate southward (Hastenrath, 1976) and, a reduction in SST and enhanced trade winds reduce precipitation (Brenner et al., 2001). Occasional southward movement of colder air masses can bring increased precipitation during the dry season. However, palaeoclimate evidence suggests that past variation in regional precipitation is most strongly linked to inter-annual variations in the position of the ITCZ (Hoddell et al., 1991; 2005; 2008; Haug et al., 2001, 2003). The Yucatán Peninsula lies within the Atlantic Hurricane belt which has a defined season from 1 June – 30 November, with the majority of tropical storms and hurricanes occurring during late August and September.

ENSO (El Niño/La Niña Southern Oscillation) has been identified as the key driver of global climate variability at both multi-decadal and inter-annual timescales (Metcalfe and Nash, 2012). The ENSO phenomenon is a variation in the ocean-atmosphere system of the tropical Pacific which, broadly speaking has two states or phases. The first occurs when the Southern Oscillation (SO) shifts from positive to negative and when central and eastern equatorial Pacific SST anomalies become strongly positive. This is widely termed as a 'warm phase' or 'El Niño' event. The opposite shift in SO and SSTs in the same region, produces a 'cold phase' or 'La Niña' event (Kiladis and Diaz, 1986; Kiladis and Diaz, 1989). After seasonal variability, ENSO is the most important cause of change in the global climate system (Washington, 2000). Any impacts of ENSO events in the Yucátan Peninsula occur the year after the onset of an ENSO event (year) and are therefore sometimes referred to as 'ENSO+1 events' (McNeill, 2010). A further series of long-duration changes in the SST of the North Atlantic Ocean is the AMO (Atlantic Multidecadal Oscilation) which, like ENSO has 'warm' and 'cool' phases, although these extend over a longer period (approximately 20 – 40 years). During 'warm' phases of the AMO, tropical hurricane intensity increases, however the frequency of hurricanes and tropical storms appears to be unchanged (Emanuel, 2005).

This physical setting has been the context for human settlement for over 9,000 years. Archaic Maya cultures were located across the Yucatán Peninsula (Table 1.1) from 7,000 BC, and the term 'Maya' is used to describe a people with a broad confluence of language and culture. However, it is understood that this blanket term implies an ethnic uniformity which would not have been recognised by the Maya cultures themselves (Graham, 2011). Equally, when devising general chronological frameworks for the Maya (e.g. Table 1.1) there are significant temporal and spatial variations in cultures and key phases that although recognised by archaeologists, were thresholds not perceptible to the Maya themselves (Coe, 2005). The possible exceptions are the Terminal Classic (c. AD 900 – 1000) and the Spanish arrival in the early 16th century (Webster, 2002). Since the first publication of Stephens' (1841; 1843) encounters with Maya archaeology, the images of vast ruined temples, monuments and intricate hieroglyphics, enveloped in dense forest, have captured the public and academic imagination for generations. Much

archaeological and scientific research effort over nearly two centuries has been devoted to unravelling the mysteries of this civilisation. The ability of the Maya to raise and sustain over centuries a complex, hierarchical civilisation with political and religious ideologies and rituals, within the tropical forest, has been the subject of much research, with studies providing differing assessments as to the ability of the Maya to successfully adapt and manipulate their environment (Deevey, 1978; Abrams and Rue, 1988; Beach and Dunning, 1995; Fedick, 1996; Abrams et al., 1996; Dunning et al., 1997; Leyden, 2002; Demarest, 2004; McNeill et al., 2010 and Rushton et al., 2013).

Perhaps the most popular source of fascination surrounding the Maya focuses on the so-called 'Classic Maya collapse' c. AD 900 – 1000, with the apparent rapid decline of a once vast civilisation being used as a 21st century morality tale (McNeill et al., 2010). Much recent intellectual effort has been expended exploring the causes and consequences of such an event, with studies demonstrating links to anthropogenic impact (Rue, 1987; Abrams et al., 1996; Webster et al., 2000), climate (Leyden, 1998), or indeed a combination of both factors) Metcalfe et al., 2009; Aimers and Hodell, 2011). However, research has also demonstrated the spatial and temporal complexity of the 'Classic Maya collapse', as well as the need for a better understanding of the site-specific responses to both climatic change and human disturbance within the regional context (Metcalfe et al., 2009; Butzer and Endfield, 2012; Rushton et al., 2013). A broad overview of palaeoenvironmental research from the Yucatán Peninsula is now given, with particular attention given to palaeoecological reconstructions from this region.

1.4 Palaeoenvironmental research from the Yucatán Peninsula

i) Sediment reconstructions from the Yucatán Peninsula

Oxygen isotope records have been a central climatic proxy for environmental reconstruction at lake sites across the Yucatán Peninsula due in part to the high temporal resolution they provide (Metcalfe et al., 2009). Curtis et al. (1996) suggest that oxygen isotope records are a more reliable record of climatic reconstruction than for example, palynological records, as they are less susceptible to anthropogenic forcing. Studies that have used oxygen isotopes as a proxy for environmental change include Covich and Stuiver (1974), Hodell et al. (1991; 1995; 2001; 2005), Curtis et al. (1996), Brenner et al. (2001; 2002) , Metcalfe et al. (2009) and Escobar et al. (2012). Brenner et al. (2002) reported that lake sediment records from Lakes Chichancanab and Punta Laguna (Fig.1.3) show a record of cyclical drought (approximately every two centuries) occurring over the past 2,600 years, with the driest period occurring during AD 800 and AD 1000. Hodell et al. (2005) sampled Aguada X'caamal, north west Yucatán (Fig.1.3), and found increased $\delta^{18}O$ values (indicating a drier climate) during AD 1400-1500, consistent with the onset of the Little Ice Age (LIA). Conditions of drought and cold weather during the

mid-15th century were also consistent with the historical and instrumental record (Hodell et al., 2005).

A 3300 year speleothem record from Macal Chasm, Belize (Fig.1.3) demonstrates 'frequent and abrupt changes in climate' (p.12). 'Major droughts' were recorded at 1225, 1007 and ~645 BC, and 'severe droughts' at 5 BC and AD 141 (Webster et al., 2007). The most prolonged droughts were observed during AD 750 – 1150 (Webster et al., 2007). The record from Macal Chasm (Webster et al., 2007) was correlated with the record from Lake Chichancanab (Hodell et al., 1995) suggesting that the Belize record is that of regional climate change. Kennett et al. (2012) observed fluctuations in precipitation during the last 2,000 years in a speleothem record from Yok Balum cave, Belize (Fig.1.3). Anomalously high rainfall coincided with population expansion during AD 440 – 660, and was followed by a drying trend during AD 660 – 1000, culminating in an extended drought c. AD 1020 – 1100. The drought signal observed is consistent with records from Lake Chichancanab (Hodell et al., 1995) and Macal Chasm (Webster et al., 2007). Gischler et al. (2008) reconstructed a 1500 year $\delta^{18}O$ record (c. AD 480 – 1980) from a sediment core extracted from the bottom of Blue Hole, a sink hole on the Lighthouse Reef Atoll, Belize (Fig.1.3). High, prolonged temperature values were observed during AD 1000 -1400 (Medieval Warm Period), with a fall in temperature at AD 1500 (Little Ice Age). Increased temperature values reoccur by AD 1600 and continue to increase until c. AD 1980. Palaeoclimatic reconstructions from wider Mesoamerica have suggested that drought has played a significant role in the disruption of pre-Columbian civilizations including the Aztec, Toltec and Maya (Hodell et al., 1995; Therrell et al., 2004; Davies et al., 2004; Metcalfe and Davies, 2007; Stahle et al., 2011; Stahle and Dean, 2011; Cook et al., 2012).

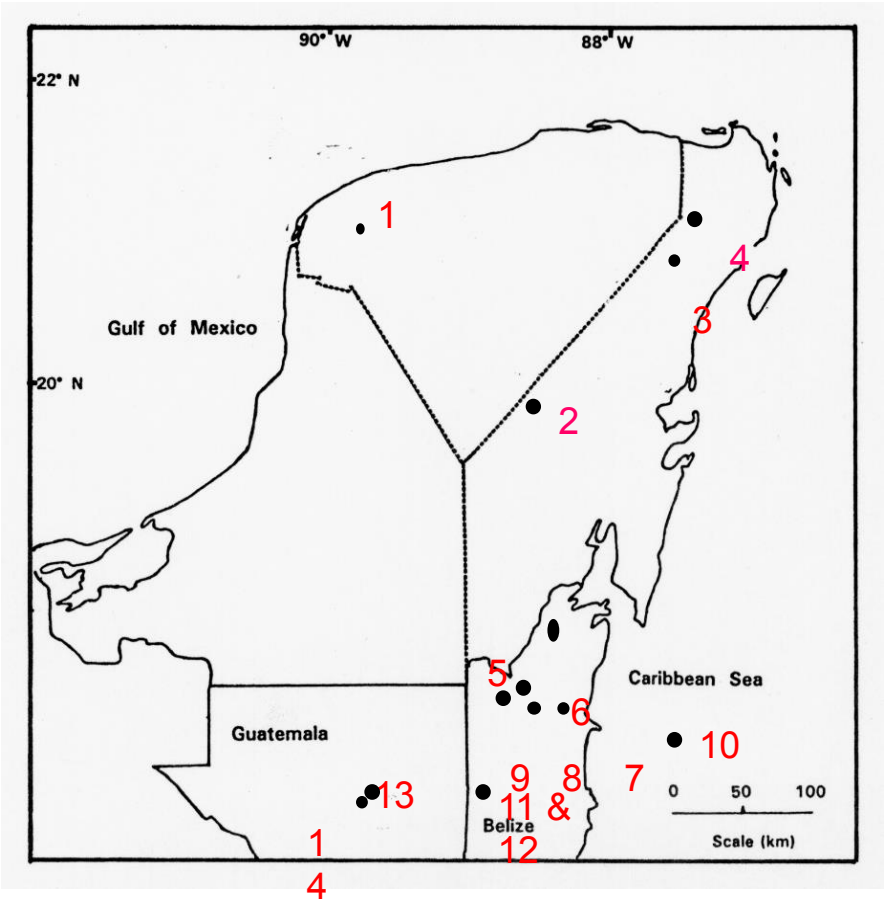

Figure 1.3 Coring sites from the Yucatán Peninsula including those in **Mexico**: Aguada X'caamal (1), Lake Chichancanab (2), Lake Cobá (3) and Punta Laguna (4); **Guatemala**: Petén Itzá (14), Salpetén (13) and **Belize**: Laguna de Cocos, Albion Island (5), Chan Cahal (6), Cobweb Swamp and Cob Swamp, Colha (7), Blue Hole Lagoon (10), New River Lagoon (8), Macal Chasm (11), Yok Balum (12) and Laguna Verde (9) (Adapted from original figure, S.E. Metcalfe).

Research from the Yucatán has shown fluctuations in water balance consistent with droughts which have been linked to the Maya 'collapse' c. AD 900–1000, with research that has demonstrated a correlation between periods of drought and substantial falls in population including Hodell et al. (1995; 2001; 2005; 2007), Curtis et al. (1996); Haug et al. (2003), Neff et al. (2006), Medina-Elizadle and Rohling (2012) and Kennett et al. (2012). For at least three decades, however, researchers have questioned the temporal and spatial variability of the 'collapse', suggesting that it might not have been as complete in some parts of the Yucatán, including north eastern Belize (Andrews, 1973; Sabloff and Rathje, 1975; Aimers, 2007; O'Sullivan, 2008; Metcalfe et al., 2009; McAnany and Gallareta Negrón, 2010; Rushton et al., 2013).

ii) Palaeoecological reconstructions from the Yucatán Peninsula

With notable exceptions that will be outlined in Chapter 2 (section 2.1), the majority of high temporal resolution palaeoenvironmental research undertaken in the Yucatán Peninsula has been located in Mexico and Guatemala (Curtis et al., 1996; 1998; Hodell et al. 1995; 2007; Leyden, 1998; 2000, Fig.1.3). Belize therefore offers an opportunity to expand the geographical range of research undertaken in the Yucatán surrounding the relationship between humans, the environment and climate over time. The distinct Maya and colonial cultural phases enable an exploration of the relative land-use practices and management strategies of different cultures. Furthermore, the establishment of British colonial governance in Belize (c. AD 1850 - 1980) is unique in the Yucatán Peninsula. Substantial collections of archival documents pertaining to the British colonial period offer new insight as to the land-use and resource extraction practices of the colonial population. Such new perspectives have the potential to improve our understanding of the relative susceptibility and resilience of tropical forests to anthropogenic disturbance, both past, present and future (Willis et al., 2007). The presence of a predominantly British population in Belize, over an extended period (c. AD 1750 – 1950) can potentially offer new insights as to how such a population interacted and engaged with the tropical environment they encountered and in particular, the tropical climate. Research undertaken in Belize has the potential to add to our understanding of the cultural dimension of European and North American engagement with the tropical realm during the 18th, 19th and 20th centuries. With this opportunity for a significant contribution to knowledge in mind, a brief general introduction to Belize will be given. A detailed summary of palaeoenvironmental research previously undertaken in Belize, and a more extensive account of the ecological, archaeological, historical and cultural contexts of Belize can be found in Chapter 2.

1.5 An introduction to Belize

Belize (88˚ 45’ and 89˚ 15’ W and 15˚ 45’ and 18˚ 30’ N) is part of the south-eastern Yucatán Peninsula and has a land area of 23,000 km^2, with 386 km of coastline and 280 km barrier reef, second in size only to the Australian Great Barrier Reef (Twigg, 2006) (Figs.1.4, 1.5). The climate of Belize is typical of the climate of the Yucatán Peninsula, with a well defined dry season and summer wet season determined by the northward migration of the ITCZ (section 1.3). The majority of the annual precipitation (annual average 1500 mm) falls in June and September, with the north of the country drier and more seasonal than the south (Metcalfe et al., 2009) (Fig.1.4). During the months of July to September temperatures peak at 38˚C, and August is characterised as the ‘mauger season’, a period of dry, calm weather with oppressive heat and increased levels of insects (Setzekom, 1981). During October to May temperatures average 21˚C and during the months of December – February frontal storms colloquially known as ‘northers’ (because they sweep down over

the Gulf of Mexico from North America) are a feature of the winter season. The hurricane season officially begins on June 1st, although hurricanes are most frequent in September and October (Setzekom, 1981). As with the Yucatán Peninsula, northern Belize rests on a Cretaceous and Tertiary carbonate platform (predominantly limestone) overlain with a patchy cover of Pliocence well-drained sand ridges and Quaternary alluvium (Metcalfe et al., 2009; Bhattacharya et al., 2011). The ecology of northern Belize is driven by this underlying geology. Pine savanna is found on well-drained acidic sand ridges, tropical forest on calcareous sediments, with herbaceous swamps, seasonally inundated savanna and marshland in the fresh water lowlands (Metcalfe et al., 2009). Grass savannas with scattered oaks, pine and *Paurotis wrightii* (palmetto palms) are characteristic of the north central region, and mangrove swamps fringe the northern coast and river inlets (Bridgewater et al., 2002; Fig.1.6).

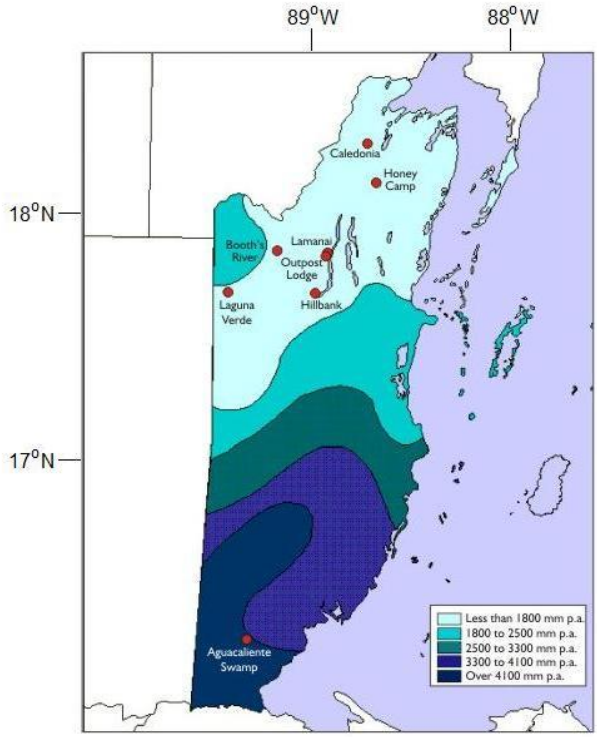

Figure 1.4 Precipitation and Relief maps for Belize (reproduced with kind permission of S.E.Metcalfe)

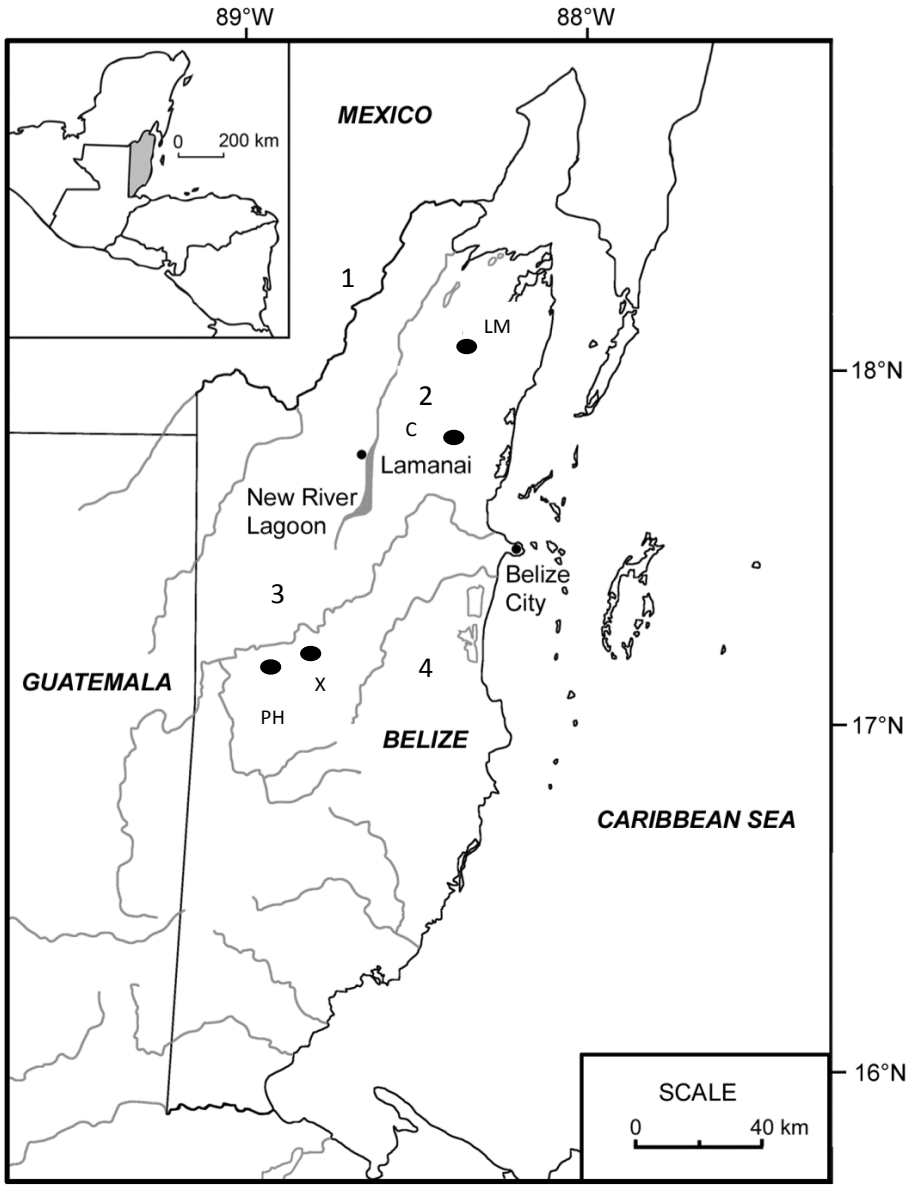

Figure 1.5 Location of the New River Lagoon, adjacent to the Maya settlement of Lamanai, Belize. The four major river systems of Belize are indicated; 1) Rio Hondo, 2) New River, 3) Belize River and 4) Sibun River. The cave and surface sites where pine charcoal assemblages are found are indicated, these are discussed in Chapter 4.6.3: Caracol (C), La Milpa (LM), Pook's Hill (PH) and Xunantunich (X).

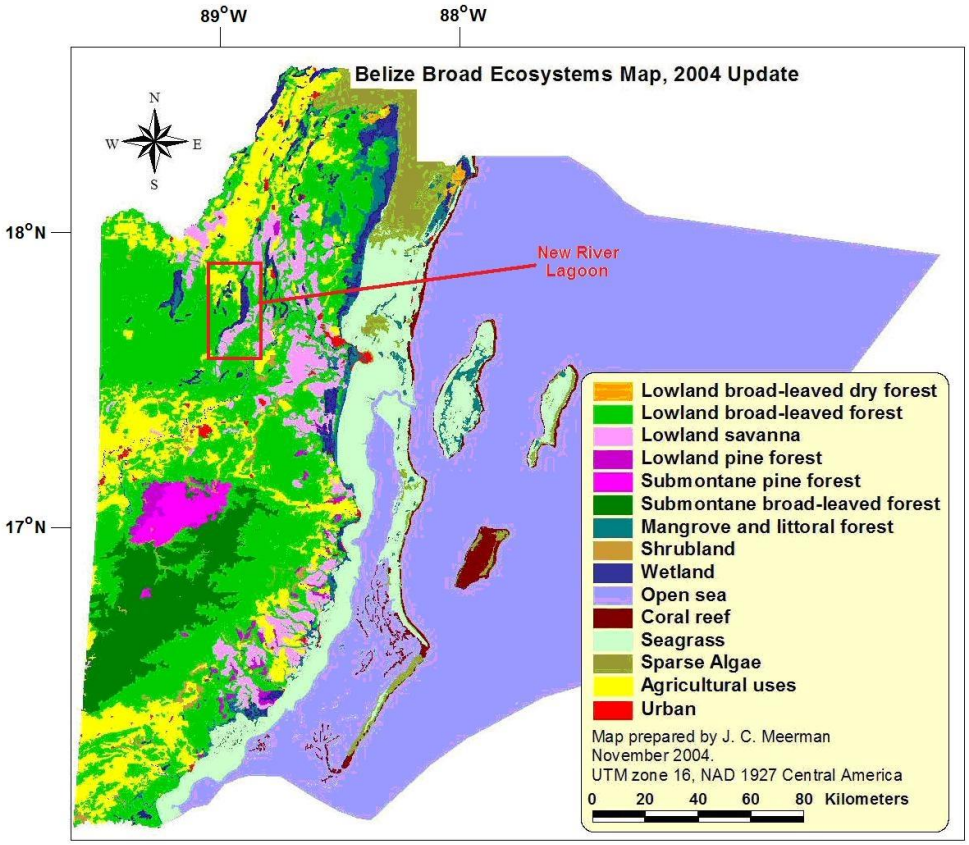

Figure 1.6. Ecosystems map of Belize, Central America (Meerman, 2004)

In keeping with the wider Yucatán Peninsula, Maya civilisation in Belize broadly followed the archaeological periods set out in Table 1.1. Belize has substantial archaeological evidence for extensive Maya occupation by the late Preclassic (400 BC – AD 250) (Graham, 2011). A large proportion of Maya sites in northern Belize seem to peak in size and cultural development in the Early Classic period (AD 250 – 600) and some of these do appear to have evidence for substantial reduction in the Late Classic (AD 600 – 800). However, there are key sites which continued on well beyond the Late and Terminal Classic periods (Graham, 2011).

Table 1.1. Key developments in the Maya civilisation of the Yucatán Peninsula.

Date	**Archaeological period**	**Key events and sites**
Pre 7000 BC	Palaeo-indian	Hunting, fishing and gathering (Coe, 2005). 1500 BC possible first settlement at Lamanai, agricultural crop evidence (Rushton et al., 2013).
7000 – 2500 BC	Archaic	
2500 – 1000 BC	Early Preclassic	
1000 – 400 BC	Middle Preclassic	Origins of village life, pottery figurines. Beginnings of social stratification and early Olmec influence on the Pacific Coast (Coe, 2005). Earliest lowland Maya villages (Tainter, 1990).
400 BC – AD 250	Late Preclassic	Construction of major platforms, pyramids and ball courts across the north and west regions of the YP (Coe, 2005). Spread of Izapan civilisation, calendar and writing (Coe, 2005).
AD 250 – 600	Early Classic	**AD 250** major peak of construction and population at Lamanai (Graham, 2004). From **AD 300 – 800** Maya developed a complex, socially stratified society across the differing Mayan regions across the Yucatán Peninsula (Santley et al., 1986). **AD 250** first lowland Maya stela found at Tikal, Guatemala (Coe, 2005).
AD 600 – 800	Late Classic	Height of Maya Civilisation – sites such as Cobá and Lamanai flourish (Coe, 2005)
AD 800 – 1000	Terminal Classic	**AD 800** cessation of building at many sites across the Yucatán (Tainter, 1990). **AD 850 - 925** This period is the focus for the Classic Maya collapse (Coe, 2005; Webster, 2002). **AD 925** Toltec arrives in the modern Mexican Yucatán.
AD 1000 – 1250	Early Postclassic	**AD 1000 - 1300** Chichen Itzá, southern Mexico dominates e.g. has thelargest ball court (Webster, 2002).
AD 1250 - 1530	Late Postclassic	**AD 1250** Shift of cultural centre from Chichen Itza to Mayapan (Coe, 2005). **AD 1400** Highland city states established (Coe, 2005).

		AD c.1530 Spanish Conquest of majority of Yucatán Peninsula.

One of these important Maya sites, continuously occupied throughout the Terminal Classic period is the site of Lamanai (17˚ 45'9.24 N and 88˚ 39'16.09 W), located on the shores of the New River Lagoon (NRL), northern Belize (Figs.1.5, 2.1, 2.3, 2.4 and 2.9).[1] The NRL is a substantial body of freshwater, approximately 35 km long, 1 km wide and approximately 10 m deep (Metcalfe et al., 2009) (Fig.1.5), and provides a coring location essential for sedimentary based palaeoenvironmental research. Furthermore, the NRL is located in the centre of diverse ecology, with SDTF surrounding the western shore (the location of the archaeological site) and mangrove and logwood swamp located on the eastern bank, which quickly grades into pine savanna (Fig.1.6).[2] Within the present day archaeological site, Lamanai has evidence of a substantial Maya city, as well as two 16th century Spanish churches and a 19th century British sugar mill, evidence of the diverse cultures active at the site and the wider region. The combination of this ecologically diverse location, with both a coring site and a Maya archaeological site that has evidence for Spanish and British phases of colonial occupation makes it an ideal location to explore the relationships between climate, environment and humans and in particular, the nature and impact of Maya and colonial utilisation of tropical arboreal resources.

Environmental history has been identified as a comprehensive methodological framework to expand our understanding of the relationships between humans and their environment. Without exception the examples of palaeoenvironmental research from the wider Yucatán Peninsula documented in this Chapter, and those from northern Belize outlined in Chapter 2, are all sedimentary proxy based. Although these records have significantly added to our understanding of ecological and climatic change over a substantial period of time and, although in many cases climatic data sets have been linked to archaeological contexts, the sedimentary palaeoenvironmental method has been essentially a mono-disciplinary approach. In recent times there have been increasing calls for interdisciplinary approaches when researching the linkages between humans, climate and the environment (Aimers and Hodell, 2011; Hulme, 2011; Butzer and Enfield, 2012) and the methodology of environmental history best meets this call.

[1] A more detailed account of the archaeological and historical aspects of Lamanai can be found in Chapter 2.

[2] A more detailed account of the modern vegetation at Lamanai will be given in Chapter 2.

1.6 Thesis organisation

This thesis is organised as follows:

Chapter 2 provides a wider context for research concerning northern Belize including an overview of the past environmental contexts, including palaeoclimate and palaeoecological records from Belize which provide a regional setting for the pollen and charcoal record presented in Chapter 4. The modern vegetation of northern Belize and Lamanai provide the present day context for the palaeoecological reconstructions discussed in Chapter 4. The archaeological and historical contexts are also presented including details of pre-Columbian (Maya) and post-Columbian (British and Spanish) cultures. These provide both important evidence of human interaction with the environment of northern Belize, but they also provide the contextual information needed to interpret the palaeoecological record of vegetation change (Chapter 4). Furthermore, an understanding of the history of the British colonial period is crucial if the documentary sources are to be examined carefully (Chapters 3, 5 and 7). Wider cultural contexts are considered, including human-environment interaction in the pre-Columbian Americas, tropical climates and acclimatisation, and yellow fever and the new world which contextualise the discussions in Chapters 4 - 7.

Chapter 3 contains a detailed account of the palaeoecological and archival principles, materials and methods adopted in this research. The opportunities and limitations of each of these two central types of research are also considered.

Chapter 4 presents the chronological framework and the sediment, charcoal and pollen results from the Lamanai I (1999) and Lamanai II (2010), New River Lagoon cores. The analysis and interpretation of these results are presented in the second part of this chapter.

Chapter 5 comprises a new 145 year record of temperature and precipitation from Belize City. This record is examined in conjunction with the documentary record to explore the possible relationship between precipitation and epidemic disease (yellow fever) and precipitation and the timber industry. A record of hurricane activity since 1787 is presented using both the meteorological record and documentary narrative accounts to explore both the frequency and intensity of hurricane events in Belize during 1787 – 2010.

Chapter 6 presents a record of British colonial economic activity in 19th and early-20th century Belize, focusing on the production and export of logwood and mahogany, and the relative impacts of such activities on the landscape of northern Belize.

Chapter 7 explores 19th century British understandings of place, health and climate in the tropics using the documentary sources that emanated from Belize during this period. It documents the changing understandings of the nature and causes of disease across the 19th century.

Chapter 8 synthesises the aspects of environmental history presented in Chapters 4 - 7 and details new understandings of human interactions with tropical forests and tropical climates. The challenges, opportunities encountered during this research are explored and suggestions for further work are made.

Chapter Two

Contextualising an environmental history of northern Belize

This chapter is divided into three themes: 'Physical contexts', 'Cultural contexts' and 'Archaeological and historical contexts'. These three themes provide the contextual information needed to understand the research strands of an environmental history of Belize, and reflects the terminologies used by McNeill (2003) (Fig.1.2). The first theme, 'Physical contexts' relates to 'material' environmental histories, 'Cultural contexts' pertain to 'intellectual or cultural' environmental histories, and Archaeological and historical contexts' provide information on all three aspects of environmental history identified by McNeill (2003) (Fig.1.2). In section 2.1, research concerning the past climate of Belize and palaeoecological reconstructions, are outlined. Along with a clear understanding of the modern ecology of northern Belize, and Lamanai in particular, this understanding of the physical setting underlies the interpretation of the pollen and charcoal record presented in Chapter 4. When the contextual information presented in section 2.1 is drawn together with the new palaeoecological record, it is possible to observe changes in the material environment, the first aspect of an environmental history (Fig.1.2).

The second theme examines the cultural contexts which may have influenced human interaction with their environment, both in terms of material and anthropogenic/ political changes, but also how the environment of Belize was perceived and understood by a population at a given time (section 2.2). These cultural settings have a broad geographical focus and encompass discussions on environment and landscape changes of pre and post-Columbian populations (see sections 2.2.1 and 4.6) as well as debates surrounding climate and healthiness of place (see sections 2.2.2 and Chapter 7). Within this consideration of climate and health there is a particular focus on the specific role that yellow fever had in the experience and consciousness of European populations resident in the tropics during the 18th, 19th and 20th centuries (see sections 2.2.3; 5.3.1 – 5.3.2 and 7.2.2 – 7.2.4). These conceptual themes and ideas, drawn from literature across the Central American and Greater Caribbean regions (Fig.1.1) provide a framework for discussions that consider the different aspects of an environmental history of northern Belize and feature in Chapters 4, 5 and 7 in particular.

The final theme examines the archaeological and historical contexts (section 2.3) and provides further insight into the effects of human activities (economic, political and social) upon the environment, the second aspect of an environmental history (Fig.1.6) (see Chapters 6 and 7). Such a record also contextualises the production of the archival record (see section 3.2) used to explore both the effects of human activities on the environment as well as the interaction of humans with their environment.

2.1 Physical contexts

2.1.1 Past environmental contexts of Belize

i) Palaeoclimate reconstructions from Belize

Webster et al. (2007) reconstructed a 3300 year $\delta^{18}O$ and $\delta^{13}C$ record derived from a stalagmite extracted from the Macal Chasm cave site (Fig.1.3). The cave is located near the Belize – Guatemala border, 15 km north of the substantial Maya site of Caracol. The record dates from 1225 BC to the present and Webster et al. (2007) suggest that it indicates 'frequent and abrupt changes in climate' (p.12). 'Major droughts' were recorded at 1225 – 1007 BC and at ~645 BC, and 'severe droughts' at 5 BC and AD 141 (p.12). They report that the most severe droughts in the record occur at AD 754 – 798, AD 871 and AD 893 – 922 and, furthermore, 'the interval in our record from AD 750 to AD 1150 was the most prolonged dry phase in the 3300-year record' (p.14). The Macal Chasam record was correlated with the record of Hodell et al. (1995) from Lake Chichancanab, Mexico, suggesting that the Belizean record is of regional climate change and does not reflect change within the cave itself. Gischler et al. (2008) reconstructed a 1500-year record of $\delta^{18}O$ variation from a sediment core extracted from the bottom of Blue Hole, a sink hole on the Lighthouse Reef Atoll, Belize (Fig.1.3). High, prolonged maximum temperature values were established during the Medieval Warm Period (AD 1000 – 1400), with a fall in temperatures at AD 1500, consistent with the onset of the Little Ice Age (LIA) (Gischler et al., 2008).

Kennett et al. (2012) present a 2000 year subannual $\delta^{18}O$ record from a stalagmite extracted from the Yok Balum Cave, Toledo District, southern Belize (Fig. 1.3). The cave is situated 1.5 km from the Maya site of Uxbenká and within 30 km of the larger sites of Pusilha, Lubaantun and Nim Li Punit. The Yok Balum Cave record suggests that anomalously high rainfall coincides with population expansion and the rise of Maya political centres between AD 440 and 660. A drying trend during AD 660 and 1000 'triggered the balkanization of polities, increased warfare' and led to the decline of the population in the context of 'an extended drought' c. AD 1020 – 1100 (Kennett et al., 2012, p.13). The drought signal observed in AD 1020 – 1100 corresponds with multiple records from across the region using a variety of palaeoclimate proxies, including: the bulk sediment titanium record from the Cariaco Basin, Venezuela (Haug et al., 2001); the sediment density record from Lake Chichancanab, Mexico (Hodell et al., 2005); the ostracod derived $\delta^{18}O$ record from Lake Punta Laguna, Mexico (Curtis et al., 1996), and the speleothem luminescence record from the Macal Chasm, Belize (Webster et al., 2007). The Yok Balum cave record demonstrates drought during AD 1020 – 1100 (Kennett et al., 2012) that is consistent with a estimated 40% reduction

in rainfall during this period (Medina-Elizalde and Rohling, 2012), with broader regional drying beginning c. AD 640, intensifying between AD 820 and 870 and culminating at AD 1020 'in a century-long dry period that is the most prolonged in the record' (Kennett et al., 2012, p.791).

In their palaeolimnological analysis of the Lamanai core from the New River Lagoon (Figs.1.3 and 1.5), Metcalfe et al. (2009) identified high evaporation rates at c. 350 BC and between c. 170 BC and AD 270, consistent with a phase of building demonstrated by the archaeological record (Pendergast, 1981). At c. AD 700, a decline in magnetic susceptibility and change in diatom flora suggest the end of construction at the site (Metcalfe et al., 2009). A further point of interest occurs after c. AD 1100, where a decreased abundance of diatoms indicates increased alkalinity associated with increased evaporation. However, magnetic susceptibility is low, which could suggest reduced anthropogenic activity (Metcalfe et al., 2009). This record does not have any isotopic evidence for drought associated with a Maya 'collapse' c. AD 900 – 1000; in direct contrast to the record of Webster et al. (2007).

These records thus far are temporally limited to c. AD 1600 either because the records finish prior (Webster et al., 2007; Metcalfe et al., 2009) or because the proxies become unreliable after this point (Kennett et al., 2012). Until a record becomes available there is no palaeoclimate record for Belize beyond c. AD 1600. This research seeks to augment the record with documentary meteorological data from the mid-19th century but cannot wholly address the gap in the palaeoclimate record.

ii) Palaeoecological reconstructions from northern Belize

Belize has extensive archaeological evidence for the occupation of the Maya, with crops appearing in pollen records throughout the region during 3400 – 2000 BC (Hansen, 1990; Jones, 1994; Pohl et al., 1996; Guderjan, 2006; Morse, 2009; Beach et al., 2009; Luzzadder-Beach et al., 2012). Crops synonymous with Maya agriculture include beans (*Phaseolous* spp.), bottle gourd (*Lagenaria siceraria*), cotton (*Gossypium* sp.), maize (*Zea mays*), manioc (*Manihot esculenta*), palms (Arecaece) and squash (*Cucurbita* sp.). Tree crops include Breadnut/ ramon (*Brosimum alicastrum*), cacao (*Theobroma cacao*), copal (*Protium copal*), hog plum (*Spondias* sp.), logwood (*Haematoxylon campechianum*), mahogany (*Swietenia macrophylla*), nance (*Byrsonima crassifolia*) and sapodilla/ chicle (*Manilkara zapote*) (Miksicek et al., 1981; Jones, 1994; Pohl et al., 1996; Leyden, 1998). Soil erosion is evident in multiple records soon after the appearance of crops (Rice, 1996; Deevey et al., 1997; Rosenmeier et al., 2002; Adams et al., 2004; Anselmetti et al., 2007; Beach et al., 2008), with some evidence of terracing (Beach et al., 2008) and wetland agriculture (Pohl et al., 1996; Berry and McAnany, 2007) as early as c. 2000 – 1000 BC. Most large-scale agricultural terracing and major hydraulic manipulation occurred from c. AD 300–500 (Scarborough and Gallopin, 1991; Beach et al., 2002; 2009). Records from northern Belize

suggest that the most intensive land-use occurred c. AD 650 – 950 (Anselmetti et al., 2007; Beach et al., 2008) however Beach and Dunning 1(995) and Beach et al. (2002; 2006; 2009) have observed soil conservation in this area

The earliest palynological evidence of agriculture in northern Belize is found at Cob Swamp (Fig.1.3), with maize and manioc pollen found at c. 3400 BC (Pohl et al., 1996). Deforestation began at c. 2500 BC and intensified at c. 1500 – 1300 BC, with the presence of multiple agricultural cultigens, including maize, squash (*Cucurbita* sp.) and bottle gourd (*Lagenaria* sp.). There is some evidence of the use of drainage canals and other modifications of fields c. 1000 BC, during a period of raised ground water levels (Pohl et al., 1996). During the period AD 600 – 800 the wetland fields were mainly flooded and abandoned (Pohl et al., 1996). Cobweb swamp forms part of the archaeological site of Colha, northern Belize, situated approximately 20 km north east of Lamanai (Fig.1.3). Anthropogenic forest disturbance appears c. 2500 BC, with the appearance of crops such as *Z. mays* and *Manihot esculenta* (manioc) (Jones, 1991; Jacob, 1992; Jones and Bryant, 1992). In a subsequent study of sediment extracted from Maya canals at Colha, Jones (1994) established two zones of anthropogenic activity. The first zone (2500 – 1000 BC) shows significant forest clearance, accompanied by the cultivation of manioc (Jones, 1994). The second zone (1000 – 500 BC) rests on a fill of 'Cobweb clay' or Maya clay, thus providing evidence of raised field agriculture (Jones, 1994). Further evidence of clearance is found in the reduction of mangrove taxa and the presence of palm pollen, which was economically valuable to the Maya for thatching and for fruits (Jones, 1994; Leyden et al., 1998).

Luzzadder-Beach et al. (2012) reconstructed broad changes in land-use in northern Belize over the last 4000 years from the wetland field site of Chan Cahal. From c. 2000 BC the pollen evidence suggests that the Maya burned and cultivated fields of *Zea mays* (maize) as well as cultivating fruit trees (Luzzadder-Beach et al., 2012). The groundwater table rose c. 350 BC, and continued to rise c. 50 BC – AD 950, with gypsum precipitated and 'the waterlogged, gypsic soil horizons and high-ion groundwater thus imposed more limits on Maya agriculture' (Luzzadder-Beach et al., 2012, p.4). In response to rising groundwater levels canals were dug and abundant charcoal is accompanied by *Z. mays* and avocado (*Persea*), grown in raised fields (Luzzadder-Beach et al., 2012). Other Maya agricultural adaptations included terracing, raised fields, drained fields, recessional fields and ditch construction (see reviews of these methods in Whitmore and Turner, 2001; Luzzadder-Beach and Beach, 2006; Beach et al., 2009). AD 950 marks the last stage of field and canal maintenance, with *Z. mays*, *Persea* and abundant charcoal giving way to tropical forest from this period until modern development in the last fifty years (Luzzadder-Beach et al., 2012). Examining pollen and stratigraphic evidence from both Chan Cahal and Laguna Verde (Fig.1.3, a lake surrounded by remnant high forest on the Rio Bravo escarpment, northern Belize), Beach et al. (2009) suggest that a palaeosol is present at

Laguna Verde and Chan Cahal at c. 2800 – 2420 BC and 2840 – 2440 BC respectively. *Z.mays* and fruit trees were present at c. 2500 – 1000 BC, and herb and cultigen taxa increased until AD 950 (Beach et al., 2009). Arboreal pollen recovered post AD 950 (Beach et al., 2009), but at Laguna Verde the forest recovery did not reach pre-disturbance levels (Morse, 2009). Dunning et al. (2012) suggest that the elevated interior of the Yucatán Peninsula was more susceptible to 'system collapse' and less able to recover than adjacent lower-lying land, although, Luzzadder-Beach et al. (2012) report that wetland field agriculture across the lowlands of northern Belize ended during or just after the Terminal Classic period, suggesting that the 'pervasiveness of collapse' extended into these low-lying perennial wetlands.

The dominant trends of land-use demonstrated by the palaeoecological records from Northern Belize suggest forest clearance for field based agriculture occurring c. 2500 BC, but as early as 3400 BC at Cobweb Swamp (Jones, 1994). Raised fields and drainage canals were constructed across the lowlands of northern Belize from 350 BC in response to raised groundwater levels. The records from Laguna Verde (Morse, 2009; Beach et al., 2009), Chan Cahal (Beach et al., 2009; Luzzadder-Beach et al., 2012), Cobweb Swamp (Jones, 1994) and Cob Swamp (Pohl et al., 1996) (Fig.1.3) suggest that the raised fields were abandoned post c. AD 950, with some recovery of forest evident. Thus far no palaeoecological records have examined the relative impacts of pre and post-Columbian societies and few examine the period of European contact. This research seeks to fill this gap, comparing different Maya society's land-use alongside Spanish and British interaction with the environment.

2.1.2 Modern vegetation of northern Belize

Meerman (2004) has produced an ecosystems map of Belize (Fig.1.6) based on initial studies by Iremonger and Brokaw (1995). The key ecosystems in the northern Belize area are lowland broad-leaved forest, lowland savanna, mangrove and littoral swamp, wetland and also agricultural and urban land. The ecology of the northern Belize area is edaphically constrained by the underlying geology (Furley, 1994; 2007). Pine savanna is found on well-drained acidic sand ridges, evergreen forest on calcareous sediments, with herbaceous swamps, seasonally inundated savanna and marshland in the fresh water lowlands (Metcalfe et al., 2009). Grass savannas with scattered oaks, pine and *P. wrightii* (palmetto palms) are characteristic of the north central region, and mangrove swamps fringe the northern coast and river inlets (Bridgewater et al., 2002). The key modern economic trees are: *Achras sapota* (Sapodilla) which is tapped for latex or chicle that forms the basis of chewing-gum; *S. macrophylla* (Mahogany), the principal export of the northern region, thriving on limestone rich soils, and *Calophyllum brasiliense* (Santa Maria) which is also used for timber, and is found mainly on the lime-poor soils of the Belizean plateau (Setzekom, 1981).

i) The modern vegetation of Lamanai

At its closest point, Lamanai is 10 km from the Rio Bravo Conservation Management Area (RBCMA) and vegetation from the latter has been described by Bridgewater et al. (2002). They suggest that in this geographical context savanna includes grasslands, woody thickets, woodlands and broken pine ridge. The defining species of the woody component are *Pinus caribaea, Quercus oleoides* (oak) and *Acoelorraphe wrightii* (palmetto palms). Common woody shrubs or small trees are *Byrsonima crassifolia, Curatella americana, Chrysobalanus icaco, Eugenia winzerlingii, Miconia albicans* and *Haematoxylon campechianum*. Herbaceous flora include *Ageratum radicans*, *Diodia teres, Sauvagesia erecta* and *Melochia spicata*. Wetlands are defined as 'permanently or seasonally inundated open areas, usually characterised by the dominance of *Cypreaceae* (sedges) in the herbaceous layer, rather than *Poaceae* (grasses) (Bridgewater et al., 2002, p.426). Trees and shrubs are (in the main) absent, but some species which can cope with the wet conditions, such as *Dalbergia glabra*, *Bucida burceras* and *Mimosa asperata* (Bridgewater et al., 2002) may occur. In a study of the modern vegetation at the archaeological site of Lamanai, Lambert and Arnason (1978) reported that the predominant arboreal species were *B. alicastrum (ramón* or breadnut tree*)*, *P. copal*, *Talisia oliviformis* and *Pimenta dioica*, and linked this association to the lime rich soil favoured by these species.

Today the New River lagoon is surrounded by a fringe of reeds dominated by *Phragmites australis* and *Cladium jamaicence*. To the west of the lagoon the reeds grade into a band dominated by logwood (*Haematoxylon campechianum*) and then into tropical evergreen seasonal broadleaved lowland forest (Meerman and Sabido, 2001) and this is the vegetation that surrounds the archaeological site of Lamanai. To the east of the lagoon, the vegetation changes from a reed fringe to marsh land (dominated by *Eleocharis intersticta* and *C. jamaicence*) and then into a band of logwood, and finally into the savanna zone (Meerman and Sabido, 2001) (Fig.1.6). The savanna zone has been described by Meerman and Sabido (2001) as short-grass savanna with scattered needle-leaved trees, with characteristic species including *Pinus caribaea, Metopium brownei* and *B. crassifolia*. Although there is a broad understanding of the vegetation that immediately surrounds Lamanai, there is a need for a higher resolution vegetation survey of the pollen source area from the New River Lagoon catchment. This would allow a comparison with the modern pollen signal to explore in greater detail what the modern pollen signal actually captures, and this would aid interpretation of past change.

Figure 2.1 A view of the New River lagoon looking south east from the top of 'High Temple' or 'El Castillo' (Str. N10-43), Lamanai, Belize, with fringing reeds to the east of the NRL and seasonal broadleaf lowland forest to the west (Rushton, 2010)

ii) An introduction to the logwood and mahogany trees

Logwood and mahogany trees are the two natural commodities that have dominated the Belizean export market since the 17th century (see section 2.3.3.i). As such, it is important to understand the ecology (see below in this section) and general history (section 2.3.3.i) of these two timber products in order to provide a context for our understanding of export trends explored in Chapter 6.

Logwood or *H. campechianum* (Caesapinoideae) is a tree native to the Yucatán peninsula and grows in swampy coastal or lowland forests (Meerman and Sabido, 2001). It is a small tree with an average height of approximately 10 m and wood that becomes extremely hard with age. The trunk and branches are covered with sharp spines and the paired inversely heart-shaped leaves are 1 - 3 cm long with yellow flowers blooming in February (Bulmer-Thomas and Bulmer-Thomas, 2012). It is found across Belize, but is particularly concentrated in the northern region, between the Hondo River and the Belize River (Meerman and Sabido, 2001). Logwood forms a distinct ecological zone around the New River Lagoon (NRL) which Meerman and Sabido (2001) have described as 'Tropical evergreen seasonal broad-leaved lowland forest, short tree variant'. When logwood blooms the ecological zone is particularly visible as the blossom forms a yellow fringe around the NRL (Figs. 2.3, 2.4 and 2.5).

Figure 2.2 Logwood (*H. campechianum*) in bloom at the New River Lagoon (Photo: Meerman, 2006)

Logwood's generic name '*Haematoxylon*' is derived from the Greek words for 'blood' and 'wood', as when the heartwood is soaked in water it produces a red liquid (Bridgewater, 2012). It was this 'blood-wood' or 'dyewood' property that made logwood such a valuable commodity in the 17th and 18th century European textile industry and, as a variety of hues could be obtained using logwood (including red, orange, yellow and even blue), this added flexibility increased its economic value (Bulmer-Thomas and Bulmer-Thomas, 2012). The most valuable parts of the logwood tree were the lower part of the trunk and the roots which contained the heart-wood. Logwood was seemingly in continuous supply; the trees were abundant in Belize and grew extremely quickly, taking approximately ten years to develop into a commercially viable plant from a seedling (Bulmer-Thomas and Bulmer-Thomas, 2012; Bridgewater, 2012). An 18th century account describing the fast growing nature of the logwood tree stated 'it blossoms and bears seed which by falling off sows the ground, from whence it springs up; and the over-flowing the ground brings the soil over it, which makes it take root and grow at great pace' (Uring, 1726).

Mahogany is the common name given to the three species of the genus *Swietenia* of the Meliaceae family (Pennington, 1981). The three described species of *Swietenia* native to Belize and the Caribbean (*S. macrophylla, S. humilis and S. mahogany*) are said to have been named after the physician to Maria Theresa, Empress of Austria (1816 - 1867), Baron von Swieten (Bulmer-Thomas and Bulmer-Thomas, 2012). The most widespread mahogany species is 'Honduran' or 'big-leaf' mahogany (*S. macrophylla*) and is found across mainland tropical America from Mexico to southern Amazonia in Brazil (Bridgewater, 2012). *S. macrophylla* is the only species native to Belize and can be found inland, in lowland broadleaf forest, particularly in the northern region of the country (Meerman and Sabido, 2001). Often described as 'the King of the Forest', mahogany was highly valued in the 18th and 19th centuries and was exported mainly to Europe where it was a prized decorative hardwood. Gibbs (1883) described it as a 'magnificent' tree which is 'unequalled by any of the forest giants, when all its qualities are considered: the height of the trunk to the first crutch, the space of ground covered by its roots, the girth, wide spread of its branches, its umbrageous foliage, coupled with the beauty and durability of its grain, and value of its timber' (p.116).

Gibbs (1883) notes the superior quality of mahogany from the northern region, describing wood from the central and southern regions as 'plain, free-grained, splitting wood, applicable only to the coarser manufactures' (p.118). An article published in *The Daily News* (1857) suggested that the mahogany found in the northern regions of Belize was of the highest quality as there is the 'rich dry soil' the tree requires:

> 'The best mahogany is found to the north of the river Belize. In consequence of the nature of the soil in that district, in which there is a great quantity of limestone, the mahogany is longer in coming to maturity, but when fully grown it is of a harder and firmer texture than that which is found in the southern portion of the settlement. There is no wood more durable than mahogany, and none which is so generally useful.'[3]

Morris (1883) also ascribed the 'harder, firmer' quality of mahogany felled in the north of Belize to the limestone based soil, as this lengthened the growing period producing a denser wood (p.42).

Generally, mahogany trees range between 20 and 45 m in height and have a trunk diameter of 2 m (at breast height) (Bridgewater, 2012). It is a deciduous species with pinnate leaves 10 - 30 cm long, and each leaf having 3 - 6 pairs of leaflets (Pennington, 1981). Mahogany produces both flowers which are greenish yellow in colour, and pear shaped fruit (Pennington, 1981). Mahogany is a low density species within the forest canopy, with approximately two trees per hectare (Bridgewater, 2012). It requires a significant amount of light and some disturbance to aid its development, with mature trees able to withstand minor hurricane and fire damage better than other arboreal species (Snook, 1996). Although *Swietenia* is the most famous genus in the Meliaceae family, there are other species within this family that have significant economic value and were also exported to Europe, including Spanish cedar (*Cedrela ordorata*).

Having reviewed the physical contexts, past and present, of northern Belize, it is important to consider the material (archaeological) and political history of Belize (see section 2.3). Before doing so, the specific material and political histories of Belize will be situated within two spatially and temporally broad cultural narratives.

[3] BLNOL_The Daily News_12_3328_15.01.1857

2.2 Cultural contexts

Two distinct aspects of scholarship or cultural narratives that inform an environmental history of Belize are considered in this section. These cultural narratives have been central to discussions surrounding the place of humans and the broader tropical environment, and include the relative impacts of pre- and post-Columbian populations on tropical landscapes (see section 2.2.1 and Chapter 4). European interaction with tropical climates in the 19th century is also a significant theme (see section 2.2.2) as ideas surrounding acclimatisation, healthiness of place, and the changing ideas surrounding disease transmission in the 19th and early 20th centuries (see section 2.2.3) feature strongly in the documentary records from Belize (see section 3.2) and as such, are a central aspect of discussions in Chapters 5 and 7.

2.2.1 Cultural narratives of the pre-Columbian Americas

Two central narratives have featured strongly in discussions concerning human interaction with tropical forests. The first narrative, the 'pristine myth', was most famously articulated by Denevan (1992), but has featured in understandings of human relationships with nature since 16th century European encounters with America (Sale, 1990; Melville, 1990 and Shetler, 1991). The 'pristine myth' imagines pre-Columbian America (pre-European contact c. AD 1492) as an unspoiled, forested wilderness, inhabited by small populations whose interaction with the landscape (which included plants and animals) exemplifies ecological balance and environmental harmony (Denevan, 1992; Whitmore and Turner, 1992). Miller (2007) suggests that 'it is an image that manages to remain standing even though recent scholarship has cut off its legs' (p.9). Slyuter (1999) suggests that the 'pristine myth', 'remains a cultural foundation for the binary catergorisation of the world into a rationally progressive West versus an irrationally traditional non-West, thus driving the social and environmental contradictions of postcolonial development efforts' (p.377). The changing nature of soil processes over time, in particular, the acceleration of soil erosion, has been linked to high pre-Columbian population and land-use as well as the introduction of European livestock and agricultural practice. Research from across Meso-America has explored the relative impacts of different populations on the landscape, with some asserting that pre-Columbian soil erosion rates of the Maya era c. AD 600 – 900, were equal to those of post-European rates (Butzer and Butzer, 1993; 1997; O'Hara et al., 1993; Sluyter, 1999; Dunning and Beach, 2000; Beach et al., 2006), whereas other research has demonstrated that post-European soil erosion rates were higher (Melville, 1990; 1994; Fischer et al., 2003).

Spanish colonial documentary records have been used extensively as a source of information concerning past land-use and climate and the

interrelationships between climate variability and societal change in colonial Mexico (Butzer, 1997; Melville, 1990; 1994; Endfield, 1997; 2008, Endfield et al., 2009). Both Butzer (1997) and Melville (1990; 1994) have used the Spanish colonial archival records to explore land-use patterns in different parts of the Mexican Bajío in the 16th century. Melville (1990) suggests that until the mid-16th century, the Valle del Mesquital was in 'ecological balance' (p.27). Although Melville (1990) is clear that the environment was not 'pristine', she does suggest that the indigenous populations lived in 'a world of barely perceptible human disturbance', that they were 'transparent in the landscape' (p. 369 - 370). By the close of the 16th century, Melville (1990) describes the Valle del Mesquital as having suffered a 'rapid and profound process of environmental degradation, caused by overstocking and indiscriminate grazing of sheep in the post conquest era' (p.24). In contrast, Butzer and Butzer (1997) find no evidence for the destructions of oak woodlands caused by colonial 'ungulate irruptions' (Melville, 1994, p.6). They suggest that descriptions from 1581 of stands of small mesquite,[4] cited by Melville as evidence of a substantial expansion of that ecological formation, is not supported by other palaeolimnological evidence. Palynological records from the Lake Cuitzeo area (central Mexico) do not show an expanded forest prior to 1521, but agricultural settlement since the 11th century (Butzer and Butzer, 1997). Broadly, Butzer and Butzer (1997) find no evidence of detrimental Hispanic land-use during AD 1540 – 1640 in the Mexican Bajío and this is supported by the palaeolimnological record from Lake Pátzcuaro (central Mexican highlands) (O'Hara et al., 1993). Butzer and Butzer (1997) assert that large numbers of introduced European livestock did not cause degradation until increasing population density in the mid 18th century caused livestock to be less mobile. This hypothesis is corroborated by both palaeolimnological research (Metcalfe et al., 1989) and travelogues (Butzer and Butzer, 1997).

Although there are some Spanish sources of Franciscan engagement at Lamanai during the 16th century (Graham, 2011) there are few other examples of published Spanish encounters with northern Belize. This leaves the initial period of European contact (c. AD 1550 – 1650) rather unclear as to what the landscape was like and how it might have been changed. Further research in Spanish archives may contribute to this current gap in knowledge and these sources may be available in archives in Spain or Mexico (none have been identified so far in the National Archives of Belize), but were not identified or consulted as part of this dissertation (which has a focus on the British colonial period) and is an area of future work.

As has been shown, Mexico and Central America have been a focus of research into the relative impacts of pre and post-Columbian societies on vegetation, in particular the forests, although there has been little research from Belize. Recent pressure on the remaining seasonally dry tropical forest, and its likely vulnerability to projected future climate change, increases the need to understand its past history and response to both climate and humans.

[4] Mesquite is a small tree or shrub from the genus Prosopis, and is associated with disturbance.

Belize, therefore, provides an opportunity to extend research concerning the changing nature of tropical forests, as well as exploring the land-use practices and management strategies of pre and post-European contact cultures. These new insights have the potential to add to a better understanding of the relative susceptibility and resilience of tropical forests to anthropogenic disturbance, both past, present and future (Willis et al. 2007).

The second narrative concerning tropical forests has emerged over the last century from research surrounding the Maya. Aimers and Hodell (2011) have suggested that the Maya civilisation has provided a story of a 'precipitous rise followed by spectacular decline' (p.44). As has been explored previously (Chapter 1), explanations for such a population 'collapse' have been numerous and are linked to anthropogenic impact (Rue 1987; Abrams et al., 1996; Webster et al., 2000), climate (Hodell et al., 1995; Leyden et al., 1998) and a combination of both (Metcalfe et al., 2009; Aimers and Hodell, 2011; Rushton et al., 2013). One of the more populist and highly publicised 'stories' of the Maya 'collapse' narrates a Malthusian crisis, where population outstrips natural resources, induced through both human overexploitation (e.g. deforestation) and regional natural disaster (e.g. drought) (Diamond, 2005). In this narrative the Maya are cast as a culture wilfully blind to long-term resource and population issues, and too focused on short-term concerns of city construction, warfare and wealth accumulation. When this account is juxtaposed with 21st century global climate concerns, the apparent 'demise' of the Maya is espoused as a modern-day morality tale (Tueth, 2000; Sewell, 2003; Peterson and Haugh, 2005; Gibson, 2006), a warning, lest we join them in 'marching synchronously towards oblivion' (Aimers and Hodell, 2011, p.44).

2.2.2. Tropical climates and European acclimatisation

The 19th and 20th century European production, interpretation and construction of the tropics has been much considered by recent literature, including a special issue of the *Singapore Journal of Tropical Geography* on *Constructing the Tropics* (2000), Nancy Stepan's *Picturing Tropical Nature* (2001) and Driver and Martin's edited volume (2005) *Tropical Visions in an Age of Empire*. During British colonial interaction with Belize, the nation was consistently identified in the documentary sources (see section 3.2) as part of the 'tropics' and broad ideas and debates surrounding climate, health and place in the tropics are introduced here (section 2.2.2) as a context for wider discussion in Chapter7. The specific characteristics of British interaction with yellow fever are explored in section 2.2.3, and provide context for Chapter 5 and Chapter 7.

For 19th and early 20th century Europe, the tropics were a region of the unknown, with the hope of untold wealth, but often the reality of unremitting illness and death; indeed, Curtin (1964, p.58) asserts that for Europeans 'a visit to the tropics meant running the gauntlet of disease and death'. This 'gauntlet' was not one of imagination or perception: during the late 18th and

early 19th century Europeans living and working in the tropics died in disproportionately high numbers. Gelfand (1965) and Headrick (1981) document doomed early European military expansions into tropical Africa in which all or nearly all the Europeans present died. Curtin (1989) comprehensively detailed the financial and human cost of European deaths to disease in the context of military relocations to the tropics and these high death rates were ascribed in the main to the heat, humidity and rapid temperature changes of the warm climates in the tropics (Arnold, 1996)

Harrison (2002) suggests that, until the 1830s, writings concerning European colonisation in the tropics were optimistic, with potential climatic dangers mitigated by cautious behaviour. Measures prescribed by colonial medical officers to prevent disease included advice on diet, clothing, limitations on the nature and amount of exercise, and frequent restorative trips to temperate climates were also recommended (Harrison, 2002). The ability of Europeans travelling to the tropics to adjust or 'acclimatise' to the different demands of a tropical climate emerged from the belief that humankind had a single origin, or 'monogenism', which was widely held until the 1830s (Anderson, 1996). The words *acclimatation* and *acclimation* entered the English language c. 1820 and was widely used across the 19th century to mean 'domestication' or 'naturalisation' (Anderson, 1992). 'Acclimatisation' became the science of the 19th century which sought to discover how and where Europeans could 'acclimatise' either fully or partially to the climate of the tropics and Livingstone (1987), Anderson (1992) and Osborne (2001) give extensive accounts of the science of acclimatisation. Veale (2010) suggests that 'discourses of acclimatisation came to pervade many aspects of colonial living. A truly interdisciplinary topic, acclimatisation was of interest to geographers, physicians, naturalists and amateurs' (p.27).

The belief in monogenism shifted over the course of the mid-nineteenth century, with 'polygenist' beliefs (or multiple sites of origin) becoming increasingly widespread and highlighted the dangers to Europeans residing in tropical climates (Anderson, 1996; Livingstone, 2002). It was Ellsworth Huntington's *Civilisation and Climate* (1915) that codified the 'moral discourse of climate' (Livingstone 1991), where the temperate northern climates 'bred vigour and intelligence' (Arnold, 2000, p.13) and the tropical regions were not only the site of origin of primitive races, but also posed an inherent risk that superior European races would degenerate. Livingstone (1999, p.106) identifies the 'pathological potency' that Europeans ascribed to the tropics and Arnold (1996, p.7) suggests that 'the tropical climate was almost universally considered to be the prime cause of European ill health'. Carey (2011) has documented the shift in British attitudes towards the tropical Caribbean climate between 1750 and 1950, with perceptions of this region transforming from an unhealthy place where Europeans were risking their moral as well as physical health, to that of a paradise destination, a place to enjoy sun, sand and sea and flee the ever indistinguishable British summer and winter.

For the British in other parts of the 19th century colonial empire, such as India, climate continued to be a key concern; by the middle of the century, sites at

altitude were identified as oases of 'sublime' and 'picturesque' landscape where the military and later civilian populations might recover from disease (Reed, 1979; Kenny; 1997; Harrison, 2002). Kenny (1991) suggests that areas that were 'free of jungle vegetation and located above the 'fever range' (which was defined as approximately 1,400 m) as environments that would escape the impact of miasmas' (p.112). However, such a medical topography that identified sites at altitude as healthy and picturesque may have reinforced the image of the pestilential lowland tropics 'for behind every enticing vista lurked a lethal miasma'. The tropics were treacherous as well as dangerous, their beauty a deadly deception' (Arnold, 1996, p.10). 19th century Indian hill stations became established British enclaves which demonstrated 'a racial and spatial category that symbolised superiority and difference' (Kenny, 1997, p.656). A predominantly lowland country, Belize's highest peak, Doyle's Delight (part of the Cockscomb Range, to the west of the country, Fig.1.4) reaches approximately 1,100 m. As such, the 'hill stations' of India identified by the British as places of respite and recovery from the tropical climate could not feature in medical topographies of Belize as no region was located above the 'fever range'. However, Harrison (2002) suggests that the British in India also identified coastal zones as restorative regions, bringing clean, fresh air and a return to health similar to that provided by the 19th century British seaside resorts and spas (Jennings, 2006). Medical topographies did not simply divide regions into healthy and unhealthy depending on the constituent parts of their environment, the rhetoric that pervaded them encompassed 'medical science, colonial ambition, evolutionary biology and moral principle' (Livingstone, 1999, p.110). As Deacon (2000) suggests, 'the genre of medical topography reveals a relationship between environment and disease deeply inscribed with moral and political overtones and profoundly influenced by social and economic trends' (p.281) (see section 7.1).

2.2.3 Yellow fever and the New World

Fever in general, and yellow fever in particular, featured prominently in the British experience of 19th century Belize and comprised a significant proportion of the correspondence emanating from the country. Indeed, in the vast majority of incidences where a disease was specifically named in the archival sources consulted (see sections 3.2.3 – 3.2.6), it was yellow fever that was identified. This could be in part due to the distinctive symptoms of the disease, which the British named yellow fever or 'yellow jack', as sufferer's bodies went yellow through jaundice as they neared death. The Spanish named it 'vomito negro' after the black vomit that also came in waves near death (Cook and Lovell, 1992; McNeill, 2010). Here, a brief outline of the nature, introduction and development of the disease in the New World is given and British encounters with yellow fever in the Greater Caribbean are explored. This provides the context for Belizean encounters with yellow fever in the 19th century discussed in Chapters 5.3 and 7.

The yellow fever virus is probably over 3,000 years old and originated from Africa, with the strain found in America genetically almost identical to the African one, implying it arrived in the Americas from West Africa only after Columbus (McNeill, 2010). Yellow fever is a viral disease transmitted to humans by the bite of the female *Aedes aegypti* mosquito, an urban insect that breeds in small, shallow bodies of water and requires a temperature range of 20 to 39˚C (Diaz and McCabe, 1999). It is difficult precisely to date the first appearance of yellow fever in the New World however the first recorded outbreak occurred in 1647 in Barbados, spreading to the Yucatan in 1648 and is recorded in Guadelopue, Cuba and St Kitts in 1648 - 49 (Cook and Lovell, 1992). Miller (2007) suggests that this outbreak killed up to 30% of the affected population. Yellow fever is recorded as reaching North America in 1693 at the port of Boston, brought by a British naval fleet returning from Barbados (Cook and Lovell, 1992). Outbreaks were common in the eighteenth century with multiple events in New York, Charleston, Philadelphia, Norfolk, Baltimore, Boston and New Orleans (Cook and Lovell, 1992).

Diaz and McCabe (1999) note that one of the most severe epidemics of yellow fever to have affected the southern United States in the 19th century was in 1878, with 100,000 cases of the disease, a death rate of up to 20%, and a financial cost estimated at $1,000,000,000. This outbreak occurred during the 1877 to 1878 El Niño (or 'El Niño/Southern Oscillation'/ENSO) episode, and Diaz and McCabe (1999) have linked seven extremely fatal (over one thousand deaths) outbreaks of yellow fever in the USA during 1793-1878 (1793; 1797; 1802 - 3; 1817; 1837 - 39; 1852 - 55; 1878) to El Niño events which occurred in the same years. El Niño and the year following (ENSO+1) promoted conditions for breeding and survival of mosquitoes, with mild winters and abundant precipitation promoting breeding and warm summers, enabling high mosquito activity (Diaz and McCabe, 1999; Chen and Taylor, 2002; Amarakoon et al., 2004; Jury et al., 2007).

i) Yellow fever in the Greater Caribbean 1750 - 1900

McNeill (2010, p.33) states that during 1750 - 1900 'yellow fever was the most feared disease among whites in the Greater Caribbean'. Death was relatively swift, coming about two weeks after the onset of the disease, with young white men more susceptible (McNeill, 2010). Children usually had a relatively mild case and survived, crucially with the added immunity that survivors of any age obtained (Cook and Lovell, 1992). McNeill (2010) has documented how European plantation sugar in the Greater Caribbean made it easier for *A. aegypti* to thrive. Deforestation reduced habitats of island birds, thus reducing mosquitoe's predators; water storage in shallow containers with sugar residues were optimal for laying mosquito eggs and producing bacterial populations which the hatched larvae fed on, and high human density gave the mosquitoes plenty of meals and enabled the fast spread and continued survival of the virus (McNeill, 2010). The sugar cane juice also provided an alternative source of food and the shipping routes provided the means for the

mosquito and virus to spread and re-spread between islands and ports (McNeill, 2010). McNeill (2010) concludes:

> 'Ships in effect were super-vectors, efficiently moving both mosquito and virus from port to port. And ports in effect were super-hosts, providing warm welcomes for mosquito and virus alike. Thus the sugar revolutions created a new world of plantations, population increase, ships and ports – a world almost tailor-made for the yellow fever vector and virus'. (p.52)

From the 1730s, if not before, yellow fever was recognised as a disease that affected newcomers from cool climates, with the 17th and 18th century understanding that yellow fever killed more of the white population reflected in the European experience in the Caribbean (McNeill, 2010). During the French invasion of Saint-Domingue in 1802, 80% of the forces died from yellow fever and there were repeated outbreaks of the disease in the Greater Caribbean across the 19th century with mortality rates amongst Europeans between 30 and 65% (McNeill, 2010). McNeill (2010, p.71) suggests that between 1650 and 1900, European's related vulnerability and resistance to yellow fever to a person's 'constitution, behaviour and environment'. Men were perceived to be more vulnerable than women due to their 'intemperance' or excessive activity, the constitution of blacks seemed more resistant than whites, and those 'in the prime of life seemed more vulnerable to yellow fever' (p.71). Behaviour and environment were also thought to have significant roles in determining an individual's vulnerability to yellow fever:

> 'Those too active put themselves at risk, whereas those more sedentary did not. The wrong diet, dress or drink and excessive devotion to the 'pleasures of Venus' raised one's risk…Filth, decaying vegetation, swamps, humidity, heat and low elevation seemed connected to yellow fever and malaria, whereas cleanliness, cool temperatures and altitude seemed to provide protection.' (p.72)

Preventative measures undertaken by the British in the Caribbean reflected concerns that the environment could induce outbreaks of yellow fever, deforestation was encouraged to open up the landscape to 'healthier' winds and situating populations at a higher elevation was also considered healthy (McNeill, 2010).

During the 19th century, climate featured predominantly in discussions of 'disease, empire, struggle and virtue' (Livingstone, 1999, p.93) with early positive assessments of European acclimatisation giving way to increasing anxieties about the moral and physical risks Europeans faced in the tropical sphere. Revill and Wrigley (2000) suggest that 'salubrity of locale was not an objectively fixed phenomenon, but subject to the contingent perceptions informed by…the climatic and moral geography of Empire' (p.18). By the end of the 19th century, debates about the ability of Europeans to settle in the tropics remained framed by 'medical diagnosis, colonial imperative, Darwinian demography and moral evaluation' (Livingstone, 1991, p.93). However, with the dissemination of germ theory from the mid 19th century doctors including Louis Sambon (1865 – 1931) and Patrick Manson (1844 – 1922), the causal

link between tropical climate and a number of diseases including malaria, yellow fever and tuberculosis began to be publicly questioned (Bell, 1993; Livingstone, 1999; 2002). Livingstone (1999) gives a detailed account of Sambon's paper 'Acclimatization of Europeans in Tropical lands', presented to the Royal Geographical Society in April 1898, which suggested that the incidents of disease Europeans experienced in the tropics were caused by parasites. Sambon had set out these ideas in a previous paper for the British Medical Journal, published in 1897, where again he identified parasites as the cause of 'the difficulties in the way of colonisation', not climate (Sambon, 1897, p.66). The author of 'Tropical Diseases: A Manual for the Diseases of Warm Climates' (1898), Manson also founded the London School for Tropical Medicine (Livingstone, 1999).

Livingstone (1999) suggests that after Sambon became the lecturer at this new academic institution, he 'emerged as a dedicated advocate of the germ theory' (p.97). During the last decade of the 19th century and early decades of the 20th century, 'germ theory' began to replace climate and in particular 'miasmas' as the central explanation of the spread of disease. Anderson (2006) suggests that American colonial bio-medical research in the Philippines during the early 20th century focused on 'the exoneration of the tropical milieu and the racialising of the pathogen distribution' (p.75). Although there was an increasing understanding and acceptance that infectious diseases were spread by microbes, place, race and morality remained an established part of the rhetoric which surrounded colonial understanding of disease (Kennedy, 1990; Stepan, 2001; Livingstone, 2002). As Anderson (2006) states 'even as scientists were postulating theories of harder, more robust heredity and identifying microbiological rather than physical causes of disease, ideas of environmental fit and stress continued to appeal to the public and to many doctors well into the 20th century' (p.76). Although viewed from the beginning of the 21st century, it is possible to discern shifts in European perceptions of, and interactions with, the tropics. These were transitions with porous boundaries, where multiple understandings and models were overlain: 'there was no simple transition from climatic constructions of tropical disease to microbial explanations' (Endfield and Nash, 2005, p.383).

2.3 Archaeological and historical contexts of northern Belize

Having explored the broad physical contexts of northern Belize (section 2.1), and the wider cultural narratives that inform cultural and intellectual engagement with Belize (section 2.2), the final section of this chapter considers the archaeological and historical contexts of the region. This section explores Maya, Spanish and British interaction across northern Belize in terms of material (archaeological) and political documentary histories, and begins with an overview of the development and history of the Maya settlement at Lamanai by exploring the archaeological record (Fig.1.5).

2.3.1 The Maya at Lamanai, northern Belize

Lamanai was an important Maya site, and has undergone extensive archaeological excavation (Pendergast, 1975; 1981; 1982a-c; 2002; Graham, 2001; 2004; 2011). The site was first uncovered by Thomas Gann in 1917 and excavation work has been undertaken by David Pendergast (1974 - 1985) and Elizabeth Graham (1998 to present) (Fig. 2.4).The importance of Lamanai is based primarily on the complex ceremonial activity at the site, coupled with continuous occupation between c. 300 BC and AD 1675 (Pendergast, 1986) that is defined by a well-established archaeological stragtigraphy (Graham, 2011, Pers. Comm.). The centre of the community was situated to the north of the site in Preclassic times and shifted south over time. The Ceremonial Precinct was formed during the Classic Period, at the southern end of the site. The site contains a number of temples, a ball court and stelae dated to AD 625. The highest temple is called 'High Temple' (Str. N10-43), which is 35 m tall, construction of which began in 100 BC (Fig.2.3).

Figure 2.3 The main temple or 'El Castillo' (Str. N10-43) at Lamanai, Belize (Rushton, 2010

Pendergast (1975; 1981; 1982a-c; 1986; 2002) and Graham (2001; 2004) have described the major phases of occupation at Lamanai, with settlement beginning at c. 1500 BC and major construction and population peaking during the early Classic period (c. AD 250). Coe (2005) asserts that Lamanai has been occupied from earliest times until the post-Conquest period; however, the most important phase is the Late Preclassic with constructions of temples such as 'High Temple' (El Castillo) (Str. N10-43) (Fig.2.3), which were often built upon Early Classic constructions. Metcalfe et al. (2009) suggest that population and erosion peaked during the Preclassic and Early Classic, with a population of approximately 10,000. A key feature of the site at Lamanai is the well-established trade network (Pendergast, 2002); Guatemalan mercury and obsidian found at the site (Pendergast, 1982b; Healy et al., 1984) support

the idea that the Maya had complex and well defined trade routes (Hammond, 1972; Healy et al., 1984) that extended to areas including Lamanai and Moho Cay (Healy et al., 1984). The main developments at Lamanai have been summarised in Table 2.1.

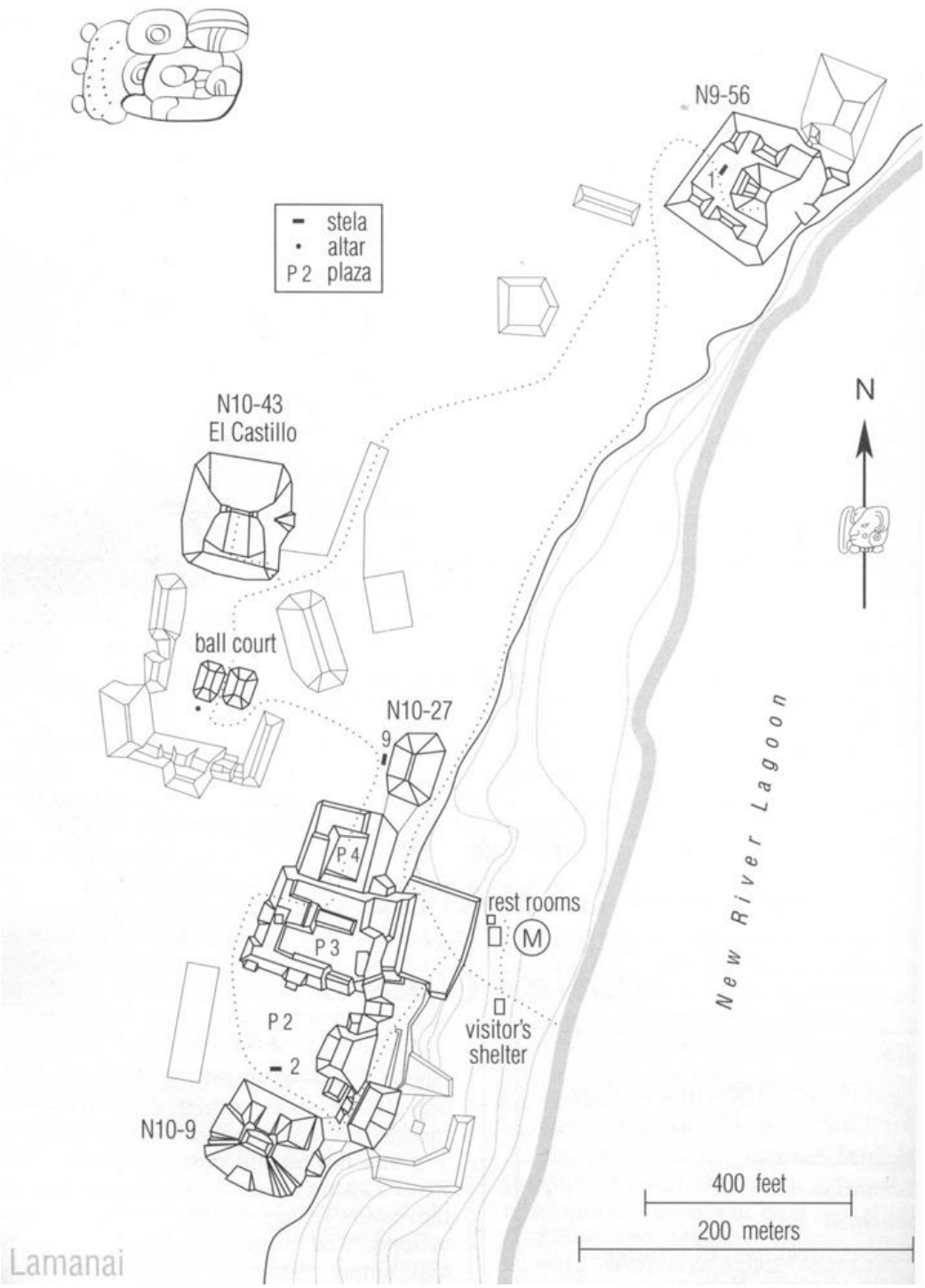

Figure 2.4. The archaeological site of Lamanai, Belize (reproduced with kind permission of E. Graham)

Table 2.1. Key developments at Lamanai, Belize.

Date	Developments	Source
1500 BC	Exact date of founding of community is unknown. Pollen evidence shows agricultural crops such as squash and chillies at 1500 BC.	Rushton et al. (2013)
600 BC	Substantial settlement and wide range of activities in evidence.	Pendergast (1981) Powis (2002)
100 BC	The context of the axial cache suggests, although not conclusively, that Str. N10-43 (Main Temple) reached 33 m in height at this time.	Pendergast (1981)
AD 100-400	Early Classic activity and construction in various areas of the site.	Pendergast (1981)
AD 400-500	Burst of construction activity in the Middle Classic as evidenced by two tombs: one associated with Str. N9-56, and another buried along the face of the main platform, north of the main stair.	Pendergast (1981)
AD 500-600	Continued construction activity; this is the time when the masks now adorning the terrace faces of Str. N9-56 (Mask Temple) (and recently conserved) were made.	Pendergast (1981)
AD 600-700	Construction activity continues and seems to expand in the early part of the Late Classic. A stela carved with the image of a ruler was placed within a building, Str. N10-27, and a number of buildings around the main plazas were added to and expanded.	Pendergast (1981; 1988) Graham (2004)
AD 700-800	This is the later part of the Late Classic. Various buildings around the site continued to be added to or altered.	Pendergast (1981) Graham (2004)
AD 800-950/1000	Despite the disintegration of sites at La Milpa and Altun Ha (both less than 42 km distance), Lamanai continues to thrive. This period is referred to as the Terminal Classic; construction of masonry platforms continues but we see diminution in the construction of masonry superstructures and increase in wood used as a material. The only ball court at the site was built at this time. A dedicatory offering found beneath the ball court marker included liquid mercury.	Webster (2002) Pendergast (1982c; 1986) Graham (2004)

Date	Developments	Source
AD 950/1000-1200	Early Postclassic period (Buk phase). Significant changes in material culture with new forms and styles of pottery (orange-red ware) in circulation among elites. Some changes in burial customs. Burials can have elaborate furnishings, such as gold sheet objects and copper ornaments from West Mexico and Oaxaca. The lagoon has always been important, but in this period, the focus on the lagoon seems to become more intense with a great deal of activity (as evidenced in residences, features, artefacts) taking place lagoon-side.	Pendergast (1982a) Graham (2004; 2006)
AD 1070	Early Postclassic. Isotopic analysis and magnetic susceptibility indicate a period of reduced anthropogenic activity and possible forest recovery. There is not enough archaeological evidence to say, but certainly construction of masonry superstructures decreases. This may be due to a reduced population or simply to a different way in which the landscape and resources were used.	Metcalfe et al. (2009) Pers. Comm. Graham (2011)
AD 1200 – 1350/1400	Middle Postclassic period. Not much known yet about this period. Most information comes from burials located in a structure near the lagoon just east of the Jaguar Plaza. Substantial continuity from Early Postclassic times.	Pendergast (1981; 1982a) Graham (2004)
AD 1350 /1400-1500	Late Postclassic period. Even less known about this period, although we have evidence in the form of effigy censers (known as Chen Mul Modeled) and other distinctive pottery that the site was heavily occupied at this time and, as in the past, there was a great deal of activity focused on the lagoon. Str. N9-56 (Mask Temple), now in ruins, was revisited at this time and about a hundred Chen Mul Modeled censers were found fragmented on the surface of the mound formed by the structure's collapse and the soil that had formed over it.	Pendergast (1981; 1982a) Graham (2011)
AD1500-1544	Terminal Postclassic/ Early Colonial Period. Although Belize was not conquered until 1544, a few Spanish explorers travelled along the Belize coast and seafarers navigating the Caribbean likely raided Belize's cayes and atolls. Lamanai seems to have been affected. Ceramics believed to date to the latter part of this period (Yglesias Phase) show poor quality manufacture both in fabric and in slip.	Pendergast (1986; 1991; 1993) Graham (2011)
Post AD 1525	Last substantial burial of noble, complete with ceramic objects and metals to suggest high status. Likely to be the last pre-Hispanic ruler of Lamanai.	Pendergast (1991)

Date	Developments	Source
AD 1544 to ca. 1641	Spanish Colonial Period. First church (YDL I) built by the Spanish upon the site of a Pre-Columbian-style temple, which was decorated with frescos. Second and larger church at Lamanai (YDL II) also built during this period. The end dates (1639 - 41) mark a period of rebellion and resistance, stimulated by the Itza of Peten. Spanish authorities never regained their hold on Belize.	Pendergast (1975; 1981) Graham (2011) Jones (1989; 1998) Graham, Pendergast and Jones (1989)
AD 1641 to 1700	Spanish Colonial Period. After the period of rebellion, authorities in Yucatan made repeated attempts to re-pacify Belize. Lamanai's fate is unknown, however, although there is evidence that occupation continued. At this time, British activity in the Caribbean increased and coastal and mainland raids of Maya communities were common. British activity known in the area of the Belize River and some inland zones in the 1660s.	Graham (2011) Pendergast (1986; 1993) Jones (1989; 1998)
AD 1700s	Evidence that occupation at Lamanai continues; masonry chapel of YDL II used as a residence; midden accumulation in evidence	Pendergast (1986; 1993)
AD 1787-1862	British settlement of Belize. Occupation at Lamanai during the earlier part of this period is unknown but British artefacts have been recovered at Lamanai that date to the 1830s as well as to the sugar mill period in the 1860s.	Bolland (1977) Bolland and Shoman (1977) Mayfield (2009)
AD 1816	British census records 3,824 settlers at the Bay colony.	Thompson (2004): pg37
AD 1837	British Sugar Mill constructed at Lamanai, in operation until 1875.	Pendergast (1982b) Mayfield (2009)
AD 1862	British Governor put in place by the British government to rule over Belize as a British Crown Colony. Widespread archaeological evidence of British ceramics imported to Belize found at the site, dating to the mid 19th century.	Thompson (2004) Mayfield (2009) Pendergast (1982b)
AD 1964-1981	Belize is a self governing British Colony.	Twigg (2006)
AD 1981	Belize became an independent nation.	Twigg (2006)

2.3.2 Colonial contexts

i) Early Spanish encounters with Belize c. AD 1502 – 1700

It has been suggested that the colonial history of Belize began in 1502 when Columbus encountered the Gulf of Honduras a decade after first sighting this so called 'New World' (Graham, 2011; Bulmer-Thomas and Bulmer-Thomas, 2012). Although colonialism did not begin with the European 'discovery' of the Americas (Schwartz, 1994), it was the Spanish and Portuguese political powers which dominated conquest throughout the 16th, 17th and 18th centuries. As Endfield (1997) suggests, 'it was the exploits of Spain in Mexico, that showed Europe how to establish a Colonial *empire* [italics author's emphasis] in the New World' (p.5). Graham (2011) asserts that Maya communities in Belize would have been aware of Columbus making landfall in the Gulf of Honduras during 1502, as trading between different Maya populations and other indigenous groups was 'intensive' along the Caribbean coast (p.122). Hernan Cortes gained control of Central America for his Spanish sovereign during the campaign of 1519 - 1521 and, in order to exert authority over modern day Honduras in 1524, 'he himself led a remarkable southwards march overland from Tabasco in southern Mexico to Trujillo, [on the northern coast of modern day Honduras] a march which, topographical descriptions suggest may have taken him throughout south western Belize' (Thompson, 2004, p.11; Fig.1.1). During the late 1520s - and for at least two further decades- the Spanish waged an extended campaign to exert control over the Yucatán in particular, which was made more difficult by the multiple and mobile Maya tribes in the region (Coe, 2005). As a consequence of this military effort in the Yucatán, the adjacent region of Belize was almost completely ignored (Graham, 2011). In the 16th and 17th centuries Belize continued to be an unnamed region, and seemingly unknown, in direct contrast to the naming of other Central American regions such as Yucatán, Petén, Chipas or Guatemala (Fig.1.1). During these two centuries, Belize was 'a liminal, elusive, shifting, dangerous space, neither land nor sea, neither here nor there, betwixt and between an idea of a 'Yucatan' and an idea of a 'Kingdom of Guatemala' (Graham, 2011, p.107).

In the late 16th century and 17th century, maps of Central America reproduced some topographical features which can be linked to modern day Belize, although the land was depicted as forming part of the Yucatán Peninsula. Wytfliet's 1597 map (Fig.2.5) shows rivers and mountains that could represent the Cockscombs or Maya mountains. These features would have been visible from coastal waters (Graham, 2011) and the lack of any named settlement in the modern day Belize region (and the inaccurate placement of Chetumal to the south of Belize) suggests that this map was drawn without Wytfliet making landfall in Belize.

Figure 2.5 Wytfliet (1597) map of Yucatan. (Reproduced with kind permission from Graham, 2011, p.114)

Figure 2.6 Sanson d'Abbeville (1650) map of Yucatan and the Gulf of Honduras (Reproduced with kind permission from Graham, 2011, p.113)

Figure 2.7 Blaeu (1665) map of Yucatan. (Reproduced with kind permission of Graham, 2011, p.113)

Two maps from the mid 17th century show some greater detail from the Central American region, including Sanson d'Abbeville's map of the Yucatán and the Gulf of Honduras (1650 - 1670) (Fig.2.6) and Blaeu's map of the Yucatán (1665) (Fig.2.7). These three maps depict many small islands along the coast of Belize and each has the larger island of Cozumel. Sanson's map (1650 - 1670) (Fig.2.6) shows a mountain region similar to the Wyfliet map (1597) (Fig.2.4) and also names 'Lamanay' as a large island off the coast of modern day Belize. Lastly, Blaeu (1665) (Fig.2.7) shows 'Lamanay' as part of the mainland. Graham (2011) suggests that the choice made by Spanish Europeans not to settle the coast, cayes and mainland of Belize was in part due to the treacherous coastline but was also due to the strategies of the Maya to prevent Europeans gaining knowledge as to what and how they might exploit natural resources they encountered. This, coupled with the 16th and 17th century Spanish military focus on their modern day Mexican territories, meant that few resources were committed away from the Mexican frontier (Setzekorn, 1981) and left Belize relatively unknown to Europeans.

ii) 16th century Spanish encounters at Lamanai

Spanish missions to establish a Christian presence in Belize were concentrated between AD 1540 and 1570, extended to northern Belize c. AD 1544-1707 and lasted in southern Belize until c. AD 1724 (Graham, 2011). Although the Roman Catholic Church consecrated Bishops of Yucatán between 1519 and 1714, the first Bishop to take office and reside in his Episcopal see was Fr. Francisco Toral in 1560 (Graham, 2011). The Christian community at Lamanai was established by Spanish Franciscans as part of

wider Central American evangelisation c. AD 1544, and may have been visited by Friar Lorenzo de Bienvenida during his travels across Belize in AD 1543 - 1544 (Jones, 1989). The extended visit of three Franciscans, namely Francisco de Benavides, Martín de Barrientos and Alonso Toral, to northern Belize during AD 1568 - 1569 (Jones, 1989) suggests that the Spanish Catholic Church sought to consolidate and broaden earlier initial evangelization of the region (Jones, 1989; Graham, 2011). In the mid-16th century, Lamanai became the centre point of a congregation (congregación) designated by the Spanish, which drew in Maya from the surrounding villages and communities to 'facilitate both their monitoring as new Christians and their integration into the tribute [tax] system' (Graham, 2011, p.192).

Lamanai has a significant Spanish archaeological component with two 16th century churches built in the Spanish style, YDL I and YDL II (YDL or Yglesia de Lamanai) (Graham, 2011) (Fig.2.8). The first of the two churches (YDL I) dates from c. AD 1544 and may have been built at the instruction of Friar Lorenzo de Bienvenida (Pendergast, 1993). The composite and 'trial and error' nature of the construction of this structure may suggest Franciscan oversight of Maya building work (Graham, 2008). The second building (YDL II) dates from c. AD 1568. The ruins of the stone chapel are recognisable today as a church structure, built in the European style, and were well known throughout the Spanish and British colonial period as 'Indian Church' (Graham, 2011). This later church was a more substantial and impressive building, with a large nave (Graham, 2008); it formed part of a complex which included a residential 'rectory' (Awe, 2007; Graham, 2008) and two cemeteries, which may hold more than four hundred individuals (Pendergast, 1986b). The church at Lamanai first appeared on a list of churches in AD 1582 (Roys, 1957) and was visited by Franciscans Bartolomé de Fuensalida and Juan de Orbita in AD 1618 (Jones, 1989). Graham (2011) suggests that the scale of the complex reflects a community of a significant size; one 'which the Spanish authorities, both civil and religious, may have seen as having the potential to grow and possibly, ultimately, to have attracted Spanish settlers' (p.236).

After a second visit to Lamanai in AD 1641, accompanied by Friar Juan de Estrada (Jones, 1989), Fuensalida reported that Lamanai was abandoned and the church desecrated. However, this did not mark the end of the Maya occupation of the site. An excavated stela probably dates to post AD 1641 as it did not from part of Fuensalida's account (Graham, 2011) (although the post AD 1641 stratigraphy relating to Spanish activity at YDL II was destroyed by 19th century British use of the structure as a smithy (Graham, 2011)). Archaeological excavations at Lamanai suggest intermittent Maya residence at Lamanai post AD 1700 (Pendergast, 1986b; Graham, 2004); however, substantial and permanent residence probably ended by the end of the 17th century with the Maya population moving to the Petén Itzá region (Jones, 1989). Enthnographical accounts highlight continued Maya use of the cemeteries associated with the YDL I structure for burials into the 20th century (Graham, 2011). This suggests that the churches and the sacred space

associated with them seem to have lived on in the collective Maya memory long after substantial residence at Lamanai (Graham, 2011).

Figure 2.8. Ruins of the two Spanish Churches (YDL I and YDL II) at Lamanai, (Graham, 2008)

2.3.3 Spanish and British interaction in Belize during the 17th and 18th centuries

The importance of trade in logwood, and the wider role that timber exports played in the material and political environmental history of northern Belize are the focus of discussion in Chapter 6. In this section, the role that logwood played as an issue of geopolitical tension between the British and Spanish is considered in terms of the historical political development of modern day Belize.

The Spanish reached Belize before the British: these ‘entradas’ have been well documented (Means, 1917; Stone, 1932; Thompson, 1988; Jones, 1989; Graham, 2011). However, the ‘history of Belize is intimately associated with the British as they were the first Europeans to establish a settlement that was more than transitory’ (Bulmer-Thomas and Bulmer-Thomas, 2012, p.8). During

the 16th century, European countries sought to expand their Caribbean territories, with Antigua settled by the British in 1632, Martinique by the French in 1635 and St Eustatius by the Dutch in 1636 (Fig.1.1). The British aim to break Spanish control of Central American and Caribbean trade was not a significant challenge until the British captured Jamaica in 1655. Bulmer-Thomas and Bulmer-Thomas (2012) suggest that the first evidence of a permanent British settlement at 'Belize' comes from the writings of a Spanish priest – Father Delgado. Delgado and his colleagues were captured in Belize by British seamen and logwood cutters in 1677, when this permanent British settlement was at most thirty years old. Bulmer-Thomas and Bulmer-Thomas (2012) refute the idea that the etymology of the settlement Belize comes from a corruption of the name of British buccaneer Peter Wallace, who was supposedly shipwrecked at the mouth of the Belize River c. 1617. They suggest that this 'myth' only appears in literature after 1827, first published in the second edition of the *Honduras Almanack*[5], which was then repeated throughout the literature until the late 20th century.

The 1670 Godolphin Treaty[6] acknowledged 'British sovereignty over territories the British occupied' (Thompson, 2004, p.16). This treaty seemingly allowed the British government to support the rights of logwood cutters to work in the territory and they provided governance for this population through the Governor of Jamaica, but still 'declined to declare these primitive settlements to be within the King's dominions' (Thompson, 2004, p.17). Grey (1869) suggests that it was the Treaty of Madrid that gave the British their first formal footing in the region. Bulmer-Thomas and Bulmer-Thomas (2012) describe the Godolphin Treaty as a 'watershed' in the history of the British Caribbean, as from this point privateers would be dealt with as if they were pirates, with many opting for a more secure existence cutting logwood. During 1670 – 1728, Spanish attacks on loggers were frequent and sustained enough to force loggers to flee the region in 1680, 1702 and 1716. A letter from a Spanish missionary in 1724 reported a population of about 300 'English' (Bulmer-Thomas and Bulmer-Thomas, 2012) and a visiting naval surgeon suggested that the population of logwood cutters in 1735 was approximately 500 people (Thompson, 2004). Bulmer-Thomas and Bulmer-Thomas (2012) suggest that the European population remained static at around 500 individuals throughout the majority of the 18th century.

The War of Spanish Succession (1701 – 1715) dominated western Europe, reinforcing trade restrictions set out in the 1670 Godolphin Treaty and limiting the British to one annual shipment of goods to and from the Caribbean (apart

[5] The *Honduras Almanack* was at first supported by funds from the public assembly in Belize and there were annual editions during 1826-1830 inclusive, and in 1839. It was succeeded by the *Handbook for British Honduras*, Bristowe, Lindsay (1892-93 and 1891-1892) Bristowe, Lindsay and Wright, Philip B. (1889-1890; 1890-1891),and was written in Belize and published in London by William Blackwood.

[6] Named the Godolphin Treaty after the British Minister Lord Godolphin who negotiated the treaty with the Spanish in Madrid in 1670.

from slaves) (Thompson, 2004). During the first three decades of the 18th century, there were continued military disputes between Spanish and British loggers, with the Spanish contesting British claims. In 1717 the British government first formally acknowledged the rights of the British loggers. During the 18th century, the latter repeatedly moved between modern day Belize and the Mosquito Shore (on the northern coast of modern day Honduras, also called Spanish Honduras; Fig.1.1) when pushed back by waves of Spanish military advancement (Twigg, 2006). The first Spanish recognition of British loggers' right to cut, load and ship logwood on the Belize River and the Mosquito Shore came in 1763 with the Treaty of Paris, partially a result of the Seven Years War (1756 - 1763) (Thompson, 2004).

In 1779, the Spanish used the American War of Independence as an opportunity to regain territory lost in the War of Spanish Succession and to gain control of the Caribbean. These ambitions were thwarted, in part, by a successful British defence of the Caribbean; however, the Spanish did take control of the Belize River and the Mosquito Shore (Thompson, 2004; Abbott, 2010). After complex negotiations, the Treaty of Versailles (1783) outlined that the British would give up all settlement rights to the Mosquito Shore and, in return, the Spanish recognised British rights to the land which forms modern day Belize, including the coastal Cays. This led to a mass movement of population (approximately 2000 people) in 1783, relocating from the Mosquito Shore to the Belize River, quadrupling the population (Thompson, 2004).

i) The geopolitics of the trade in logwood

Bulmer-Thomas and Bulmer-Thomas (2012, p.41) suggest that the early economic history of the British Settlement in the Bay of Honduras is 'intimately associated with the trade in logwood' and that, for the first one hundred years of the settlement (c.1650 – 1763), logwood was the only export, the revenue from which had to finance all other costs. The nature and scale of logwood extraction and the different phases of export of logwood from Belize are discussed in section 6.1. The initial trade in logwood was controlled by the Spanish; in 1662 Charles II legalised the import of logwood into Britain and thus incentivised the British to establish their own logwood settlements. Bulmer-Thomas and Bulmer-Thomas (2012) suggest that it was in 1662 that the first British logwood settlement on the coast of the Americas was founded, on the north-eastern point of the Yucatán Peninsula, called 'Cabo Catoche'. During this early period of settlement, the political situation was ever changing, complex, and dominated by the 'Baymen'. These were mainly British men who had left Jamaica from the early to mid-17th century to seek a living as pirates and privateers; they finally became logwood cutters in the swampy coastal land, initially in the north eastern Yucatán Peninsula, and later along the coast to the north of Belize City. Not only was logwood plentiful in this northern region, but there were rivers and creeks along which the wood could be transported to the port of Belize City, to be shipped on to European markets in merchant vessels via Port Royal (Jamaica) or Boston (New England) (Bulmer-

Thomas and Bulmer-Thomas, 2012). Morris (1883, p.61) noted that logwood 'is found in rather moist lands to the north and west [of Belize], where it forms immense thickets'. Furthermore, the Spanish relocation of Maya populations in parts of northern Belize during the early 18th century meant that there was then little or no resistance to the progress of the 'Baymen' by the indigenous people (Graham, 2011). Jones (1989; 1998) suggests that the Spanish relocated the Tipuans in response to the British threat from both slaving raids and timber extraction, despite the efforts of this Maya community to repeatedly repel logging 'Baymen'.

Throughout the 1700s, the Spanish claimed the Belizean territory as its own, despite the increasing cutting and export of logwood by the British from Belize City. In a report to the British Council of Trade (1705) the settlement was described thus: 'sixty leagues from Porto Cavallo lyeth the River of Bullys [sic. Belize], where the English for the most part now load their logwood' (cited in Bulmer-Thomas and Bulmer-Thomas, 2012, p.45). In 1718, after the Spanish attacked a logging settlement along the coast at Campeche (modern day Mexican state, with the Petén region of Guatemala to the south and Belize to the east; Fig.1.1), the export of logwood shifted southwards to Belize City, where, although not immune from attack, 'it was more difficult for the Spanish to harass the British settlers in Belize as the western or northern approach involved a long march over difficult terrain, while the eastern approach required navigation of the shallow waters inside the barrier reef' (Bulmer-Thomas and Bulmer-Thomas, 2012, p.45).

From the settlement of Belize to the end of the Seven Years War between Spain and Britain (1756 - 1763), the British settlement had no legal basis (Bulmer-Thomas and Bulmer-Thomas, 2012). It was only with the Treaty of Paris (1763) that the Spanish recognised the rights of the settlers in Belize to cut logwood. With this Spanish concession came the requirements to limit British activities to logwood extraction only, the removal of all fortifications and the acceptance of Spanish sovereignty (Bulmer-Thomas and Bulmer-Thomas, 2012). The Spanish recognised the British settlement with the de facto boundaries of the Rio Hondo (Hondo River) to the north, the Belize River to the south and the New River to the west (Fig.1.5). The importance of these rivers as the early demarcations of settlement is recorded in the Belize National Anthem 'Land of the Free'[7] within the following verse;

'Our fathers, the Baymen, valiant bold

Drove back the invader; this heritage hold

From proud Rio Hondo to old Sarstoon,

Through coral isle, over blue lagoon;'

[7] 'Land of the Free' was adopted in 1981. The lyrics and music were composed in 1963 by Samuel Alfred Haynes and Selwyn Walford Young respectively.

Subsequent political agreements during the 18th century (including the Treaty of Versailles (1783) and the Convention of London (1786)) enshrined the rights of British subjects to cut logwood within Spanish territory. However, neither the settlers nor the British ever fully recognised Spain's authority and, in 1798, the 'Baymen' defeated the Spanish at the Battle of St George's Caye. After this substantial victory the settlement was increasingly under British rule (Thompson, 2004).

The population that had the closest interaction with the SDTF is the loggers, and these voices are relatively absent from current knowledge. These voices from the early 18th century are present in three published accounts (Dampier, 1699; Uring, 1726; Atkins, 1735) and form an important part of the discussion surrounding the production of logwood in Chapter Six (Section 6.1). However, there are no sources from the 17th century and little information concerning the experiences of the mahogany cutters. These voices have been searched for extensively in the archives consulted (see Tables 3.1 and 3.2) however they could be retained in archives such as The Commonwealth Archives, Marlborough House, London, which were not consulted and remain an area for future work.

2.3.4 Colonial contexts: an overview of British Governance of Belize, AD 1786 – 1981

The first Superintendent of British Honduras, Edward Marcus Despard, arrived at Belize River in June 1786, but by 1790 he had returned to London in failure, unable to mediate between the demands of old settlers and those newly arrived from the Mosquito Shore, and also unable to cultivate positive relationships with the neighbouring Spanish. Colonel Peter Hunter was sent as a temporary replacement in 1790 and he put in place twelve elected magistrates to rule after his departure in 1791. This elected body ruled for the next five years (Thompson, 2004). After the Spanish declaration of war against Britain, Colonel Thomas Barrow arrived in 1796 to prepare the defence of the settlement as its Superintendent. The central battle of St George's Cay (1798) saw the British navy defeat the Spanish, and a Spanish retreat. The 1808 Napoleonic War saw Britain and Spain on the same side; and, in 1815, the Spanish lost control of their Central American territory and any remaining interest in British Honduras (Twigg, 2006).

The first Superintendent to leave a lasting impact upon British Honduras was Lieutenant Colonel George Arthur (1814 - 1822). Lester (2012) describes Arthur's reluctance to accept the 'less than glamorous' posting to British Honduras, with the modest settlement comprising '150 British settlers, mostly mahogany cutters and merchants, 900 'free blacks' and 3,000 enslaved people' (p.1475). British Honduras remained a settlement, not a British colony, tolerated on Spanish colonial territory (Lester, 2012). A central proclamation by Arthur in 1815 was that all unclaimed land was British Crown land, and as such could only be allocated by the Crown (Twigg, 2006). All

claimed land had to be registered within six months; this proclamation was partly in response to the substantial expansion of wood cutting, extending as far as the extreme south of the country (Twigg, 2006). The 1816 census lists the population of the settlement at just under four thousand (Thompson, 2004).

Following a trip to the inland region in 1820, during which Arthur witnessed the cruel treatment of slaves by their settler owners; Arthur vigorously promoted the rights of the enslaved in British Honduras which Lester (2012) suggests was promoted by Arthur's Christian faith. Arthur's other key contribution to the colony was to draw power away from a few established settler families and place it in the office of the Superintendent (Setzekorn, 1981). By the end of Arthur's posting in British Honduras he had successfully petitioned the Colonial Office to apply Jamaican law to the settlement, so 'that enslaved people had some protection from the arbitrary punishment of masters, and the freeing of descendants of Mosquito Coast Indians who had been enslaved illegally by settler parties' (Lester, 2012, p.1475 - 1476).

Belize only officially became a Colony of the United Kingdom in 1862, with oversight provided by a Lieutenant-Governor who reported to the Governor of Jamaica. It was finally made a fully fledged Crown Colony, with its own Governor in 1871. A possible by-product of these political developments was increased British investment in infrastructure in the north of Belize during the mid 19th century. In the 1860s at Lamanai a British firm, Hyde Hodge and Co. invested in sugar plantation complete with sugar mill and Chinese indentured labour (Pendergast, 1982a; Mayfield, 2009) (Fig.2.9).

Figure 2.10 is a British map of Belize City made in 1872 which demonstrates the extent of the settlement in the early period as a recognised Crown Colony, with the town lying between the Caribbean sea to the east and undrained swamp and marsh land to the west. In 1897, a treaty between Mexico and Britain, originally made in 1893, which had firmly established and agreed borders, was ratified. This gave 'both Mexican recognition of British sovereignty and final settlement of the northern and north western borders of what is now Belize' (Thompson, 2004, p.96). British Honduras adopted the name 'Belize' in 1873 and in 1981 the nation became a fully independent state (Twigg, 2006), remaining part of the British Commonwealth of Nations.

Figure 2.9 British sugar mill (c. 1866) at Lamanai (Photos: Rushton, 2010)

Figure 2.10 'A Plan of Belize, British Honduras', 1872 (Royal Geographical Society with IBG, mr_Belize_G.8 (1872))

i) The market for mahogany: a geopolitical context

In the early 18th century, mahogany was illegally cut alongside logwood in accessible coastal areas close to the rivers of northern Belize. Bridgewater (2012) suggests that the earliest logging areas were around the Belize River, with the Treaty of Versailles paving the way for the first formal resolutions concerning the price, extent and demarcation of mahogany works and gangs (Hooper, 1886). The Convention of London, which appointed a resident British Superintendent to govern the settlement, also released further land for extraction around the Sibun and New Rivers (Bridgewater, 2012). From 1805, it was declared that no Spaniard might cut wood in the colony and from this point the British settlements may be considered a colony in all but name, and not subject to formal Spanish rule (Hooper, 1886). The arboreal resources of the Belizean forests were however, being felled and exported more than 150 years before Belize was a British Crown Colony.

By the middle of the 18th century, mahogany was in common use in Great Britain and was the favoured wood of master furniture craftsmen, including Chippendale and Hepplewhite. Furniture makers found the beautiful colour, stability, and figuring of this timber ideal for their work and provided an insatiable demand, laying the foundations of the mahogany trade between Belize and Britain (Pennington, 2002) which would continue until c. 1930. Initially, Jamaica was an important supplier but, by the end of the 18th century, its supplies were exhausted and Britain began to look to other countries for a ready supply (Bulmer-Thomas and Bulmer-Thomas, 2012). Towards the end of the 18th and early 19th centuries, mahogany began to be used in other industries, including ship building, and began to appear in a variety of contexts including churches (where it was used to build pulpits, pews and altars), office doors and tables, concert hall pianos, and scientific instruments. From the mid-19th century onwards, it was also used in the construction of railway carriages and coaches (Bulmer-Thomas and Bulmer-Thomas, 2012). The importance of the mahogany tree to the Belizean people is memorialised in their national moto ‘Sub Umbra Floreo’ or ‘Under the shade I flourish’ - which is incorporated into the national coat of arms, adopted on 28th January 1907. The coat of arms features a mahogany tree in the centre with a woodsman on either side, surrounded by a ring of fifty mahogany leaves. The national flag, first unveiled on 21st September 1981, has this coat of arms in its centre (Fig. 2.11). Section 6.2 explores further the specific nature of the extraction, production and trade in mahogany, reconstructing different phases of extraction using documentary sources outlined in section 3.2.

Figure 2.11 The Belize national flag (Photo:www.mapsoftheworld.com, 2013)

2.3.5 The development of Christianity in Belize

As will be shown in detail in section 3.2, Christian missionaries and clergy provided the most temporally extensive and voluminous record of 19th century Belize. Indeed, Spanish Roman Catholic Friars were perhaps the first Europeans to visit Lamanai (Graham, 2011). As such, it is important to document both the development of Christianity in Belize and explore the linkages between 19th century British governance of Belize and Christian missionary expansion. This provides the context for both the production of a significant majority of the documentary sources (section 3.2) but also gives insight into the relationships between missionaries and the British populations working across northern Belize, predominantly in the timber industry (Chapter 6) and the engagement the British missionaries both observed and experienced with the tropical realm (Chapter 7).

Roman Catholicism accompanied the spread of the Spanish across Belize in the 16th century (Jones, 1989), and this has been outlined in part b of section 2.2.2. Graham (2011) has suggested that the Maya remained Christian until after 1700 even when Spanish control had waned, although this may have been a decision made by the indigenous population based upon economics, in order to continue to benefit from colonial trade routes. During the 17th and 18th centuries, no known substantial stone European style Christian churches were constructed; however, it is highly likely that both Catholic and Anglican (or Church of England) wooden structures were built and used throughout this period.

i) 19th century British governance and Christian expansion in Belize

The expansion of British missionary activity in 19th century Belize grew with the expansion of British governance, and this matched the growth of missionary activity across the British global empire (Bebbington, 1989) and it is from this period that the vast majority of missionary documentary sources date from (see sections 3.2 and 7.1). The first known Anglican Church building was consecrated in 1812, although the mission must have begun prior to the construction of this substantial building. Bristowe (1894) reports that, unusually for the time, the church (dedicated to St John the Evangelist), was a brick building with a bell tower and a capacity of 450 people. It is a remarkable achievement for the then insubstantial European population to fund such an expensive project; unfortunately no records or accounts survive to show the contribution (if any) made by the Church of England. A second, more modest, wooden church (dedicated to St Mary the Virgin) was erected in 1851 to serve the growing population (Bristowe, 1894). Bristowe (1894) suggested that it was only in the latter part of the nineteenth century (from c. 1875) that the Anglican influence was felt in the colony, with a new building constructed for St Mary's in 1882 and, in 1888, work formally extended to the Northern district, with simple wooden, thatched roof churches built in Orange Walk and Corozal (Bristowe, 1894). The slow development of the Church of England in Belize may have been caused in part by the relative isolation of Belize from other Anglican communities, the nearest of which was Jamaica, some 1500 km and five days travel away. Bristowe (1894) reports that after a public meeting in 1850, the need for a Presbyterian Church of Scotland to serve the population in Belize was established and 'a lot was acquired north of the courthouse on River Belize and a temporary building was erected. In January 1852, Revd Arthur from Stewarton, Scotland, arrived to take charge of the Kirk' (Bristowe, 1894 p.165).

ii) 19th century British missionary expansion in Belize

In the first thirty years of the nineteenth century, British missionaries were much engaged with the African populations enslaved on British Caribbean colonies, with multiple missions established in Jamaica and Barbados by 1824 and coverage across the West Indies increasing until the mid-nineteenth century (Porter, 2004). The Wesleyan Methodist Missionary society (WMMS) (later the Methodist Missionary Society or MMS) alone sent 722 missionaries to the West Indies during 1826-1906, with an average term of 9.4 years; of these, 205 died in service in the West Indies.

Ministering to the slave populations in the British greater Caribbean was not without its difficulties, with many slave owners viewing missionaries as agents of the anti-slavery movement, who would stir up their slaves in a revolt against them. Indeed, the missionary societies themselves were eager to distance themselves and their agents from the abolition movement and clearly instructed them not to engage in political disputes. In Clause VII of Instructions

to Missionaries, published in the Annual Report of the Wesleyan Methodist Missionary Society, 1816, missionaries were cautioned of the specific problems of working in the West Indies:

> 'Those of you who are appointed to the West-India Colonies, being placed in stations of considerable delicacy, and which require, from the state of the society there, peculiar circumspection and prudence on the one hand, and zeal, diligence, and patient perseverance, on the other…your only business is to promote the moral and religious improvement of the slaves to whom you have access, without in the least degree, in public or private, interfering with their civil condition…The Committee caution you against engaging in any of the civil disputes or local politics of the Colony to which you may be appointed, either verbally, or by correspondence with any person at home, or in the Colonies.'[8]

The early nineteenth century Christian missionary endeavour in the Caribbean was entirely dependent on the goodwill of the plantation owners and overseers (Porter, 2004). Missionaries often faced arrest and imprisonment, and were accused of encouraging and even organising slave rebellions, perhaps the most notable of which is the Baptist Missionary Society (BMS) missionaries involvement in the Great Slave Rebellion 1831 - 2 (Short, 1976). The WMMS regulations of 1816 gave clear instructions to missionaries as to how they should behave if they were accused of involvement in social disorder by plantation owners:

> 'In cases of opposition to your ministry, which may arise on the part of individuals, or of any of the Colonial Legislatures, a meek and patient spirit and conduct are recommended to you. You will in particular guard against all angry and resentful speeches, and in no case attempt to inflame your Societies and hearers with resentment against your prosecutors and opposers. Your business, in such cases, after every prudent means of obtaining relief has failed in your own hands, is with the Committee at home; who will immediately take such steps as may secure to you that protection, from a mild and tolerant Government, which they hope your peaceable and pious conduct, your labours and successes, will ever merit for you.'[9]

This clear understanding by the WMMS in 1816 that missionaries in the West Indies might encounter opposition and even persecution suggests that any substantial missionary expansion in Belize prior to emancipation (1834) may well have required governmental support. Between May 1820 and March 1822, the then Superintendent of Belize, Lieutenant-Colonel George Arthur (see 2.3.4), wrote eight letters to the Secretary of the Colonial Office of the British Government, Earl Barthurst, documenting the condition and treatment of slaves both domestic and those working in the Belizean logging industry. Throughout these letters (now housed in Lambeth Palace Library), Arthur documents cases of ill treatment of slaves by their British owners, and calls for compassionate treatment of slaves to be more widespread (these slaves were, in the vast majority of cases, employed in the logging industry and the

[8] MMS_Annual Report_1816_.p12
[9] SOAS_WMMS_AR_1816

role of logwood and mahogany extraction in changing the nature of the Belizean landscape is considered in Chapter 6). These accounts mark a substantive shift in Arthur's attitude towards slavery which is a direct result of his own personal encounter with the slaves and their conditions during his travels to the logging regions of the Northern District in 1820, and his subsequent religious awakening (Lester, 2012).

Arthur's active interest in the welfare of the slave population resident in his colony is reflected in the earliest known accounts of British Missionary activity in Belize; a causative link, between this missionary expansion and Arthur's personal and direct encouragement of their mission to the slave population, merits consideration. In September 1819, Henry Moore, a representative of the Church Missionary Society (CMS), left Liverpool bound for British Honduras. After a prolonged stay in Jamaica due to an outbreak of Yellow Fever, Moore arrived at Belize City on 25th January 1820. In a letter dated 2nd August 1821, Moore states that 'Colonel Arthur still proves a zealous and steady friend of the Christian cause among us'.[10] In a further letter dated 27th September 1821, he recounts two cases of cruelty against slaves by their British owners and repeatedly asks that this be made known to the British public, 'that they might become better acquainted with the dark parts of the earth that are full of the habitations of cruelty'.[11] Moore returned to Britain in 1825, ending the involvement of the CMS in Belize.

At least four further Missionary Societies sent agents to Belize during the early 19th century. The BMS was established in 1792, largely at the instigation of the Northamptonshire Baptist Association. It was the first Protestant society to be founded specifically for the purpose of overseas mission and its earliest mission was that founded in 1793 by William Carey (1761 - 1834), Joshua Marshman (1768 - 1837) and William Ward (1769 - 1823) in Serampore, Bengal (now West Bengal, India), (Stanley, 1992). During the nineteenth century it established missions in the West Indies, the first in Jamaica (1813) and played an active part in the abolition of slavery. Ten missionaries were sent to Belize during 1822 - 1844, the first of whom, Mr Bourn, arrived in June 1822. Bristowe (1892) suggests that the leading merchants of the day were responsible for extending this invitation:

> 'Sometime about the year 1820, certain merchants of this town Messrs Angus and Co. interested themselves in the spread of the Gospel, and called the attention of several of the then existing missionary societies to British Honduras and the Mosquito Shore. As a result of these appeals the Baptist Missionary Society determined to send a missionary to this colony' (p. 168).

The Society for the Propagation of the Gospel (SPG) had agents working in Belize, mainly distributing Bibles and Christian materials during the 1880s to 1930s. The most temporally extensive and numerically substantive involvement in Belize came from the WMMS. The Wesleyan missions 'among the heathen' began in 1786, when Thomas Coke, destined for Nova Scotia,

[10] UBSC_CMS_CW_059_1
[11] UBSC_CMS_CW_059_3

was driven off course by a storm and landed at Antigua in the British West Indies. There he developed a successful mission of both slaves and landowners. Within a few years almost every colony in the West Indies had been reached. Throughout the 19th century, the WMMS sent missionaries to West Africa, Australia, New Zealand, China and the West Indies, with approximately 50 agents sent to Belize during 1826 - 1906.

Endfield and Nash (2005) have sought to situate the role of missionary women and their collection and dissemination of geographical knowledge within the wider contribution of white women to the production of such knowledge, during an age of empire (Mills, 1991; Bell, 1993; Blunt, 1994; Blunt and Rose, 1994; McEwan, 1996). Bell (1995) has highlighted how physical differences between men and women drove the assessment of women as 'the weaker sex' (p.142). Such 'weakness' encompassed physical and mental inferiority, which led to a higher risk of moral, mental and physical deterioration in the tropics (Bell, 1991; 1993). Theories of acclimatisation (see section 2.2.2) determined that women and children were particularly vulnerable to constitutional degradation in tropical environments, and these concerns led some missionary societies to delay considering female missionaries for work abroad until the late 19th century (Endfield and Nash, 2005) (see sections 7.1 and 7.2).

Within the WMMS, work formally organised by women began relatively early, in 1858, with the establishment of 'The Ladies Committee' as part of the 'Women's work of the WMMS'. Initially, support of missionary wives and education were their chief concerns, with attempts made to improve existing schools, found new ones, and train teachers to staff them. Endfield and Nash (2005) have suggested that such 'women's work' became a central part of British missionary societies during the latter part of the 19th century, which mirrored 'a more general process of female professionalization in metropolitan Victorian society' (p.372). As The Ladies Committee of the WMMS expanded it embraced other work, with the most significant aspect being medical work, which flourished during the 1880s and 90s. This medical focus was reflected in the change of name to the 'Women's Auxiliary of the WMMS' in 1928 (Martin, 2003). An annual report of the Ladies Committee, dated 1881, stated that the Committee was established to 'become a centre for the isolated efforts of Christian ladies, and of small associations of ladies who had long been helping individual Missionaries and their wives'. Susannah Gooding Beale, the first such missionary sent out by this committee, was appointed as Headmistress of the Girls School, Belize City, in 1859. The regulations for the Ladies Committee, set out in an annual report of 1860, stated that all women selected as missionaries had to produce a medical certificate to ensure their 'fitness for a foreign climate.' This concern for the constitutional status of missionaries deployed to the perilous tropics was prevalent amongst nineteenth-century missionary societies (Endfield and Nash, 2005). Women employed by the WMMS had to agree to a minimum three year term and remain unmarried; if they wished to end their association with the Missionary Society prior to the agreed term, or indeed to marry, they had to give the Society a minimum of six months notice or incur financial penalties. Again,

these terms of deployment were common within missionary societies and, in comparison to other organisations such as the London Missionary Society, were generous (Endfield and Nash, 2005).[12]

The role of missionaries in the colonial history of Belize is of particular significance as it is these societies that provide the individual and organisational documentary accounts (see section 3.2) that enable the reconstruction of the extraction of logwood and mahogany during the 18th, 19th and early 20th centuries (Chapter 6) and an exploration of British colonial interaction with tropical climates and ideas about health and place (Chapter 7).

2.4 Summary

This chapter has drawn on a wide variety of literature in order to contextualise an environmental history of Belize. The lake sediment derived proxies, in particular the palaeoecological proxies, record a context for the 3,500 year vegetation history of Lamanai, the 'material' environmental history (Fig.1.6) presented in Chapter 4. The archaeological and historical contexts, and the discussion of some of the cultural narratives apparent in research concerning the land-use of the pre-Columbian Americas, provide the anthropogenic and political context for a palaeoecological reconstruction. The geo-political history of the development of Belize, from Maya polities to modern day independent Commonwealth nation, informs the record of timber extraction for export since the 17th century (Chapter 6).

An understanding of Belize's colonial past is important when considering the genesis of all documentary records emanating from a period of British governance, including the meteorological records presented in Chapter 5 (material environmental history) and the export records reconstructed in Chapter 6 (political environmental history). Similarly, an understanding of the history of Christian missionary engagement with Belize, as part of 19th century global missionary expansion, is necessary to appreciate the motivation and cultural context of the accounts presented in Chapter 7 (cultural or intellectual environmental history). As a nation of the neo-tropics, Belize is part of a region historically viewed as unhealthy, owing to its tropical climate. The narratives surrounding tropicality and health inform both the 19th century narrative missionary accounts (Chapter 7), but also provide an important context to the more discursive elements of the meteorological record documented in Chapter 5.

This diversity of approaches and contexts demonstrates the opportunity for the multi-disciplinary methodological approach utilised in this research. Although there have been recent studies of the palaeolimnological, palaeoecological,

[12] Endfield and Nash (2005) report that female candidates working for the LMS in the 19th century had to formally agree in writing to remain unmarried for the first five years of their contract, or to reimburse the LMS the expenses provided for their training, salary and transport to the mission field (p.372).

economic and cultural of history of northern Belize (some emanating directly from Lamanai), no work has sought to integrate a range of histories derived from sedimentary, archaeological and archival sources. In a recent environmental history of Latin America (Miller, 2007) which explores the relationship between tropical nature and human culture, Belize does not feature. This research seeks to directly address this absence, by drawing together diverse material to produce the first integrated environmental history of northern Belize.

Chapter Three

Principles, materials and methods of an environmental history of northern Belize

3.0 Introduction

The interdisciplinary nature of environmental history offers rich opportunities to explore the relationships between humankind and the environment it inhabits over time. As has been demonstrated in Figure 1.2 environmental histories draw together information that explores change at a range of spatial, temporal and societal scales. This approach enables the comparision of different phases of landscape changes and the consideration of the possible drivers of change. This approach can help us explore which land-use practices have had the longest lasting impact upon different ecosystems and how resilient forests are to varied phases of land-use. This chapter outlines the methodological principles and approaches used in this research. The 'material' component of this integrated environmental history of Belize (Fig.1.2) is a sedimentary record from the New River Lagoon, northern Belize (Fig.1.5) which reconstructs past vegetation using pollen and charcoal records, over the last 3,500 years. The 'political' and 'cultural/ intellectual' aspects of this Belizean environmental history (Fig.1.2) are reconstructed using a variety of documentary archival sources. British colonial records provide the majority of records which enable the exploration of the effects of human economic, political and social activities upon the environment of northern Belize. British missionary and administrative records provide insight as to thoughts and feelings the predominantly British colonial population had about Belize during the 18th, 19th and early 20th centuries. Documentary archival sources have enabled the reconstruction of temperature and precipitation records for Belize City during the mid 19th century until the mid/ late 20th century. Although this is a component of 'material' environmental history, the reconstruction of temperature and precipitation has been considered in the second section of Chapter 3 that considers the archival records since it is entirely derived from documentary sources. The palaeoecological principles, materials and methods are considered first, and are followed by the archival approaches.

3.1 Palaeoecological principles, materials and methods

This section outlines the principles and methods of palaeoecological reconstruction, with particular reference to pollen and charcoal analysis. Secondly, the methods of each of the different analysis techniques performed on the sediment are documented. The results of these analyses are presented in Chapter 4.

3.1.1 Sediment collection and sampling

This study draws on two cores extracted from the New River Lagoon, at the end of a jetty adjacent to Lamanai in a water depth of approximately 2 m, and in both cases material was stored at 4˚C.The first core measured 319 cm and was extracted in 1999 using a square-rod modified Livingstone piston corer and was shipped to the UK in plastic piping. This core was previously examined by Metcalfe et al. (2009), as part of a study of environmental change since the latest Pleistocene using diatom and stable isotopes (supported by mineralogical and major elemental data). Twenty-five samples for pollen and charcoal analyses from each of the stratigraphic sub-sections (described shortly after the core was extracted) were sampled as part of the Masters dissertation of Rushton (2010). This study was enhanced in 2011 as part of this doctoral thesis. Eight further samples were analysed for pollen and charcoal to complete a sampling strategy of a sample every 10 cm. All 33 sample points were re-analysed using an improved methodology (Whitney et al. 2012) developed during trials undertaken in 2011 – 2012; this is outlined in the methodology section below, and a detailed preparation protocol can be found in Appendix I.

A second core of ‘core-top’ semi–liquid sediments, containing the sediment-water interface, and measuring 52 cm was extracted in 2010, from the same location and water depth using a 5 cm diameter Perspex® tube Glew corer to retrieve the sediment-water interface intact. Samples were extruded in the field and were shipped in sealed plastic bags. Samples for pollen, charcoal and LOI analysis were taken at 1 cm intervals. The top 1 cm surface sediment from the Glew core was analysed for comparison with the modern vegetation.

3.1.2 Chronology

In order that the results of this investigation can be put into a meaningful context, the sediments need to be dated. This research benefits from the chronology established by Metcalfe et al. (2009) for the Lamanai 1999 core (these results are reported in detail in section 4.1). Here the dating methods used are considered in terms of their methods and limitations.

i) Radiocarbon dating

Radiometric dating techniques are based on the time dependent radioactive decay which unstable isotopes undergo. Radiocarbon dating was one of the earliest radiometric techniques to be developed (Libby, 1955). ^{14}C is the radioactive isotope of carbon and eventually decays to the stable element ^{14}N. ^{14}C atoms are rapidly oxidised to carbon dioxide and along with $^{12}CO_2$ become mixed throughout the atmosphere and are stored in the atmosphere,

biosphere and hydrosphere (Lowe and Walker, 1997). The activity of ^{14}C is halved every 5730 ± 40 years (Goodwin, 1962), a revision of Libby's (1955) estimate of 5568 ± 30. As a large number of dates had been published using the original estimate an internationally agreed constant was established at 5570 ± 30 years (Mock, 1986).

ii) Issues of dating in limestone geology

A large proportion of northern Belize is underlain by limestone and thus the introduction of ^{14}C deficient carbon into the reservoir of dissolved inorganic carbon in surface and ground-waters is a key issue (Leyden et al., 1998). When ^{14}C deficient carbon is incorporated into the carbonate shells of aquatic organisms this causes erroneously old radiocarbon ages. This phenomenon is known as the 'hard-water effect' (Deevey and Stuiver, 1964). Terrestrial organic matter is free from this influence as it is in isotopic equilibrium with the atmosphere, and care was taken to identify terrestrial leaves and twigs in the core material. Such terrestrial matter was abundant in the Lamanai II 2010 core but was sparse in the Lamanai I 1999 cores.

A strategy which has been used to overcome the lack of terrestrial organic matter in other studies undertaken in Central America is the dating of gastropod shells. Curtis et al. (1996) dated both terrestrial wood and aquatic gastropod species from Punta Laguna, Mexico, and demonstrated that the dates obtained from the shells were consistently older by 1200 - 1300 years. This correction factor was then applied to the other gastropod dates as it was believed to represent the hard-water error in the system. Similarly, Hodell et al. (1995) found dates obtained from aquatic gastropods from Lake Chichancanab, Mexico, were 1200 years older than those obtained from terrestrial organic material. Using paired dates on gastropod and organic material from the Lamanai I 1999 core Metcalfe et al. (2009) established a 'hard water error' correction of 1660 years. To summarise, two strategies have been employed in the literature with regard to the correction factor applied to gastropod dates:

1) Paired dates (i.e. terrestrial organic matter and a gastropod from the same level) can be obtained and the difference between the two dates can be regarded as the hard-water error.
2) Where it is not possible for dates to be obtained from both media at the same depth, results from each can be plotted separately and the difference between the two gradients can then be used as the correction factor to be applied to the gastropod dates.

iii) Issues of calibrating radiocarbon dates

A crucial aspect of radiocarbon dating is the calibration of results using internationally recognised calibration curves (e.g. OXCal Ramsey, 2009; CALIB Reimer et al., 2009) which allows for the correction of factors which might affect the concentration of ^{14}C. Calibrated radiocarbon dates are not central dates with an error term, they are a range or ranges of dates which give only an approximate age. This is important to consider when comparing different kinds of sources, calibrated radiocarbon dates can give an indication of age in terms of centuries which does not offer resolution in terms of a human life span in the same way that documentary sources, dated to within a single day can provide. These differences in prescision are important to consider, when attempting to bring together information from both sedimentary and documentary sources. Of particular concern is the possibility of accurate and precise dating of material from the last two centuries and in particular since AD 1950. Burning large amounts of fossil fuels has reduced the radiocarbon concentration of the atmospheric carbon reservoir (called 'The Suess effect') and the testing of nuclear weapons in the 1950s and 1960s has had the opposite effect, dramatically increasing the amount of ^{14}C in the atmosphere (called 'The Bomb effect' (Bowman, 1990). Both of these anthropogencially driven changes to the amount of atmospheric carbon significantly reduced the ability to measure age accurately using radiocarbon dating from the recent past, even with the use of calibration curves and further emphases the challenges of research which seeks to use both sedimentary and documentary proxies.

iv) AMS radiocarbon dating methodology

When the Lamanai 2010 core was sampled any material which was thought to be suitable for radiocarbon dating was removed and placed in a darkened petri dish and stored in the cold store in the laboratory at the School of Geography, University of Nottingham. Undamaged terrestrial leaves and young twigs (rather than bark) were identified for radiocarbon dating as these would be least likely to be affected by 'old wood effect'. When a sample is used from the heart-wood of a long-lived tree species, this may be centuries old before it was felled. In addition, wood may remain in the system for a number of years before it is deposited, which may also artificially increase the radiocarbon date (Bowman, 1990). Conversely, bioturbation and secondary deposition can re-work more recently deposited leaf and twig material, resulting in an artificially young radiocarbon age (Bowman, 1990). To limit this source of possible error, samples for dating were obtained from the second unit of the Lamanai II 2010 which contained more consolidated sediment, and a third sample was taken from the top of the core to confirm whether the top was indeed modern.

Samples for radiocarbon dating were analysed by both BETA Analytic (Beta-339605) and at the NERC Radiocarbon Facility (SUERC-43153; SUERC-43156; SUERC-43157). All samples followed a standard pre-treatment as

documented in the reports of D.Hood (Beta Analytic) and C.Bryant (NERC Radiocarbon Facility, Allocation Number 1624.0312). The samples were dispersed in deionized water before being digested in 2 M HCl at 80˚C for eight hours. Samples were washed free from mineral acid with deionized water and then dried and homogenised. The total carbon in a known weight of the pre-treatment was recovered as CO_2 by heating with CuO in a sealed quartz tube. The gas was converted to graphite by Fe/Zn reduction. The results of these radiocarbon analyses are presented in Chapter 4.

3.1.3 Loss-on-ignition

The organic and carbonate content of the samples were estimated by the process of loss-on-ignition (LOI), a widely adopted method based on differential thermal analysis. Organic matter begins to ignite at about 200˚C and is completely combusted at about 550˚C (Dean, 1974). Most carbonate minerals are destroyed at higher temperatures (e.g. calcite between 800 and 850˚C, Santisteban et al., 2004). The method used in this research follows that of Dean (1974) and Bengtsson and Enell (1986), as outlined below. All samples were sub-sampled to obtain a wet mass of 2 g, which were then oven-dried at 150˚C for 12 hours and weighed before and after drying (all masses were measured to an accuracy of ± 1 mg) to calculate the moisture content. Once dry, samples were burned in porcelain crucibles at 550˚C for five hours, causing organic matter to oxidise to carbon dioxide and ash. After cooling, each sample was weighed to deduce the organic content. The proportion of carbon in the organic matter can be estimated by using a conversion factor. Organic matter is commonly assumed to contain 40 - 60% carbon (Bengtsson and Enell, 1986) however, the choice of conversion factor depends on the nature of the material analysed (Hesse, 1971) and an accurate value is yet to be determined. For this reason, and also because an accurate estimate of carbon content is not essential for the aims of this research, no conversion factor was used. The samples were returned to the furnace at 925˚C for two hours and then reweighed to determine the carbonate content. At this temperature carbonate is removed and the remaining material is referred to as the residue and consists of the non-carbonate inorganic fraction. The estimates of the carbonate content using this method provide an approximation. Moisture content, LOI and carbonate content were calculated and expressed as percentages.

3.1.4 Palynological analysis

Palynology is the study of pollen grains and spores, and is concerned with both their structure and formation and also with their dispersal and preservation under certain environmental conditions (Moore et al., 1991). Each cubic centimetre of sediment typically contains hundreds of thousands of pollen grains, which, in suitable conditions, retain their original shape and

structure. Faegri and Iversen (1989) have described the three central elements of a pollen grain:

1) The living cell in the central part of the grain;
2) The intine, which is a cellulose layer surrounding the living cell, neither of which survive in the fossil form;
3) The exine, which is a resistant outer wall made of sporopollenin designed to protect the gamete from oxidation and microbial attack (Moore et al., 1991). This is the only part of the pollen that can survive in fossil form.

Pollen analysis is one of the most common methods used to investigate past environments. Pollen grains and spores are widely dispersed as part of the plant reproductive cycle. The family, genus, and occasionally the species of the parent plant can be identified by examining the characteristic features of the pollen exine (Traverse, 1988). The pollen grains and spores are particularly well preserved in waterlogged locations such as lakes and bogs, and the progressive accumulation of sediment over time in these systems allows the extraction of a series of pollen assemblages from a core of sediment which reflects changes in the vegetation cover of the wider landscape over time (Moore et al., 1991). Reconstructing past vegetation using palaeoecological records is now considered, with a particular focus on pollen source area.

i) Reconstructing past vegetation using pollen analysis

The interpretation of the pollen record is based on the premise that the pollen assemblage provides an indication of the past vegetation assemblage, and that changes in past vegetation can be tracked therefore through time. This premise applies to the relative abundance of pollen types and relative abundance of past vegetation types. However, there are a number of factors that affect the relationship between the pollen and vegetation assemblage, and therefore their interpretation. Firstly, many pollen grains cannot be identified to species level, so different species of a family or genus that are present in the past vegetation assemblage may not be detected in the pollen assemblage. In the neo-tropical context, Gosling et al. (2009) have suggested that when there are insufficient morphological differences between grains such as Moraceae/Urticaceae, and Chenopodiaceae/Amaranthaceae, these families are grouped together. This inability to identify pollen beyond family level can have a significant impact in the interpretation of past vegetation assemblages. Moraceae is not only abundant in terms of species diversity (>1000 species), but is over-represented in sedimentary record (Burn and Mayle, 2008). The recent taxonomic key for the Moraceae family (Burn and Mayle, 2008) enables the identification in the Lamanai cores of SDTF species such as *Brosimum* type, *Maclura* type and *Ficus* as distinct from the general Moraceae/Urticaceae grouping which encompasses taxa that belong to a wide variety of vegetation types (Gosling et al., 2009). Similarly, Chenopodiaceae

and Amaranthaceae include taxa that are associated with both weedy varieties as well as edibles.

Secondly, when interpreting a pollen diagram in terms of the abundance of individual taxa, it must be considered that that pollen production, dispersal, transport and representation differs between taxa. As a consequence, some pollen types are known to be over or under-represented in the pollen assemblage compared to their actual abundance in the vegetation assemblage. Therefore, different levels of pollen production affect the interpretation of the pollen record by over or under-emphasising the role of particular taxa. In addition to the abundance of Moraceae (Burn and Mayle, 2008), *Pinus* is widely regarded as being over-represented in pollen diagrams as it has both high productivity and dispersal rates (Prentice, 1988). Bush (2002) suggests that interpretations of Poaceae in a tropical fossil record that do not consider possible changes in lake size, and assume that Poaceae percentage is a simple indicator of regional vegetation change, are likely to overstate transitions from forest to scrub environments.

Thirdly, the presence of pollen does not necessarily indicate that the taxa were growing in the local environment; it may have been deposited in the NRL after long-distance transport (by wind). Certain grains are more likely to be transported long distances due to their morphological characteristics e.g. *Pinus*. Conversely, pollen released closer to the ground surface e.g. from non-arboreal taxa, or large grains (>100 mµ) e.g. Arecaceae or *Zea*, are less likely to be transported long distances. Arboreal populations with low densities (e.g. 2 trees ha^{-1}) in the catchment may remain undetected by pollen analysis (Bennett, 1985). As a result of this, Bennett (1985) proposed that low intermittent frequencies of under-represented taxa before the onset of continuous values may indicate the local presence of small populations rather than long-distance transport.

To help determine the local presence of taxa, several criteria are employed in this research:

1) A taxon with a continuous percentage trend is interpreted as indicating a presence in the NRL catchment.
2) An under-represented taxon (e.g. Arecaceae) with a semi-continuous percentage trend is interpreted as indicating local presence in the NRL catchment.
3) A well-represented taxon's rise to sustained high percentage values (rational limit, Smith and Pilcher, 1973) is interpreted as indicating the expansion of that taxon.
4) An under-represented taxon's increase to continual presence in consecutive samples (empirical limit, Smith and Pilcher, 1973) is interpreted as indicating expansion.

However, in order to clearly distinguish changes in the palaeoecological record that derive from local *versus* regional vegetation, the pollen source area of the NRL must be established and this is now considered.

ii) Pollen source area

As has been demonstrated previously, pollen assemblages are used to infer changes in vegetation. However, translating these assemblages into quantitative estimates of vegetation is not a simple exercise, as the relationship between pollen abundance and plant abundance is complex. The pollen assemblage is dependent upon a number of factors including:

- The composition and abundance of the vegetation assemblage;
- The amount of pollen produced by the parent plant;
- The transport potential of individual taxon;
- The preservation potential of the individual taxon;
- The sedimentary conditions at and after the time of deposition.

Over the last fifty years an algebraic linear model (commonly known as the Prentice-Sugita model) has been developed, to model the relationship between pollen assemblages and producing vegetation, and used to estimate vegetation cover (e.g. Davis 1963; 2000, Andersen 1970; 1973, Prentice 1985; 1988, Sugita 1993; 1994, Jackson, 1994). Prentice's (1985) model incorporates the relationship between basin size, pollen productivity and dispersal to pollen accumulation, to estimate the pollen source area of individual taxa. Prentice's model assumes homogeneous vegetation, whereas Sugita (1994) proposed the 'Relevant Source Area of Pollen' (RSAP) and assumed spatial heterogeneity. The RSAP was defined as the distance at which the goodness-of-fit of the linear modelled pollen-vegetation relationship and the observed pollen-vegetation relationship does not improve (Sugita, 1994). The difference in pollen abundance from similarly sized sites is therefore a factor of plant abundance within the RSAP, which is overlain on a constant pollen background coming from beyond the RSAP (Sugita, 1994; 2007). Landscape spatial heterogeneity and patchiness strongly influences the RSAP, so estimating values for the past is difficult (Bunting et al., 2004; Broström et al., 2005; Hellman et al., 2009; Bunting et al., 2013).

Pollen source area differs with site size (Tauber, 1967; Jacobson and Bradshaw, 1981); large sites of several kilometres in diameter are dominated by regional pollen, as the influence of local pollen from around the site becomes increasingly weaker as site radius increases (Sugita, 1993). Sugita (1993) has demonstrated that much of the research on pollen source area has been based on small sites (radius <1.5 km) and is not applicable to larger sites. In the REVEALS model, Sugita (2007) refined understanding of the relationship between lake size and pollen source area. Large lakes which record a regional pollen signal were defined as having an area of >100 - 500 ha. The pollen source area of the NRL is of regional extent. The NRL is a long narrow water body (23 km long and <1 km wide) and has an area of 1,355 ha (13.5 km^2) (Fig.2.1). In terms of pollen source, lakes are classified by their

radius (Sugita, 1993) and surface area (Sugita, 2007). The width of the NRL is well within the 'small lake' classification (<1.5 km), however the total surface area is well above the 'large lake threshold (Sugita, 2007). Given the extensive surface area of the NRL the site can be considered as providing a signal of regional vegetation change.

Before pollen can be used for vegetation reconstructions, the material surrounding the pollen grain must first be removed, and this preparation procedure is now outlined.

iii) Preparation procedure

The process used to prepare sediment for pollen analysis removes carbonates, humic colloids, cellulose and silica contained in sediments in order to concentrate the pollen grains and spores to a level practical for microscopic analysis. Table 1 in Appendix I outlines the preparation process for all pollen samples (85 in total). Prior to chemical digestion all samples were sieved at 250 µm to remove larger shells present (sometimes abundantly) in the sediment (Fig.4.1). A cold 10% HCl treatment was applied until the sample stopped effervescing to remove carbonates from the predominately calcareous sediments of the NRL. Standard chemical digestion protocols were used (Faegri and Iverson, 1989; Bennett and Willis, 2001) including hot 10% NaOH and acetolysis treatments. HF was not used on the samples, but instead hot Calgon® was used to remove clays, and the samples were repeatedly rinsed with distilled water until the supernatant was clear.

Whitney et al. (2012) have outlined the need for an improved methodology for the recovery of *Z. mays* and other large cultigens which does not require two sediment samples from a given stratigraphic horizon (e.g. Bowler and Hall, 1989), as this is both wasteful of sediment and time consuming. The methodology of Whitney et al. (2012) was developed using two sites from Central America, one of which was Lamanai, NRL, and sediment extracted in 2011 from the 1999 Lamanai core was used in this study. A summary of the methodology reported in detail by Whitney et al. (2012) is now described, as this preparation protocol was used on all pollen samples analysed (Fig.3.1). After the chemical digestion protocol outlined above was completed, samples were passed through a 53 µm aperture sieve to isolate maize and other large cultigens pollen, based on the minimum size of maize pollen in Mesoamerica determined by Holst et al. (2007) and *Cucurbita* sp., *Ipomoea batatas*, and *M. esculenta* (Herrera and Urrego, 1996). Preparations for sieving were begun by suspending the pellet of sediment in 10 ml of 10% NaOH, and heating in a boiling water bath for 5 min, stirring occasionally to disaggregate the sample. The sample was passed through a 53 µm sieve using deionized water, and all filtrate was concentrated by centrifuging and saved for the standard terrestrial pollen count. The residue of >53 µm grains was washed into a separate centrifuge tube and reserved for large pollen grain analysis. These separated 'fine' (filtrate) and 'coarse' (residue) fractions from the same sample were

initially scanned to ensure whether the sieving had been successful. Once this had been ascertained *Lycopodium* tablets (Stockmarr, 1971) were added to each tube containing the filtrate and residue and then both fractions were dehydrated in tertiary-butyl alcohol and mounted in silicone oil for analysis.

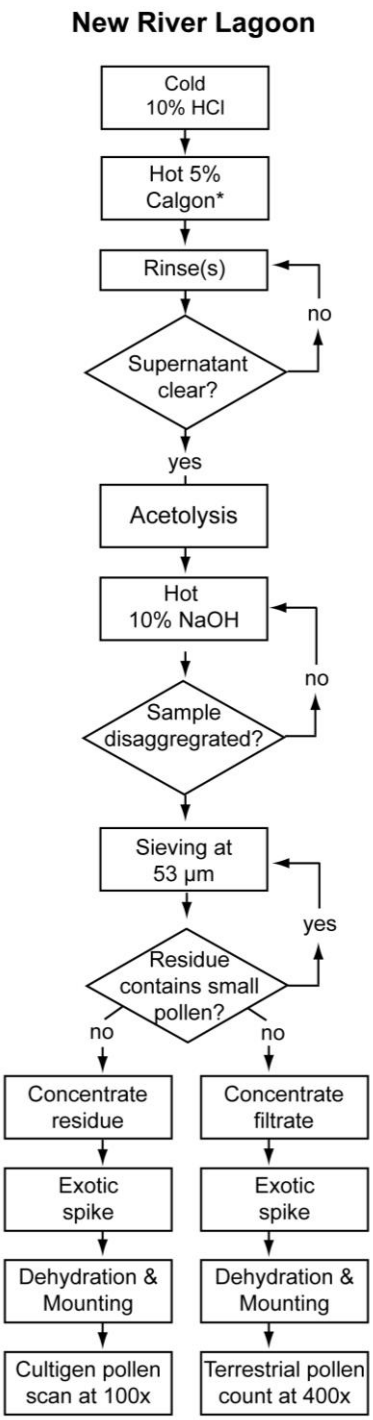

Figure 3.1 Flowchart of the pollen preparation method used for the Lamanai I (1999) and Lamanai II (2010) cores, incorporating the sieving stage (Whitney et al., 2012).

iv) *Pollen counting and identification*

Samples were counted using a Zeiss Axioscope photomicroscope at x100, x400 and x1000 magnification, and the 'coarse' and 'fine' fraction of each sample was counted separately using the two residues prepared using the methodology outlined above (Whitney et al., 2012). To relate the volume of sample analysed from the coarse fraction to that of the standard terrestrial pollen count, the number of *Lycopodium* spores found on the coarse fraction slide was expressed as a proportion of the *Lycopodium* count of the main pollen sum. For example, if 100 *Lycopodium* spores were encountered in the standard terrestrial pollen count and 1000 spores were counted on the coarse fraction slide, then the volume of material on the coarse fraction slide represents 10x the amount of sample analysed for the standard terrestrial pollen count (Whitney et al., 2012).

Pollen grains were, in the main, identified using the Central American pollen reference collection held in the School of Geography, University of Nottingham, and supplemented using the pollen reference collections held in the School of GeoSciences, University of Edinburgh and the Department of Geography, University of Leicester. Pollen atlases were also consulted, including those of Quintana Roo, Mexico (Palacios Chávez et al., 1991) and Barro Colorado Island, Panama, as well as digital images from the 'Neotropical Pollen Database' (Bush and Weng, 2007). Pollen grains were identified to the lowest taxonomic level possible, but broad categories or types were used when identification to genus or species level was not possible. Apart from three samples from the Lamanai I 1999 core where the pollen preservation restricted the main sum to 250 grains, a minimum of 300 and a maximum of 320 fossil terrestrial grains were counted: the main pollen sum is exclusive of unidentifiable damaged grains, aquatic taxa and fungal spores. Cyperaceae were included in the pollen sum because sedges comprise a large proportion of the herbaceous component of the adjacent savanna communities, as well as forming the marginal fringing semi-aquatic vegetation at NRL. Species of Rhizophoraceae (mangroves) are components of littoral forest in central Belize, however these were not included in the pollen sum, as the dominant vegetation formation in which Rhizophoraceae features, is the marginal fringing vegetation which surrounds the NRL.

Pollen taxa were separated according to ecological groups: seasonal forest, savanna, herb taxa, palms, crop taxa and aquatic taxa. Taxa were allocated to groups based on those identified from other pollen diagrams from the wider region including those from Belize (Jones, 1994; Pohl et al., 1996; Bhattacharya et al., 2011), Mexico (Leyden, 1998; 2002; Islebe and Sánchez, 2002; Carrillo-Bastos et al., 2010) and Guatemala (Islebe et al., 1996; Curtis et al., 1998). Chenopodiaceae and Amaranthaceae could not be distinguished and so were grouped together as Cheno/Ams in the pollen diagram. Leyden (1998) and Bush et al. (1992) both record biporate and triporate grains from the Urticaceae/Moraceae families as arboreal taxa and these families were

further differentiated with reference to Burn and Mayle (2008), enabling the identification of *Brosimum* type and *Maclura* type, and all other Moraceae/Urticaceae were classed as other 2 pore Moraceae/Urticaceae.

Palms (Arecaceae) have been described as economic taxa (Ford, 2008) that are 'selectively grown for their economic value particularly for use as thatch, and fruits' (Jones, 1994, p.209). As a group, palms have been presented separately from other agricultural crops. The occurrence of *Z. mays* pollen has been established as a key indicator of pre-Columbian agriculture in palaeoecological records throughout South and Central America (Bush et al., 1989, 2007; Northrop and Horn, 1996; Clement and Horn, 2001; Berrio et al., 2000, 2002; Piperno, 2006; Kennedy and Horn, 2008; Niemann and Behling, 2010). *Z. mays* was separated from other wild grasses using the criteria set out by Holst et al. (2007), and included analysis of the distribution of exine intertectile columnellae using phase contrast at 1000x magnification, however it was not possible to distinguish it from its ancestor Balsas teosinte (*Z. mays* subsp. *parviglumis*) (Matsuoka et al., 2002; van Heerwaarden et al., 2011) due to morphological similarities, particularly size (Holst et al., 2007; Piperno et al., 2009). However, teosinte is not native to Belize and as such it is likely that observed pollen grains morphologically consistent with *Zea* are domesticated *Z. mays*. Other food crops include squash (*Cucurbita*) and chilli pepper (*Capsicum*), although there are insufficient morphological studies to distinguish domesticated varieties from their wild relatives.

v) Palynological data presentation

Pollen counts were plotted using C2 software (Juggins, 2003) and were calculated as percentages of the main sum where: pollen percentage = raw pollen count/ (main sum x 100). The components of the main sum have been outlined in the section *pollen counting and identification*. Pollen percentages represent the relative contribution that each taxon makes to the main sum, and an assumption is made that this approximates the percentage composition of trees within the forest canopy. As vegetation changes, the percentage value of one taxon can increase, often at the expense of another. The interdependence of percentage values complicates the interpretation of pollen data; changes in the pollen diagram do not necessarily represent changes in absolute pollen abundance (Davis, 2000). A solution is to use pollen concentration data to determine whether the change in percentage is due to this problem of closure or due to actual ecological changes: an increase in percentage that is accompanied by an increase in concentration suggests a real change in pollen abundance. Conversely, a change in percentage data with no corresponding change in concentration indicates the change may be an artefact of percentage interdependence.

Pollen concentration, sometimes referred to as the absolute pollen abundance, is the number of grains per unit volume of sediment (grains per cm^{-3}) (Birks and Birks, 1980). Pollen concentration indicates the size of plant

populations and can be calculated using the exotic *Lycopodium* spores, of which a known quantity was added to a known volume of sediment (see section 3.1.4.). The ratio of *Lycopodium* spores to sediment volume allows the number of pollen grains of each taxon per cm^3 of sediment to be calculated, using its ratio to *Lycopodium* spores. Pollen concentration data avoids the problem of interdependency found in percentage data by displaying changes in the total number of pollen grains per unit volume of sediment. However, pollen concentration values can be affected by factors other than pollen influx changes, such as variations in sediment deposition rates causing artificial changes in pollen concentration, even when pollen influx remains steady in absolute terms.

In this research, data are presented as relative percentage abundance (Figs.4.4 – 4.7); pollen concentrations are also shown (Figs.4.6 and 4.7) to establish whether changes in pollen percentages are indeed reflections of the true changes in abundance. Rarefaction analysis has been undertaken separately on the samples from both cores, using Psimpoll 4.27 (Bennett, 2005) and plotted against time in each case (Figs. 4.4 and 4.5) and the value of this type of analysis is demonstrated in Chapter 4.

vi) Pollen zonation

Pollen diagrams (Figs.4.4 – 4.7) have traditionally been separated into smaller units, or zones – a series of neighbouring samples with similar pollen assemblages – to define periods of *quasi* uniform vegetation character for the purpose of description, correlation and comparison. Traditionally, sequences have been split into zones ‘by eye’, but the process is now commonly completed using numerical procedures which are rapid, repeatable and reduce the element of subjectivity. The basic principles were established by Gordon and Birks (1972) and Birks and Gordon (1985), and remain unchanged. The NRL cores have been split into zones by agglomeration using constrained incremental sum squares clustering developed by Grimm (1987) and has been commonly used as CONISS, implemented by the software Psimpoll 4.27 (Bennett, 2005). Only pollen grains comprising 1% in at least one point in the sediment core were included (this cut-off was not applied to crop pollen). This analysis identified four zones in the Lamanai I core (33 samples) and six zones in the Lamanai II core (52 samples), tending towards the suggestion of Bennett (1996) of the optimal number of zones being one tenth of the number of samples.

vii) Rarefaction analysis

Reconstructing temporal changes in ecological diversity through changes in the palynological profile is an important aspect of palaeoecology, as such diversity may result from historical processes, including anthropogenic activity and changing climate. Such changes in diversity or palynological richness cannot be investigated unless the pollen count (or main sum) of the samples is

standardised, as the number of pollen types found invariably increases as the pollen count size increases (Bottema, 1982). Rarefaction analysis is a statistical technique which provides this standardisation (Birks and Line, 1992); it produces unbiased estimates of the expected number of taxa (*t*) in a random sample of *n* individuals taken from a collection of *N* individuals containing *T* taxa (Birks and Line, 1992). The expected number of taxa ($E(T_n)$) must be based on a common value of *n*, conventionally 250, or as the lowest total count in the samples to be compared (Birks and Line, 1992; Bennett, 2007). In this research $n = 250$. Once pollen counts are standardised through rarefaction analysis, the number of taxa present in each sample is a measure of palynological richness or diversity of a pollen sample as demonstrated by Birks et al. (1988) and Birks and Line (1992). Bennett (2007) suggests that if the standardised count is kept constant between cores then it may be possible to compare palynological richness between multiple cores.

3.1.5 Charcoal analysis

Charcoal is a product of incomplete combustion of woody debris during fires and can be defined as an intermediate stage between vegetation debris and soot (total combustion) (Clark, 1984; Chabal et al., 1999). Charcoal is relatively resistant to chemical decomposition (Habib et al., 1994; Hart et al., 1994; Quenea et al., 2006); the level of microbial decomposition is also minimal, although it can increase when sedimentation rates are slow (Verardo, 1997; Hockaday et al., 2006). Changes in charcoal abundance through time are interpreted as a proxy for changes in fire regimes (Whitlock and Millspaugh, 1996; Haberle and Ledru, 2001; Carcaillet et al., 2002; Daniau et al., 2007) although transport and taphonomy may affect this relationship (Whitlock and Anderson, 2003). High fire frequency and/or intensity are expressed by charcoal peaks in sediment (Singh et al., 1981). When combined with pollen records, charcoal analysis can assist in understanding the palaeoclimate, the cause and processes of regional vegetation succession, and the developmental history of the local environment (Tolonen, 1986). Research from Central American and Amazonian tropical forests has demonstrated a significant increase in anthropogenic burning during the late-Holocene, which was associated with the slash-and-burn agriculture of pre-Columbian societies across the region (Bush et al., 2008; Nevle and Bird, 2008; Dull et al., 2010; Nevle et al., 2011). At the beginning of the 16th century anthropogenic burning declined significantly with increasing reforestation. This trend has been attributed to the reduction of indigenous populations through the spread of European disease (Bush et al., 2008; Nevle and Bird, 2008; Dull et al., 2010; Nevle et al., 2011). In contrast, evidence from Amazonian savannas suggests that pre-Columbian societies practised very limited fire management, and that fire use is predominantly a post-Columbian phenomenon (Iriarte et al., 2012)

The size of charcoal particles in smoke varies from sub-microscopic to several centimetres (Schaefer, 1976). Particle size largely determines how far the

particle is transported, although meteorological conditions and basin and landscape morphology are also important for controlling charcoal influx to an area (Swain, 1980). Microcharcoal (particles < 250 µm) provide an estimate of distant and regional fires (e.g. Tolonen, 1986; Clark et al., 2002; Whitlock and Anderson, 2003; Whitlock and Bartlein, 2004), and macrocharcoal (particles >250 µm) indicate more local fires, such as the burning of the wetland surface (Mehringer et al., 1977; Whitlock, 2001). All samples were analysed for macroscopic and microscopic charcoal counts. For each macroscopic charcoal sample, 0.5 cm^3 of unprocessed sediment was measured using displacement of water in a 5 ml measuring cylinder. Samples were then disaggregated in 10% KOH and the entire sample sieved with a 125 µm screen. Particles retained on the screen were counted and their dimensions recorded.

Microscopic charcoal counts were made from material prepared for pollen analysis and therefore the preparation technique is identical to that outlined in Fig.3.1, with charcoal counts undertaken on both the coarse and fine fractions. Microcharcoal concentrations were calculated at the same resolution as pollen (every 1 cm in Lamanai II 2010 core and every 10 cm in Lamanai I 1999 core). The technique used was based on Clark's (1982) point-count technique. A graticule with a 10 x 10 grid was inserted into the microscope eye-piece. The number of *Lycopodium* spores and number of intersects of the grid that charcoal fragments touched were tallied. Each charcoal piece counted was assigned to a size class based on the longest axis: small (<100 µm) and large (> 100 µm) with those large particles added to the macrocharcoal counts. Charcoal pieces <25 µm were disregarded due to the possibility of misidentification (e.g. for pyrite). A minimum of 30 charcoal pieces, 50 *Lycopodium* and 100 fields of view were analysed. This method is suitable for a large number of samples, although it does not permit the analysis of the morphology and structure of the particles (Tolonen, 1986). Using the same material prepared for pollen analysis requires no additional preparation time, costs or sediment however, charcoal particles may be broken during the preparation procedure, which would artificially increase the fraction of small particles (Whitlock, 2001). The charcoal area is expressed per cm^3 of sediment using the following equation:

$$ac = (c\ v\ p) / (n\ e\ s)$$

Where:
ac = charcoal area (cm^3)
c = number of grid intersects touched by charcoal piece
v = field of view area
p = exotics added
n = number of possible grid intersects per field of view
e = exotics counted
s = sediment volume

Charcoal area was calculated for both macrocharcoal and microcharcoal and plotted using C2 (Juggins, 2003)

Having considered the principles, materials and methods that concern the palaeoecological record, the 'material' component of an environmental history of northern Belize, the second part of Chapter 3 considers the archival documentary approaches. These archival sources provide insight into all three components of an integrated environmental history described in Fig.1.2.

3.2 Archival principals, materials and methods

Archival research forms the core of the investigation into nineteenth-century discourses emanating from the British population in Belize. Throughout this research, archives and collections have been viewed as dynamic objects that are products of 'the physical environment, the serendipity of bureaucrats, and the care and neglect of archivists…' (Burton, 2005, p.6). As part of this approach, the partial nature of the archive is also recognised, where it is a visible or unknown absence, 'either through the (un) availability of sources, the negotiation of absent, powerful or powerless voices, or the immaterial qualities of certain kinds of historical source' (Gagen et al., 2007, p.4). The subjectivity of the archive also renders their nature partial, with 'silences' and 'absences' as informative as the articulated voice: 'Archives are not only about what they contain within their walls. They are also about absence, although the absences in the colonial archive are not neutral, voluntary or strictly literal' (Ballantyne, 2005, p.345).

This section further explores some of the methodological issues associated with working with archival collections, beginning with a consideration of the nature of archives associated with British imperial administration. The extent of the documentary sources available with which to study nineteenth-century Belize will then be outlined, before the most important documentary sources utilized in this thesis are examined in turn. The nature and extent of each source or collection will be described, before considering their various advantages and limitations.

3.2.1 Nineteenth-century archival sources: working through the imperial lens

During the nineteenth-century the gathering of information by both institutions and individuals, for private and public consumption, resulted in the construction of extensive archives where global knowledge was collated and controlled as the 'acquisitive tentacles of empire snaked their way around the globe' (Livingstone, 2003, p.32). Institutional archives, of governmental or other bodies (e.g. the church), particularly those emanating from the administrative records of formal and informal empire, have been described as both 'supreme technologies of state' (Stoler, 2002, p.89) and the 'haphazard accumulation of stuff' (Withers, 2002, p.305). While there is veracity in both

descriptions, the nature of institutional archives can be found somewhere at the mid-point, with the acknowledgement that these collections were self-consciously compiled as nineteenth-century sites of 'knowledge deposit and retrieval' rather than 20th century sites of 'knowledge production' (Schultz, 2008, p.vii). It is particularly important to consider the absent, incomplete or hidden voices in imperial documentary records, with absences as revealing as the material that is present, particularly when the absences are involuntary and politically motivated (Burton, 2005). Brázdil et al. (2010) acknowledge the extensive spatial and temporal coverage and consistency of institutional records, owing to their administrative origin. Administering the nineteenth-century British Empire resulted in copies of documents concerning British colonies, dominions and protectorates overseas being retained as part of the records of global colonial government (Banton, 2008). In many cases, and especially in the case of Belize, these UK based holdings are the only records that remain from this period. As institutional sources are shaped by those who collate them, individual sources, produced by a single person, are also shaped by the social backgrounds, experiences and personal preferences of the author. Brázdil et al. (2005) caution that these sources are variable in nature, and that their scope is often limited to the lifetime of the individual, as integration with other sources can be problematic. Inhabiting the space between individual and institutional sources is the documentary output of individuals, working and or living within the confines of an institution. Here, care is required to identify observations coloured by the institutional ethos or formal instruction, as opposed to the idiosyncrasies of the individual.

3.2.2 Reconstructing the documentary history of 19th century Belize

Sources pertinent to this enquiry are diverse and extensive, scattered across disparate and unrelated collections, often reflecting the marginal place or 'small story' that was Belize in nineteenth-century British imperial endeavour. Data has been gathered from twenty different archive collections located in Belize, the UK and the USA, and electronic sources (see Table 3.2 for the temporal range and location of archival sources and Table 3.1 for a list of abbreviations of archives used in the text). The scope of the enquiry is predominantly focused on the nineteenth-century output of an English speaking population, and this is reliant upon English language sources. Throughout this thesis primary sources accessed through an archive are referenced in footnotes which state the archive code, title or series title and then where relevant or available a page number or date. Published books, including 17th, 18th and 19th century travelogues are cited in the using the Harvard system of author followed by date, with a complete reference in the final reference list.

Table 3.1 Archive abbreviations used in the main text

Archive Abbreviation	Archive name
BLB	Bancroft Library, Berkley, USA
BLNOL	British Library Online Newspaper Archive 1600-1900
BMS	Baptist Missionary Society
BNA	British Newspaper Archive
CMS	Church Missionary Society
EOL	Economist 1843-1975 Online Archive
FBS	Foreign Bible Society
GB	Google Books
GBNA	Genealogy Bank Newspaper Archive
LPL	Lambeth Palace Library
LOC	Library of Congress, Washington D.C. USA
MMS	Methodist Missionary Society Archives
NAB	National Archives of Belize
NMM	National Maritime Museum
RBGK	Royal Botanic Gardens, Kew
RGS	Royal Geographical Society (with the IBG) Collections
SPG	Society for the Propagation of the Gospel
TNA	The National Archives, UK
TNA/CO	The National Archives UK/ Colonial Office
TNA/ADM	The National Archives UK/ Admiralty Department
TUL	Tulane University Library, USA
UKMO	UK Meteorological Office Archives
WI	Wellcome Institute Library
19CPOL	Nineteenth Century Periodicals Online

On site research at the Belize National Archives (NAB) in November 2010 revealed that these collections are limited in scope and usefulness until the twentieth century. As such the vast majority of the sources are from UK based collections. The disparate nature of archival holdings pertaining to Belize was exacerbated by confusion surrounding the key search term ‘Belize’, as the Colonial name ‘British Honduras’ was used until 1982, whereas the earliest term for the settlement was ‘Belize’, then ‘Belize City’. Furthermore, many collections housed documents pertaining to nineteenth-century Belize in their ‘West Indies’ holdings, as Belize was often viewed as part of British imperial expansion in the Greater Caribbean, rather than a Central American settlement. The variable nature of the classification of documentary sources relevant to this investigation has meant that electronic finding aids have had to be supplemented with extensive detective work, often in close collaboration with archivists. This has enabled sources to be located on site that were otherwise unidentifiable using a printed or electronic collection indeces. Such complexity encountered when locating sources will inevitably reduce the amount of documents consulted, however, the often marginal archival space that these holdings have inhabited has meant that they have had little if any use prior to being deposited, and once located they offer a previously unexplored view of nineteenth-century Belize.

Table 3. 2 Temporal range and locations of documentary archival sources (for archive abbreviations see Table 3.1)

MATERIAL	Archive/ Depart.	18th C.		19th C.										20th C.					
		1780	90	1800	10	20	30	40	50	60	70	80	90	1900	10	20	30	40	50
Admin/Gov. Docs./ official correspondence and reports	RGS																		
	LPL																		
	TNA/CO																		
Admin. and Gov. Docs./ Economic Blue Books and Almanacks	WI																		
	TNA/CO																		
Naval docs: Surgeon's reports.	TNA/ADM																		
	NMM																		
Missionary correspondence, journals, letters, pamphlets, images.	WMMS																		
	BMS																		
	CMS																		
	FBS																		
	LPL																		
	SPG																		
	19CPO																		
Newspapers and periodicals	BLNOL																		
	EOL																		
	BNA																		
	19CPO																		
Meterological records.	TNA/ADM																		
	TNA/CO																		
	UKMO																		
	LOC																		
Published traveller's accounts from Belize. (Number indicates number of volumes) NB 1 book from each of the following years, 1699; 1727; 1735, 1740	WMMS								1						2				
	RGS										1	1		1					
	WI										1			1	1				
	GB			1	1				1										

Rather than 'reimagining' or 'reconfiguring' an already present collection of documents in a single national archive, the research for this thesis has *rediscovered* and *reconstituted* the 19th century documentary history of Belize by drawing together fragments and extensive accounts, scattered across many different collections in Belize, the UK and the USA.

Initial scoping visits and remote electronic searches identified The National Archives (TNA), Kew, and the Methodist Missionary Society (MMS) collections held at the School of Oriental and Asian Studies (SOAS), London, as those archives with the most substantial collections relating to Belize. The first phase of archival research focused on these two collections, with a view to identifying and codifying key themes and terms which might contain information relevant to the environmental history of Belize. These terms were kept broad so that, in this first phase, as much information as possible was gathered. Research themes included any descriptions of the landscape of Belize, both in terms of actual observations of the author as well as their perceptions and commentary, including the benefits and limitations of living in Belize. Any references to the site of Lamanai or the British name for the settlement, 'Indian Church' were also noted. More general geographical features, including descriptions of vegetation, swamps, marshes, mountains and winds or breezes were documented. Weather events were also included, for example rain or the lack of rain, temperature, flooding, droughts and more infrequent events such as hurricanes. Where mentioned, references to health and disease were noted, especially when linked to climate. Economic themes concerning trade and economic conditions were included, with two key economic crops identified as particularly pertinent to British interaction in Belize, namely mahogany and logwood. Any material relating to the trade, forestry, working population (including accounts of slavery) and economic value of these key timber crops was also considered. Lastly, reports and descriptions of encounters with the Maya people were documented, especially when this was linked to land-use and cultivation.

The research themes and terms that emerged from the first phase of archival research at the National Archives, and at the MMS collections, were then used in the second phase of archival research, where further collections were identified that may have information relating to the broad themes previously outlined. It should be noted that the research themes were only used as a 'gateway' into the collections consulted in the second phase of the archival research process and that, wherever possible, as much as possible of the material relating to Belize was viewed. Archives consulted in this 'second phase' included the collections at Lambeth Palace Library, London; The Society for the Propagation of the Gospel, Rhodes House, Oxford; The Foreign Bible Society, University Library, Cambridge; The Baptist Missionary Society, Regent's College, University of Oxford; Church Missionary Society, Special Collections, University of Birmingham; The National Maritime Museum, Greenwich; The Wellcome Institute Library, London; The UK Meteorological Office, Exeter; The Royal Geographical Society (with the IBG),

London, and The United States National Archives, College Park. The breadth of sources consulted demonstrates a rigorous archival approach.

In summary, archival sources consulted included newspaper articles, periodicals, missionary letters, reports and journals, ship's surgeon's records, British Colonial office export, import and population data, British government official correspondence and instrumental data from British medical and meteorological officers based on land and sea.

3.2.3 Missionary archives: materials and methods

Initial research undertaken at the Belize National Archives, and subsequent UK-based research (see above), revealed that the British missionaries working in Belize provided both the most prolific and continuous accounts of 19th century Belize, forming the core of this project's archival research. At least five different missionary societies including the Methodist Missionary Society (MMS), the Baptist Missionary Society (BMS), the Church Missionary Society (CMS), the Society for the Propagation of the Gospel in Foreign Parts (SPG), now part of the United Society for the Propagation of the Gospel (USPG), and the Foreign Bible Society (FBS) (now simply known as the Bible Society) were active in Belize in the 19th century, with movement into Belize part of a widening scope of the established missions to Caribbean islands such as Jamaica, Barbados and Antigua. These societies sent over 200 representatives, often accompanied by wives and children, to Belize City between 1821 and 1900, ministering to the slave, apprentice and then 'free hand' populations working in the logging industry. In addition to these sources, approximately thirty items of correspondence, between the Anglican Bishops of British Honduras and Anglican priests, dating from the mid – late nineteenth-century were consulted at the Lambeth Palace Library Archive.

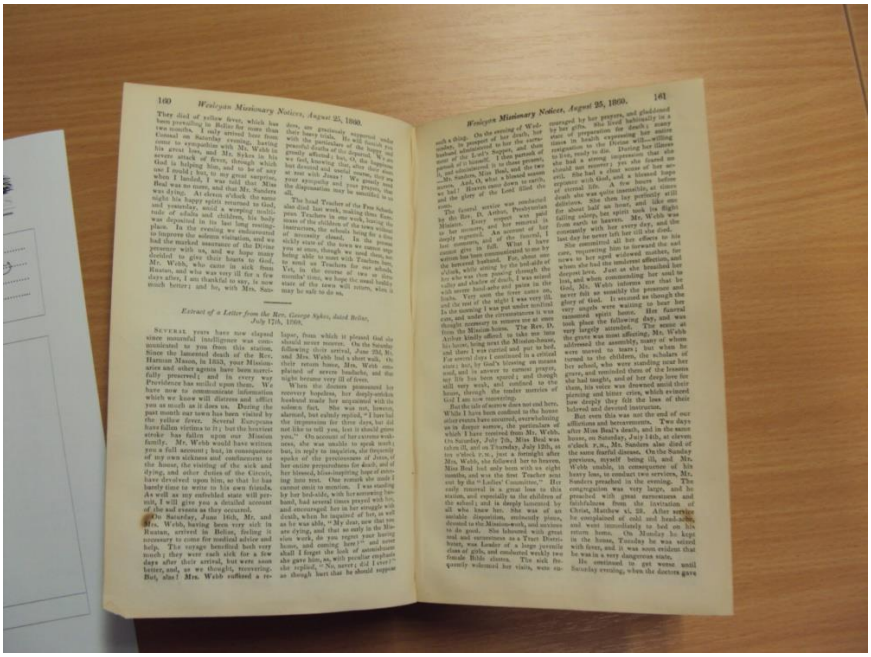

Figure 3.2 An example of a Missionary letter extract published in the Methodist Missionary Society Missionary Notices, 1860[13] (Image: Rushton, 2011)

Over 600 items of original correspondence were analysed, with the most substantial collection held in the MMS archive in the School of Oriental and African Studies (SOAS), University of London; the material pertaining to Belize was part of the 'Greater West Indies' holdings. Wherever possible, original correspondence was consulted in the first instance, in chronological order, with only documents that were identified as place (i.e. Belize or British Honduras) and date (c. 1800 - 1950 AD) specific included in the analysis, to limit as far as possible spatial and temporal ambiguities and inaccuracies. Documents were scrutinized for information concerning the environmental history of Belize including references to climate, weather, geographical features and descriptions of the landscape, health and disease, trade and economics – particularly concerning natural resources such as logwood and mahogany, and these observations and descriptions were recorded verbatim. These accounts included statements concerning the relative healthiness of Belize; the links between climate, health, place and race; daily weather events; accounts of climate anomalies, natural disasters and their societal and economic impacts; reports of epidemic disease and descriptions of the European, Maya and slave populations and their settlements. This data in original form were supplemented with over 300 items of printed materials published by missionary societies, including periodicals, magazines, reports and notices, as well as published missionary memoires and travelogues, held both in missionary society archive collections, and also electronic archives of nineteenth-century periodicals (Fig.3.2). Printed materials were only used as secondary sources; when comparing the original correspondence of the missionary in the field with the published extracts, the vast majority of references to climate and weather were removed prior to publications. All

[13] MMS_MissionaryNotices_25.08.1860_p.160-161

references linking climate to poor health were likewise redacted (often in blue or red crayon), unless it was a brief explanatory report describing the removal of an individual missionary from a station in Belize to another, due to illness.

Missionaries were expected to be regular correspondents, furnishing their Societies with letters containing journal extracts, and reports that were reproduced in periodicals, books and newspapers for wider public consumption, often to encourage subscriptions and recruit more people to the missionary endeavour. As such, missionary sources must be considered as both individual and institutional sources, where the Church institution sent individuals as its agents. In the Methodist Missionary Society regulations of 1816 it clearly states the need for regular, measured information:

> 'It is *peremptorily required* of every Missionary in our Connexion to keep a Journal, and to send home frequently such copious abstracts of it as may give a full and particular account of his labours, success, and prospects. He is also required to give such details of a religious kind as may be generally interesting to the friends of the Missions at home; particularly accounts of conversions. Only we recommend to you not to allow yourselves, under the influence of religious joy, to give a *high colouring* of the facts: but always write such accounts as you would not dislike to see return in print to the place where the facts reported may have occurred…'[14]

Missionary sources including unpublished letters, journals and papers and published reports and annual accounts have been widely scrutinised for their climatic and environmental descriptions and observations, with the nineteenth century particularly well documented (Endfield and Nash, 2002a&b; Kelso and Vogel, 2007; Endfield and Nash, 2008; Endfield et al. 2009; Grab and Nash, 2010). The limitations of document-derived climate chronologies have been widely discussed (Bradley, 1999; Endfield and Nash, 2002a and Kelso and Vogel, 2007), with concerns surrounding issues of standardisation of different individual's observations, exaggeration/underreporting of climatic events, and the unknown motivations and subjectivities of the writer and their audience. These limitations are less problematic, and in fact a source of information in themselves, when reconstructing a cultural climate and/or environmental history (as opposed to a climatological reconstruction), as cultural influences on perceptions of climate are an essential element of an environmental history.

3.2.4 British governmental and administrative records

Established in 1801, the 'War and Colonial Department' produced and received innumerable documents concerning the administration and governance of British interests overseas. In 1854, a year after the outbreak of the Crimean war, this department was split into two and this administrative role fell to the 'Colonial Office' (Banton, 2008). The records of both the

[14] MMS_Annual Report_1816_p.10

'Colonial Office' (CO) and its predecessors are held in The National Archives, Kew. The records of each colony, protectorate or dominion are housed in geographic departments, within the CO archives, and documents relating to Belize are labelled 'British Honduras' and held within the 'West Indies Series' (WIS). It is important to note that the collection of documents pertaining to British Honduras was substantial, with over eighteen thousand references to the search terms 'Belize' and 'British Honduras' identified by the electronic catalogue, and this collection provided the contrast to the disparate nature of other collections, as Forsythe (2012, p.76) says 'although archival practice can be an exercise in piecing together the fragmented, it can equally be a task of sifting through the over-abundance of material presences from the past'.

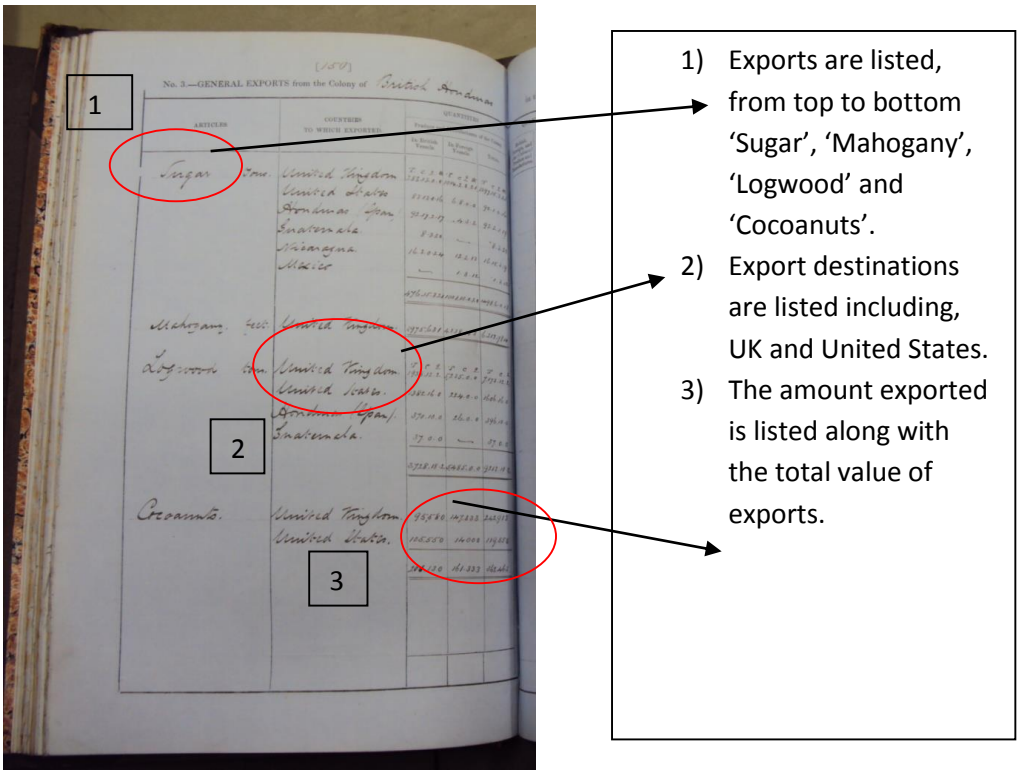

Figure 3.3 An extract from the Blue Book of 'British Honduras' 1874, showing a page of annual exports (CO128_76) (Image: Rushton, 2011)

Two key series of documents were of particular interest, 'Original Correspondence' (CO123) and 'Miscellanea' (CO128). 'Original Correspondence' is a chronological collection of bound volumes; for Belize, it numbers 409 volumes, which span the period 1744 - 1951. Banton (2008) divides the 'Original Correspondence' into three categories. Firstly, official letters or 'despatches' from the governor of a colony or his agent to the secretary of state for the colonies, secondly, correspondence from UK government departments to the Colonial Office, and lastly, correspondence from individuals in the UK to the Colonial Office. Each volume was viewed in

chronological order and examined for key research themes and terms listed above for the missionary archives. Volumes of particular interest were identified and subsequently examined closely. The series titled 'Miscellanea' contained 117 volumes, spanning the period 1807 - 1943; it comprised one volume of shipping returns (1807 - 1812), and 116 volumes of Blue Books of annual statistics (1822 - 1943). The Blue Books of annual statistics provided information on population data, import and export statistics, the provision of churches, schools and prisons in Belize and, from 1893 - 1950, summary meteorological data (Fig.3.3). Data on exports (particularly mahogany, logwood, sugar and other natural resources), population and meteorological data were extracted for the period 1822 - 1943, and supplemented by the single volume of shipping returns (1807 - 1812). 'Government Gazettes' (CO127) were also viewed.

The gazettes are defined as 'the official newspaper of the colonial government, comparable to the London Gazette' (Banton, 2008, p.118). Gazettes produced (generally) quarterly in Belize cover the period 1866 - 1975, and these contained mainly advertisements and small articles; were usually 10 - 12 pages each. Each volume of 'Government gazettes' was viewed for the period 1866 - 1950 and any items of interest noted. Government sources have their own biases, and with colonial governments these biases may be both those of the local government as well as the overarching imperial governance. The geographical sensitivity of colonial governmental records, particularly in the earlier stages of colonization was perhaps limited – reports on various events from different regions may have been amalgamated to be 'packaged up' in a report for a distant Colonial Office Secretary based in London.

In the second phase of archival research, further work was undertaken at TNA to identify items of interest concerning particular research themes including 'health and climate', and in particular 'yellow fever'. Initial electronic searches revealed that the 'Admiralty Department' (ADM) held items including naval surgeon's logs and reports concerning the health and climate of Belize in the 19th century, particularly 1850 - 1870, including items in the series ADM101. Further reports concerning outbreaks of Yellow Fever, which affected British Naval vessels during 1856 - 1864, were identified in the National Maritime Museum archives, Greenwich including the 'Milne papers' (MNL/126) and Ship surgeon's reports form the North American and West Indies Station (MLN/153).

3.2.5 Newspapers and published periodicals

Newspapers published in the UK, USA and Belize were consulted using both electronic holdings and archival collections. British newspapers were searched using electronic holdings, hosted by GALE Databases and include *British Newspapers 1600 - 1900*, *19th Century British Library Newspapers*, *The Economist Historical Archive* (1843 - 1975) and *The Times Digital Archive*

(1785 - 1985). The Genealogy Bank newspaper archive contains over 6,500 newspaper titles published across all of the fifty American states during 1690 - 2011 and was accessed using the subscription based online search engine[15]. Five American titles contained information particularly pertinent to Belize, including, *The New York Times* (1851 - 2008) and *The Washington Post* (1877 - 1995), the *New York Herald* (1840 - 1940), *New Orleans Picayune* (1850 - 1930) and *New Orleans Daily Delta* (1850 - 1930). British periodicals were accessed using 19th Century UK Periodicals, which encompasses the collections of the British Library and the National Libraries of Scotland, South Africa and Australia. In each case, collections were searched using the terms 'British Honduras' and 'Belize'. Collections of newspaper titles published in Belize have not been digitised; however there are holdings of four titles with late nineteenth and early twentieth century coverage at The British Library Newspaper Archive at Colindale, London. Daily titles included *The Belize Advertiser* (1881 - 1889), *The Belize Independent* (1888 - 1896) and *The Clarion* (1897 - 1935), and one weekly title, *The Colonial Guardian* (1882 - 1913). Both the electronic and archival holdings were consulted and references to climate, weather anomalies, hurricanes and other natural disasters, disease and health and trade and economics were recorded verbatim. In addition to these sources, other newspaper articles and reports were consulted when they formed part of supplementary material, provided as part of missionary accounts and reports and Colonial Office correspondence.

Newspapers are often an underutilised source of historical climate data (Mock, 2012; Mock et al., 2007) but recently have been increasingly used, both in terms of climatic reconstruction (Mock et al., 2007; Gallego et al., 2008; Grab and Nash, 2010) and cultural climate histories (Grattan and Brayshaw, 1995). Increasing digitisation of newspapers (with search functions) and online availability of past issues has increased accessibility of such information. Mock (2012) and Gallego et al. (2008) note that the periodic nature of newspapers can build high resolution data sets. Although only a small amount of newspaper volumes contained meteorological data tables, these remain important frameworks for long instrumental time series (Mock, 2012). The use of meteorological data taken directly from newspaper sources can be problematic as these records may have inherent non climatic biases 'due to undocumented changes in location, observer or simply changes in the editorial board that can occur in a long series' (Gallego et al., 2008, p.11). In addition, almost all newspapers contain some information pertinent to weather and climate. Mock et al. (2007, p.83) suggest that newspapers can provide 'very detailed verbal weather descriptions, but most information [is] generally related to extreme daily weather events'. Reporting on extreme weather events can often capture the economic and societal impacts of such events, for example the occurrence of floods, hurricane, drought or snowstorms (Chenoweth, 2006; Mock et al., 2007; Gallego et al., 2008). However, Mock (2012, p.351) highlights the need for the historical climatologist to take 'utmost

[15] The Genealogy Bank newspaper archive is available at www.genealogybank.com Subscription is done individually, at either US$20 for one month or US$70 for one year.

care' when using newspapers for climate and weather information, and to use original newspaper versions, as republished and duplicate versions were sometimes altered during the editing process.

3.2.6 Published traveller's accounts

Electronic searches and secondary literature reviews revealed ten published traveller accounts of journeys and lives spent in Belize during the 18th, 19th and early 20th centuries. Further accounts were found as the result of archival research. One account from the 17th century, Dampier (1699), and three accounts from the 18th century, Uring (1726), Atkins (1735) and Cockburn (1740), were accessed using Google Books (www.googlebooks.com). Henderson (1811) was available through 19POL, Crowe (1850), Morris (1883) and Gibbs (1883) were accessed using the British Library and Samuel (1850) was identified in the MMS archive. Two early 20th century accounts were also identified and viewed using the MMS including Gadsby (1911) and Brindley (1916). Such published accounts can be valuable sources of descriptive weather, climate and land-use data, and Mock (2012) suggests that some diaries may record weather and climate events with more immediacy than newspapers, annals and government reports, and that duplication and re-editing of these published traveller's accounts occurs less frequently. The primary problem of interpreting environmental information from individual accounts, such as missionary sources, is the subjectivity of verbal information (Mactaggert et al., 2007; Mock, 2012). Furthermore, the biases and preferences of individuals also determine the type and quality of environmental information included (Mock, 2012).

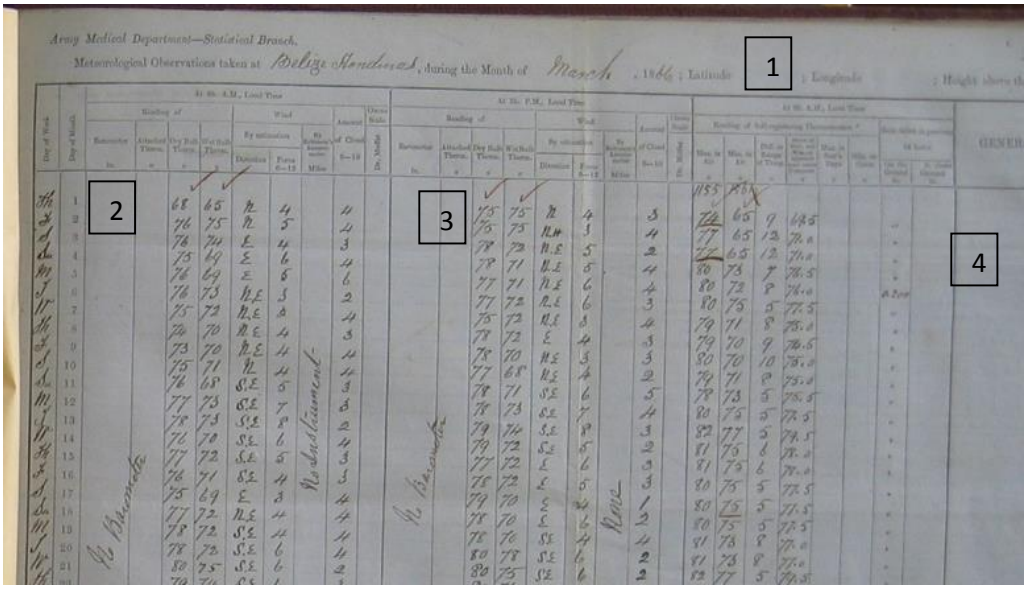

Figure 3.4 Meteorological observations from Belize City, Belize for March 1866 1= date and location of observations, 2= barometer readings, 3= temperature readings, 4= space for general remarks (Photo: Mock, 2010)

3.2.7 Instrumental meteorological data

The instrumental meteorological record from Belize centres on the handwritten daily record kept by successive Colonial Surgeons at the Public Hospital, Eve Street, Belize City for the period 1866-1947 (Fig.3.4; Table 3.2). This was supplemented using monthly mean temperature and precipitation data for 1865 – 1866 observed by Reverend Richard Dowson, Rector of St John's, Belize (1861 - 1870) and included in 'Official Correspondence' (CO123) 1869 (TNA/CO). Further gaps in the daily instrumental record in the years September 1905 – December 1905, 1909, 1915 - 1916 and 1922 were filled in the record using monthly mean data from meteorological tables contained within the 'Blue Books' (CO123) held in the TNA.

Name of observer (Role of observer given in brackets if known)	**Dates of observation** (Daily temperature and precipitation data unless otherwise stated)	**Archival location of records**
Revd R. Dowson (Vicar of St John's Belize City)	1865 –June 1866 (monthly average)	TNA/CO
T. White (Public Hospital Record = PHR)	July – August 1866	UKMO
A. Hunter (Public Medical Officer)/ E. Barrett Kearney (PHR)	Sept 1866 – March 1868	UKMO
T. White (PHR)	April 1868 – Nov 1868	UKMO
W. Hemphill (PHR)	Dec 1868 – April 1870	UKMO
May 1870 - Dec 1877 NO DATA AVAILABLE		
A. Hunter (Public Medical Officer)/ J. Jenkyns (PHR)	1878-1887	TUL (CM)
J.M. Moir (PHR)	5 August 1887 – 22 March 1888	TUL (CM)
C.H. Eyles (Colonial Surgeon, PHR)	23 March 1888 – 28 April 1892	TUL (CM)
F. Gahne (Acting Colonial Surgeon, PHR)	29 April 1892 – 26 Jan 1893	TUL (CM)
C.H. Eyles (Colonial Surgeon, PHR)	27 Jan 1893 - October 1897	TUL (CM)
J.H. Hough Harrison (Acting Colonial Surgeon, PHR)	Nov 1897 – May 1903	TUL (CM)
C.H. Eyles (Colonial Surgeon, PHR)	June 1903 – August 1905	TUL (CM)
Unknown (PHR)	Sept 1905 – 1909 (monthly averages)	TNA/CO
J.H. Hough Harrison (Acting Colonial Surgeon, PHR)	Jan 1910 – Dec 1914	TUL (CM)
J.H. Hough Harrison (Acting Colonial Surgeon, PHR)	1915 (monthly average)	TNA/CO
T. Gann (PHR)	1916 (monthly average)	TNA/CO
P.J. Berry (PHR)	Jan 1917 – Sept 1919	UKMO
Unknown (PHR)	October 1919	UKMO
R.A. Gill/ J.O. Hall (PHR)	Nov 1919 – Dec 1921	UKMO
J.O. Hall (PHR)	1922 (monthly averages)	BLB (CM)
R.A. Gill / A. Fairweather (PHR)	1923 – 1947	UKMO

Table 3.2 Details of meteorological observers, dates of observation and the location of archival repositories for the Colonial Surgeons, Public Hospital, Belize City

Modern data for the period 1973 - 2010 is available courtesy of the Belize Meteorological Service and was obtained by Prof Cary Mock (University of South Carolina). The modern meteorological observations are taken at a station at the Belize International Airport, Ladyville which, is approximately 15 km north from the Belize Hospital site; the latter is in Belize City, adjacent to the water front.

Mock (2012) asserts that pre-modern instrumental meteorological records are considered proxy records because 'they involve substantially different instrumental exposures and observational practices in the past, compared with standardised modern meteorological records' (p.346). The use of daily data (where available), as opposed to monthly, enables the resolution of some quality issues (Mock, 2012). The weather variables examined included temperature, wind (force and direction), precipitation in the previous 24 hours and descriptive weather conditions; however, for this thesis the focus remained on reconstructions of temperature and precipitation. The number of precipitation days (days with >0.01 inches/ >0.25 mm precipitation) was reconstructed in addition to the total daily amount of precipitation. Instrumental data was carefully screened for data quality (Chenoweth, 1993). Temperature data limitations included different fixed observations times, which is problematic when making comparisons with modern data (Mitchell, 1958). Other quality problems included unrecorded station moves and the use of different thermometer exposure situations (Chenoweth, 2007). Here, only detached 'in air' daily minimum and maximum measurements were used, in order to standardise exposure situations (Chenoweth, 1992; 1993) there were no changes of station location within the historical and modern records that are known to the author. Daily instrumental precipitation records can be biased due to infrequent observation of precipitation gauges, changes in instrumentation and the high placement of rain gauges (between eight and thirty ft / 2.5 – 9 m high). In addition, changes in the environment which surrounds the gauges which may alter collection of precipitation; in the main, this leads to under-recorded precipitation (Mock, 1991; 2000; Daly et al., 2007; Dodds et al., 2009). Mock (2002) and Dodds et al. (2009) have reported that the under-recording of precipitation is a prevalent problem in historical precipitation records.

As Dodds et al. (2009) have highlighted, warm season precipitation data is not without bias and, in order to minimise any non-climate variations in the records from Belize, each of the three substantial periods of almost continuous daily data (1878 - 1905; 1917 - 1947 and 1978 - 2010) were screened using a method outlined by Dodds et al. (2009) and Mock (2012). Line graphs of daily precipitation frequency were constructed to assess the frequency of different amount classes. This enables the evaluation of the quality of longer (>10 year)

records. A smooth negative exponential curve would be expected for higher quality precipitation data (i.e., a higher frequency of 0.01 in. amounts (2.54 mm) than 0.25 in. amounts (63.5 mm) (Fig.3.5 series 1917 - 1947; 1978 - 2010). Spikes are visible in the 1878 - 1905 series at values ending in zero and five (e.g. 0.10, 0.05, 1.0 and 1.5 in.), and this is mostly likely due to the '5/10' bias which, may indicate 'estimated values, sporadic observations, and observer inattentiveness to lighter amounts' (Dodds et al., 2009, p. 65). In spite of some of the constraints identified with the historical meteorological data sets reconstructed for this study, this record is the first to be produced for Belize, and is the earliest, most continuous daily record from Central America published to date.

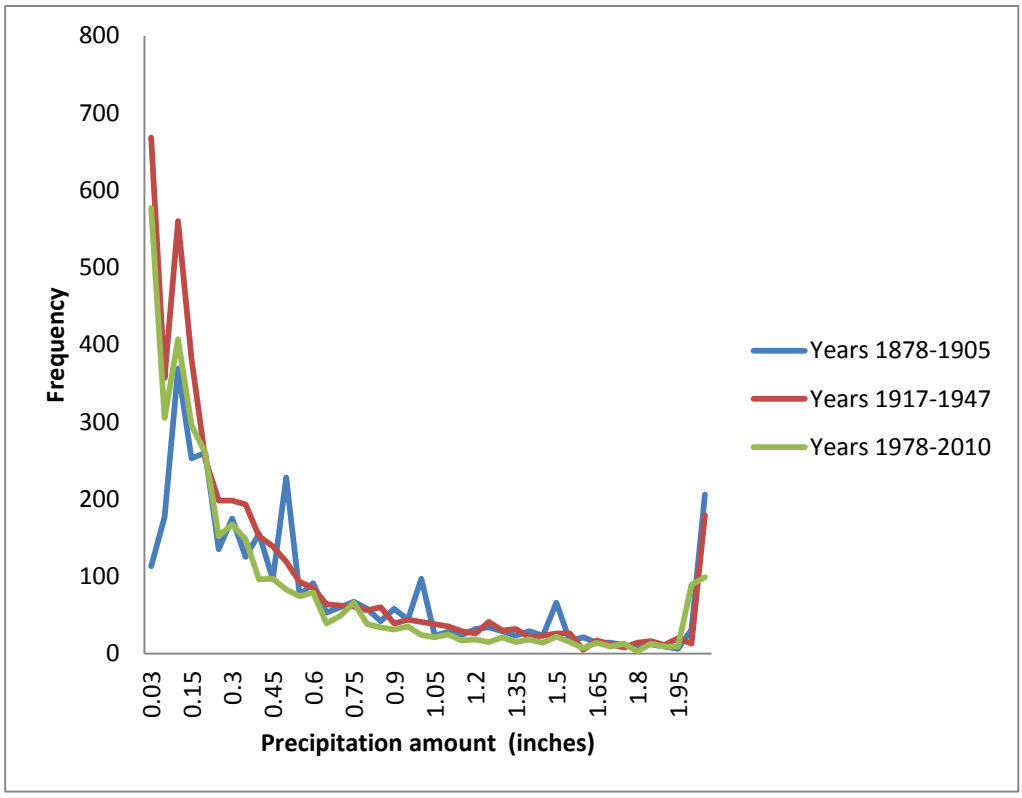

Figure 3.5 Precipitation class frequency of daily data from Belize City for the periods 1878 - 1905, 1917 - 1947 and 1978 - 2010

3.2.8 Maps

Three main collections provided the majority of the maps of Belize that were publically available, and each collection has distinct temporal coverage. Five 16th and 17th century maps of the Yucatan region, which includes modern Belize, were viewed from the collections of The Library of Congress, Washington D.C. The National Archives UK held maps of Belize in both the Foreign Office and Colonial Office collections, and date from the late 18th century and throughout the 19th century, and finally, the RGS (with IBG)

collection held mainly late 19th century maps of Belize, and one of Belize City. This temporal delineation may reflect changing regional geo-political power structures, with British influence on Belize increasing throughout the 18th century, and culminating in formal governance in the 19th century. When viewing and analysing these maps, it is crucial to regard them as dynamic, culturally and politically constructed documents that have the capacity to communicate knowledge and exert power (Harley, 1989; 2001; Turnbull, 1996; Crampton, 2001).

Harley (1989, p.9) asks the reader to consider the culturally constructed 'second text within the map'. He argues: 'The scientific rules of mapping are, in any case, influenced by a quite different set of rules, those governing the cultural production of the map…[the rules] are related to values, such as those of ethnicity, politics, religion or social class, and they are also embedded in the map-producing society at large' (Harley, 1989, p.5). Harley (1989, p.13) identifies both 'internal' and 'external' power at work within and through cartography, with maps the subject and centre of external political power and, in addition, the embodiment of internal cartographic power, 'to catalogue the world is to appropriate it'. Alongside the more traditional weapons of Empire, Harley (2001) suggests that maps were not only part of the European arsenal deployed to conquer and subdue native peoples, but that maps and map makers 'anticipated empire'; maps were used to legitimise the reality of conquest and empire. They helped create myths which would assist in the maintenance of the 'territorial status quo' (Harley, 2001, p.57). Meinig (1986) asserts that the European mapping and partitioning of North America demonstrates both the dominance of colonial expansion and the silencing of native peoples; 'the very lines on the map exhibited this imperial power and process because they had been imposed on the continent with little reference to indigenous peoples, and indeed in many places with little reference to the land itself'. The absence of the indigenous voice is also demonstrated by Harley (2001, p.67), 'throughout the long age of exploration, European maps gave a one-sided view of ethnic encounters and supported Europe's God-given right to territorial appropriation'. Mundy (1996) has documented the coeval roles of both indigenous Amerindians and Spanish colonisers in producing 16th century maps in Mexico, recognising both the explicit and implicit roles that indigenous knowledge held within colonial maps.

Richards (1993, p.15) has decribed official administrative government departments such as the British Colonial Office (TNA) as an 'imperial archive', and the RGS (with IBG), founded in 1830, was also a body which enabled the exploration and mapping of the British Empire. As much of the cartographic material considered here emanated from such 'imperial archives' it is especially important to consider the cultural context and textuality of these documents, and the added opportunities that this brings for engagement and interpretation, as Harley (2001, p.8) says; 'By accepting their textuality we are able to embrace a number of different interpretative possibilities. Instead of just the transparency of clarity we can discover the pregnancy of the opaque. To fact we can add myth, and instead of innocence we may expect duplicity'.

3.3 Summary

This Chapter has presented the two distinct methodologies and sources used to reconstruct an environmental history of northern Belize namely, sediment derived palaeoecological reconstruction primarily based on palynolologcial and charcoal analysis and documentary dervived reconstructions primarily based on governmental and missionary archvial sources. The challenges and opportunities presented by these sources have been considered and the significant challenge of dating has been outlined and will be further developed in Chapter 8. The analyses of the documentary sources are presented in Chapters 5, 6 and 7. The results, analyses and discussion of the palaeoecological record follows next, in Chapter 4.

Chapter Four

A 3,500 year vegetation history from Lamanai, northern Belize

4.0 Introduction

This chapter provides the detailed 'material' environmental history of northern Belize (Fig. 1.6), which observes ecological changes over time (Worster, 1988). The first part of this chapter outlines the chronology and stratigraphy of the two Lamanai cores, Lamanai I (1999) and Lamanai II (2010) introduced in section 3.1. The second part of the chapter describes the results of the charcoal and pollen analyses. Interpretation and discussion of the data is presented in the final part of the chapter.

4.1 Chronology and stratigraphy

The sediments from the Lamanai I (1999) core were mainly greyish-brown silts and clays, with accumulations of gastropods, focused at 180 - 179, 154 - 153, 75 - 72 and 30 - 20 cm. The stratigraphy of the Lamanai II (2010) core is shown in Fig.4.1, with unit two similar to the Lamanai I (1999) sediments of greyish-brown clay unit from 39 cm through to the base, and a darkish brown organic rich silty unit (unit one) above. Abundant gastropod shells were found throughout the Lamanai II (2010) core with some larger snail shells also present (coring methods are described in Chapter 3).

Metcalfe et al. (2009) reported the results of six radiocarbon dates obtained on the Lamanai I (1999) core and, this previously established chronology is used by this study (Table 4.1). Two of the dates were on gastropods and a hard-water correction of 1660 years was applied (Metcalfe et al., 2009). The age-depth curve for the Lamanai I (1999) core is approximately linear (r^2 =0.99 for the OM dates only, 0.94 including the corrected dates) (see section 3.1.2). The surface sediments from the Lamanai 1999 core were missing and the date AD 1500 was assigned to the top of this core (Metcalfe et al., 2009); with an average sedimentation rate of ~0.1 cm a^{-1}. Due to the length of time that has elapsed since the 1999 Lamanai I core was first extracted, and multiple other proxies that have used sediment sampled from this core, the core length at the time of sampling for pollen analysis in 2010 had decreased to 309 cm, with the majority of core lost in the basal section, however, all the units described in 2001 were visible when sampling for this study. The samples analysed for pollen analysis in 2010 and 2011 were extracted from sediment that has been calculated to represent the period c. 1650 BC – AD 1500.

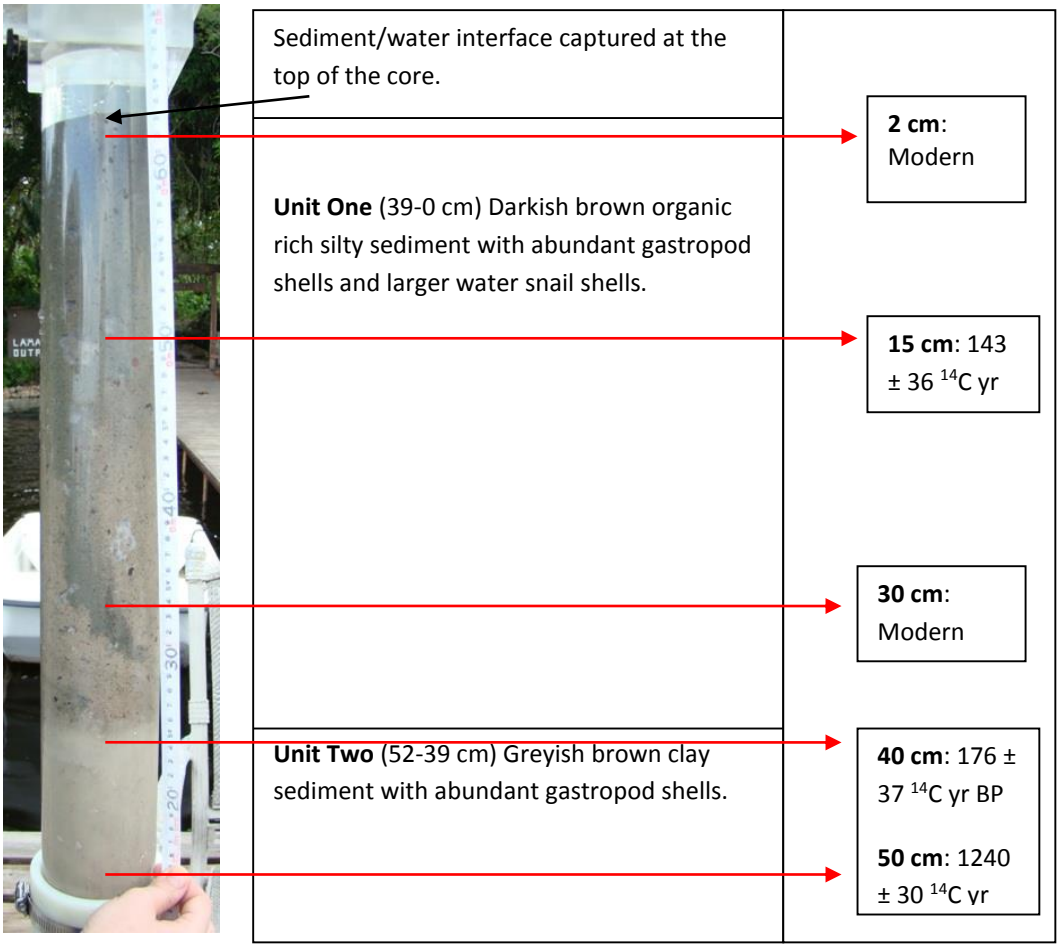

Figure 4.1 Stratigraphic diagram of the Lamanai II (2010) core with the depths of the AMS radiocarbon dates (Table 4.2)

Table 4.1. AMS radiocarbon dates for the Lamanai I (1999) core (Metcalfe et al., 2009)

Code	Depth (cm)	Material	^{14}C yr BP	δ^{13}CVPDB‰±0.1	Cal. yr BP (2σ)	Cal. yr BC/AD (2σ)
AA-35787	38.5	OM	810 ± 40	-32.4	AD 1224, 1231, 1239	AD 1161-283
CAMS-77196	38.5	G	2470 ± 40	-6.9	-	-
SUERC-4104	72-75	G	3260 ± 50	-6.7	-	(c. AD 400)
SUERC-4108	178-180	G	4445 ± 35	-5.6	-	(c. 900 BC)
AA-35786	259	OM	3070 ± 50	-27.1	3159-3383	1433-1132 BC
CAMS-77195	312	OM	3440 ± 40	28.6	3629-3780	1880-1636 BC

As has been described in section 3.1.2, AMS radiocarbon dates were obtained from terrestrial plant material extracted from the Lamanai II (2010) core at 2, 15, 30, 40 and 50 cm. All dates were calibrated using the INTCAL.09 calibration curve (Reimer et al., 2009) using the radiocarbon program Calib 6.0 (Stuiver and Reimer, 1993) to yield dates in calibrated years BP and years BC or AD, which enables comparision with archaeological and colonial records. The calibrations of these AMS are listed in Table 4.2 and Fig.4.1 and plotted on Figs.4.3, 4.5 and 4.7.

The ^{14}C AMS dates obtained for the Lamanai II provided a date at 50 cm which constrains the base of the record to 1240 ^{14}C yr BP (± 30) (2σ cal. AD 686 - 873) (Table 4.2); this record therefore captures the Late Classic Maya period (Chapter 2). The coring description recorded that the water sediment interface was captured (section 3.1.1), and the modern date obtained at 2 cm suggests that the top of the core represents AD 2010, rather than the commonly assumed modern AD 1950 (Bowman, 1990). The top of the core has a further date of 143 ^{14}C yr BP (± 36) at 15 cm, which when calibrated (Table 4.2) suggests a date of c. 19th century. The age-depth model of the middle of the core is more uncertain. A modern date at 30 cm and similarly 'young' date at 40 cm could have resulted from modern terrestrial material moving down the sediment column during coring or sampling. A change in sediment occurs at 39 cm (Fig. 4.1), and without a coherent date at 40 cm it is not possible to reliably calculate sedimentation rates within the core. Therefore the age-depth model for this core relies on a well constrained top and base, with some further constraint at 15 cm, but beyond this the dates are less certain. Section 4.4.5 presents the palaeoecological data which suggests that the bottom of the Lamanai II core overlaps with the Lamanai I core. The next section considers the loss-on-ignition analyses of both cores.

Providing accurately and precisely dated chronologies is an essential aspect of coherent palaeoclimatic, palaeoecological and archaeological research. As Hodell et al. (2007) comment, 'with inaccurate chronologies, there is always a potential danger of inadvertent temporal correlation of events that occurred at different times' (p.238). When palaeoclimate and archaeological records are drawn together to examine historical patterns of societal change, an accurate and detailed chronology becomes imperative. Hodell et al. (2007) suggest that chronological control…is currently too weak to achieve more than a general temporal correlation between palaeoclimate and archaeological data' (p.238). Caseldine and Turney (2010) maintain that, although there have been substantial improvements in radiocarbon dating, 'chronological control is likely to remain an area that will need constant improvement' (p.90). The sediment derived palaeoecological record presented in this thesis relies on a chronology constrained by radiocarbon dates. The Lamanai I (1999) chronology and sampling strategy provides palaeoecological information in c. 150 year time slices over a 3,000 year period. In the Lamanai II (2010) core, the top and bottom of the core is constrained with AMS radiocarbon dating, but the chronology of the middle section remains uncertain. This means that the palaeoecological record can at best examine change in periods of 150 – 200

years or more. However, Diaz and Stahle (2007) suggest that within the commonly understood limits of radiocarbon derived chronologies it is possible to identify 'major climatic shifts that are coeval with significant cultural changes in different parts of the world' (p.2). Broadly speaking it is not possible to examine change observed during anthropogenic generations in the record from Lamanai. However shifts in vegetation composition observed in the palaeoecological record can be examined alongside the archaeological record to explore possible chronologies and causes of change (section 4.6). High temporal resolution records of natural exports are brought together with the palaeoeological record in Chapter 6 and this demonstrates how the chronology of the palaeoecological record can be further clarified and illuminated.

Table 4.2. AMS radiocarbon dates for the Lamanai II (2010) core (all calibration data Reimer et al., 2009)

Code	**Depth (cm)**	**^{14}C yr BP**	**δ^{13}CVPDB‰±0.1**	**95.4% (2σ) cal. age ranges (BC/AD)**	**Relative area and distribution**
SUERC-43153	2	Modern	-29.6	Modern	-
SUERC-43156	15	143 ± 36	-28.3	1668 – 1782	0.463
				1797 – 1892	0.365
				1908 – 1948	0.165
				1950 – 1953	0.007
SUERC-43157	30	Modern	-28.0	Modern	-
SUERC-45706	40	176 ± 37	-27.6	1651 – 1706	0.203
				1770 – 1819	0.511
				1832 – 1882	0.100
				1914 – 1953	0.187
BETA-309657	50	1240 ± 30	-28.4	686 – 873	1.000

4.2 Loss-on-ignition

Figs.4.2 and 4.3 presents the loss-on-ignition analyses undertaken on both the Lamanai I (1999) (Fig.4.2) and Lamanai II (2010) (Fig.4.3) cores and reflect the methods discussed in sections 3.1.3 and basis of zonation in section 3.4.1. The analyses on Lamanai I (1999) core were undertaken by Dr. Malcolm Murray, at the University of Edinburgh as part of an investigation funded by the Leverhulme Trust (F/158/BQ) and reported by Breen (2001) and Metcalfe et al. (2009). These results have been made available for use in this research (Fig.4.2). When compared with analyses from the Lamanai II (2010) core they could provide insight as to the stratigraphic relationship between the two cores.

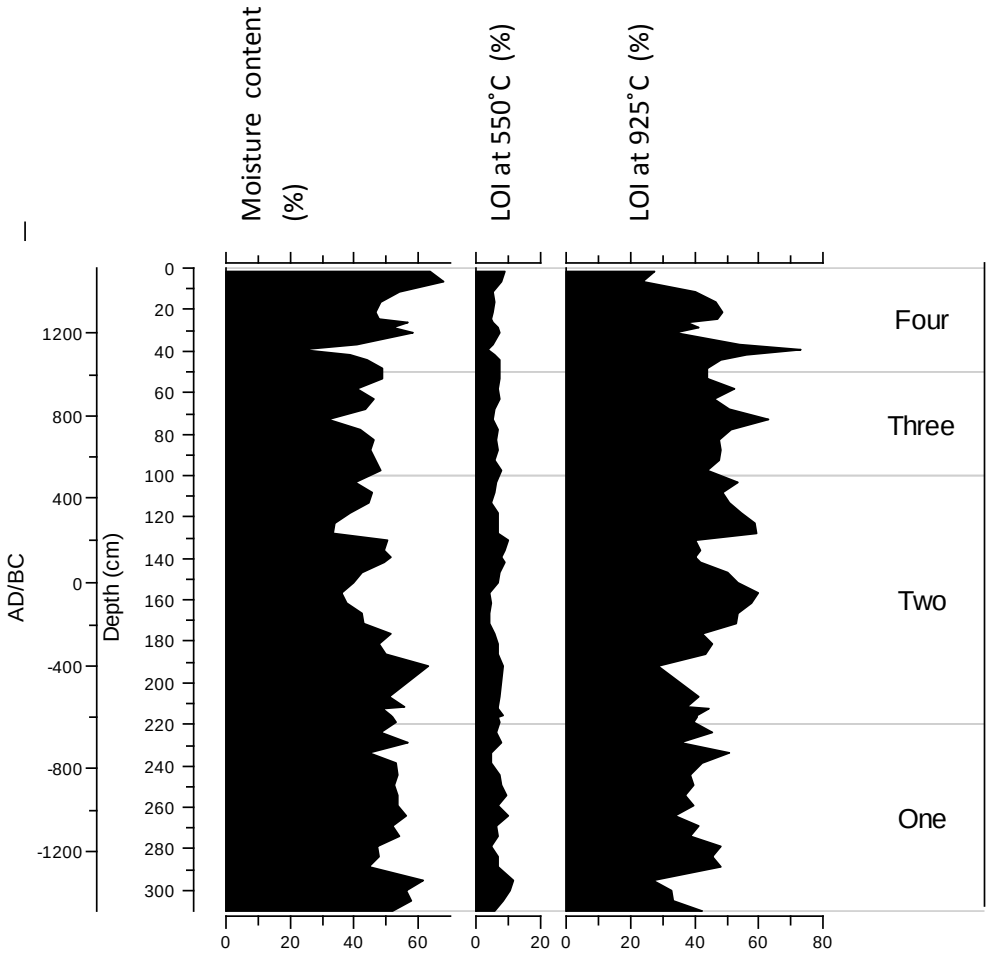

Figure 4.2 Moisture content, loss-on-ignition and $CaCO_3$ percentage diagram presented with CONISS derived pollen zones for the Lamanai I (1999) core.

Moisture content in the Lamanai I (1999) core (Fig.4.2) averages 52%, which is similar to the average value (49.5%) of the bottom unit (52 - 35 cm) of the Lamanai II (2010) core. Moisture content in the top unit of the Lamanai II (2010) core decreases after 39 cm, averaging 34.9% between 28 cm and 24 cm, and decreasing to an average 27% between 27 cm and 0 cm. Organic matter values are similar across both Lamanai I (1999) and Lamanai II (2010) cores, averaging 6.8% and 4.1% respectively, and neither core has values >11%. Calcium carbonate values at the top of the Lamanai II core are 20%, which is similar to values observed in the bottom unit (52 – 39 cm) of the Lamanai I core (19.4%). Calcium carbonate values decrease in the Lamanai II (2010) core above 39 cm, averaging 8.9%. In summary, the moisture and calcium carbonate values for the top of the Lamanai I (1999) core are very similar to those observed in the bottom unit (52 – 39 cm) of the Lamanai II core, and with the similarities in sediment description support the ^{14}C AMS dates (Tables 4.1 and 4.2) which suggest that the Lamanai II (2010) core encompasses part of the Lamanai I (1999) record.

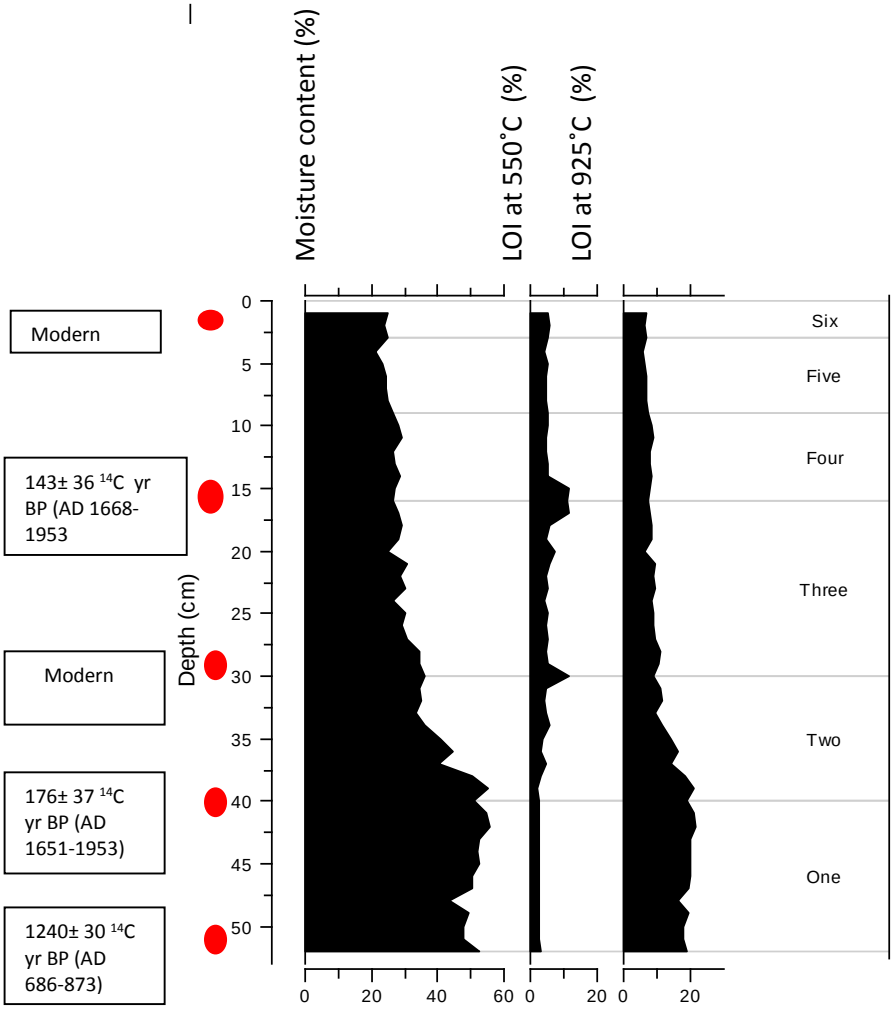

Figure 4.3 Moisture content, loss-on-ignition and $CaCO_3$ percentage diagram presented with CONISS derived pollen zones for the Lamanai II (2010), NRL core.

4.3 Charcoal analysis

In the Lamanai I (1999) core, micro charcoal particles (<100 µm) are found throughout all four zones (Fig.4.4), although the concentration in Zone Four is low (95 particles per cm^3). The peak concentration in this core (725 particles per cm^3) occurs at the base of Zone Three (c. AD 590) and this zone has the highest average concentration of both cores (302 particles per cm^3). A secondary peak in charcoal (451 particles per cm^3) is observed in Zone One (c. 1250 BC), with an average of 189 particles per cm^3, and a tertiary peak (401 particles per cm^3) in Zone Two (c. 40 BC).

In the Lamanai II (2010) core (Fig.4.5), charcoal concentration is subdivided into macro (>100 µm) and micro charcoal particles, with the macro charcoal representing a local signal and the micro charcoal a regional signal (Whitlock

and Larsen, 2001). In Zone One, the macro charcoal signal has a secondary peak (6 particles per cm^3) at 48 cm, which forms part of a cluster at 49 - 46 cm before decreasing. Zone Two has a high, consistent concentration of macro charcoal, and this zone has the highest average (3.4 particles per cm^3) in the Lamanai II (2010) core. Macro charcoal is found at the beginning of Zone Three (30 – 28 cm) and from 23 cm to the top of the zone, with an average of 1.5 particles per cm^3. The peak macro charcoal signal is found in zone four (8 particles per cm^3); however between 13 and 15 cm, macro charcoal is absent. In Zone Five (average 0.9 particles per cm^3) macro charcoal only appears at 5 cm and 4 cm and is absent from Zone Six. Broadly speaking, the micro charcoal particle signal follows the peaks of the macro, with peaks found at 15 cm (772 particles per cm^3) and 30 cm (702 particles per cm^3). Micro charcoal concentration is lowest in zone one (43 particles per cm^3) and is also low in Zones Two and Five (170 particles per cm^3). Concentrations increase in Zone Three (average 246 cm^3) and peaks in Zone Four (average 294 particles per cm^3). Micro charcoal concentrations are reduced in Zones Five (170 particles per cm^3) and Six (195 particles per cm^3). In the modern sample, only micro charcoal is observed, with a concentration of 81 particles per cm^3.

4.4 Pollen analysis

The pollen analyses are presented in Figs.4.4, 4.5, 4.6 and 4.7 and reflect the principles and methods described in section 3.1.4. The following section provides a description of each pollen zone. Rather than a lengthy description of all, only key taxa in each zone are noted. Each core is treated individually, with range values and average values considered separately for each core.

4.4.1 The modern pollen assemblage

In the modern pollen assemblage, seasonally dry tropical forest taxa totalled 18.2%; this included Moraceae/Urtiaceae (4%), *Brosimum* type (3%), *Manilkara zapote* (3%), and *Swietenia* type (2%). The pine savanna signal (46%) comprised *Pinus* (16%), and also *Mimosa* (4%), *Metopium brownei* (4%) *Byronsima* (2.5%), *Quercus* (2.5%) and *Cecropia* (1%). Combretaceae/Melastomaceae comprised 12%, and could be representative of both pine savanna species, e.g. *Miconia* (Melastomaceae) and also seasonally inundated forest species associated with the logwood fringe (*H. campechianum*, 2%) that surrounds the modern NRL, including *B. buceras* (Bhattacharya et al., 2011) (see 2.1.2 for a description of the vegetation at the NRL). Herb taxa (22%) included Chenopodiaceae/Amaranthaceae (9%), Asteraceae (7%) and Poaceae (6%). There were low palm levels (1%) and very low crop taxa, with only *Z. mays* present (1%).

4.4.2 Long core record (Lamanai I, 1999, Figs.4.4 and 4.6)

The palynological and charcoal results from this core have been published as a record of vegetation history from Lamanai, NRL for the period 1500 BC to AD 1500 (Rushton et al., 2013) and the four zones from the Lamanai I core are now described.

Zone One: 300 - 220 cm, c. 1630 - 900 BC

The arboreal signal for this zone is dominated by *Brosimum* type, *Pinus* and *Maclura* type with *Quercus* recorded in lower percentages (<2%). Seasonal forest signal ranges between 27% and 40.5% (average 34%) with a broadly increasing trend between c. 1630 and 900 BC. Pine savanna signal peaks (20%) in Zone One at c. 1600 BC (Zone One average is 9%) and then declines during c. 1500 - 900 BC, ranging between 3.5% and 12% (the average for this period is 4%). Herb taxa have an average of 29% throughout Zone One, with a low in this zone of 20% at 1600 BC, and a peak of 40% at 1240 BC. Palms peak (16%) at 1630 BC and have values ranging from 4% to 12% during the period 1630 - 1150 BC (average 6.5%). No palms are present between 930 and 820 BC. *Z. mays* is present between 1630 and 930 BC (average 3.5%), and has a peak (5%) at 1240 BC. *Cucurbita* and *Capsicum* are both present (<1%) at c. 1630 BC. Semi-aquatic pollen types including, Rhizophoraceae and *Cladium* are also present during period 1630–1150 BC (average 3.5%).

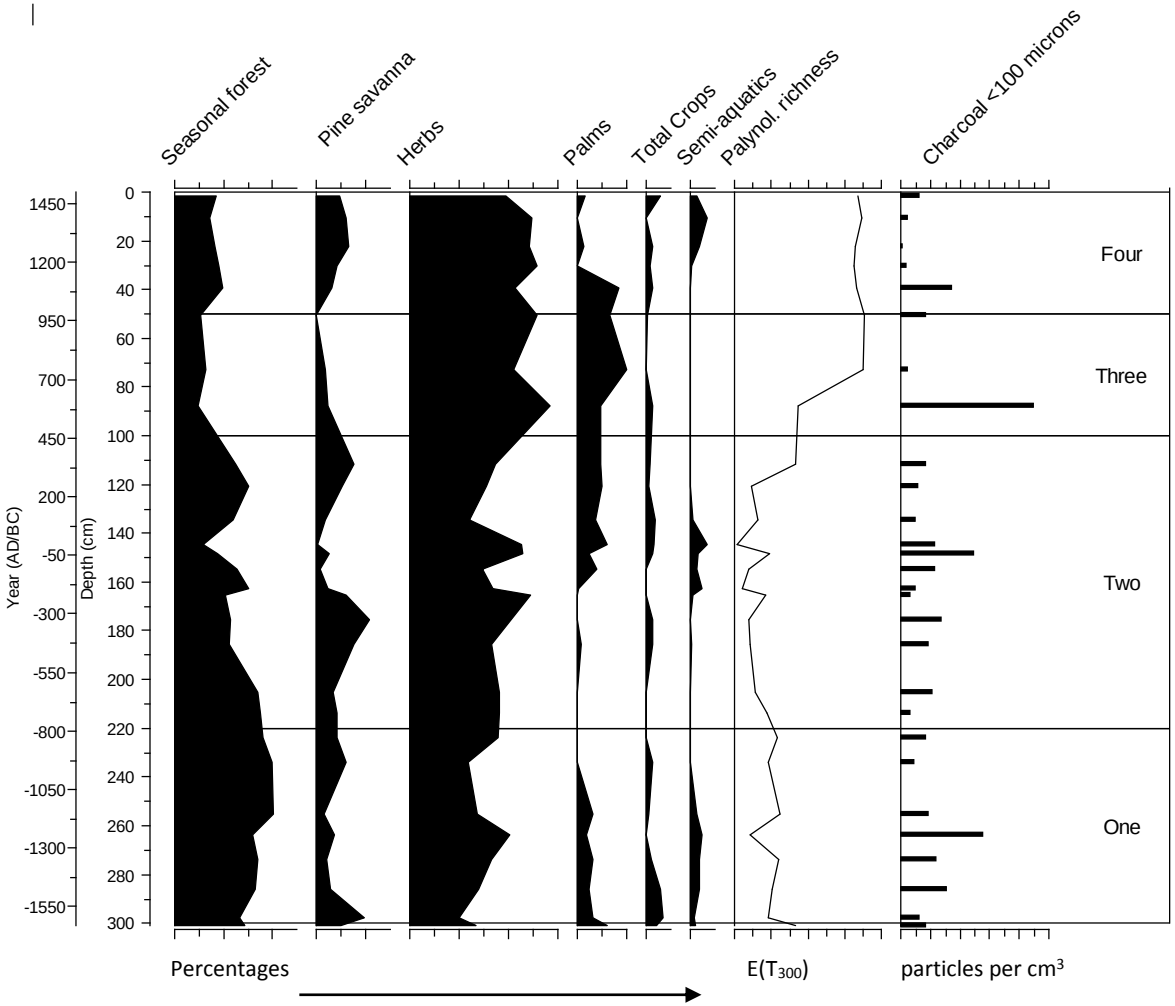

Figure 4.4 Summary pollen percentage and palynological richness diagram, with charcoal concentration (presented with pollen zones) for the Lamanai I (1999) core, NRL

Zone Two: 220 - 100 cm, c. 900 BC – AD 350

In Zone Two, the seasonally dry tropical forest signal (the average for this zone is 27%) can be divided into two trends. Between 720 and 10 BC the arboreal signal declines from 35%, where Urticaceae/Moraceae, *Brosimum* type, *Maclura* type and *Pinus* dominate and *Bursera simaruba* is found in smaller proportions, to its lowest level of 11% at 10 BC. From 10 BC to AD 470 the arboreal signal increases, rising to 40% at AD 250. Here arboreal taxa include *Brosimum* type, Urticaceae/Moraceae, *Pinus* and *B. simaruba*. The pine savanna signal follows a similar trend, ranging between 11.5% and 35% (the Zone Two average is 25%) followed by a sharp decline, (*Pinus* in particular) falling to <1% at 10 BC. Herbs have a mean value of 37% throughout this zone, with two notable peaks at 220 BC (49%) and 40 BC (46%). Palms are either absent or present in relatively low abundance (<1.5%) between 720 and 190 BC, rising during the period 100 – 10 BC to between 4% and 12% (average for this zone is 4.4%). *Capsicum* and *Cucurbita* are both present in low abundance at 10 BC (<2% and <1%), respectively. *Z. mays* is not present between 820 - 640 BC and 220 - 190 BC, but is present between 430 - 320 BC (2.5%) and 40 BC - AD 350 (ranging between 2.5% and 4%). In this zone the highest levels of *Z. mays* occur at AD 100 (4%). Aquatics are found in low levels (<1%) between 220 BC and AD 100, peaking at 10 BC (7%).

Zone Three: 100 - 50 cm, c. AD 350 - 1000

Seasonally dry tropical forest values ranges from 12% to 20%, declining from 20% c. AD 590, to 12% c. AD 970, with a mean value for this zone of 11%. The dominant taxa are Urticaceae/Moraceae, with *Maclura* type, *B. simaruba*, and *Celtis* absent from this zone. Pine savanna values are low (zone average of 3%), ranging between 0% and 4%, with *Pinus* absent from the assemblage. Herb taxa have an average of 46%, and peaks (56%) at AD 590, declining to 42% at AD 740. The levels of herbs increase to 51% between AD 740 and 970, and the decline at AD 740 may be caused in part by the peak in palms (20%) at this point. Palms have a mean value in this zone of 4.4%. No Cyperaceae is present in this zone, and *Z. mays* is the only crop taxon recorded. The peak in *Z. mays* for this zone (3%) is found at AD 590, with levels decreasing during AD 740 - 970.

Zone Four: 50 - 0 cm, c. AD 1000 - 1500

During AD 1000 - 1500, the seasonally dry tropical forest signal ranges from 14.5% to 19.5% (average is 17%), with a peak of 19.5% in this zone at AD 1100. Arboreal taxa include, *Brosimum* type, *Maclura* type, Urticaceae/Moraceae and *Zueliana guidonia*. The pine savanna signal ranges

from 6.5% to 11.5%, with an average of 10%. *Pinus* dominates the pine savanna signal, with a tertiary peak (12.5%) from all zones, occurring at *c*. AD 1250. Herb taxa have an average of 37%, ranging from 37% to 55%. The secondary peak of palms occurs at AD 1090, however from AD 1190 to 1480 decreases to <4%, and the zone average is 4.5%. *Z. mays* is present between AD 1090 and AD 1270 (1 – 2.5%) but is absent or represented by a single grain between AD 1390 and AD 1480. *Cucurbita* occurs at AD 1480 and both *Cucurbita* and *Capsicum* are present at AD 1270. Cyperaceae is present between AD 1180 and AD 1480 and peaks at AD 1390 (7%), accompanied by *Cladium* (<2%).

4.4.3 Short core record (Lamanai II, 2010, Figs.4.5 and 4.7)

Zone One: 52 - 40 cm

Zone One has the lowest seasonally dry tropical forest percentage assemblage of the Lamanai II (2010) core, with a mean value of 19.4%. This is a similar value to the modern pollen signal (18.2%), and the seasonal forest value of Zone Four (50 - 0cm, c. AD 1000 - 1500) of the Lamanai I (2001) core (17%). The only zone in either core which has a substantially lower seasonally dry tropical forest average value is that of 11%, which is found in Zone One (300 – 220 cm, c. 1630 - 900 BC) Lamanai I (2001) core. In Zone One of the Lamanai II (2010) core, seasonally dry tropical forest taxa comprises Morticaceae/Urticaceae (2 - 6%), *M. brownei* (1 - 3.9%), *Brosimum* type (0 - 3%), *B. simaruba* (0 - 2.8%) and *M. zapote* (0.7 - 2.6%). *Spondias* type, *Acalypha* type*, Luehea* type, *Swietenia* type, *Maclura* type, *Drypetes* type, *Talisia* type and *Guazuma* type are present in low amounts (<2%). Pine savanna values are also reduced in this zone (21%), with the lowest average value of the Lamanai II (2010) core. This is the third lowest value across both Lamanai I (2001) and Lamanai II (2010) cores, with the two lower values of 3% and 10% found in zones three (100 – 50 cm, c. AD 350 - 1000) and four (50 – 0 cm, c. AD 1000 - 1500) respectively. Pine savanna taxa include *Pinus* (0.6 - 15.5%), *Byrsonima* (2 - 7.7%) and *Curatella* (0.8 - 6.6%), with lower levels (<4%) of Combretaceae/Melastomaceae, *H. campechianum, Cecropia*, *Mimosa* and *Quercus*.

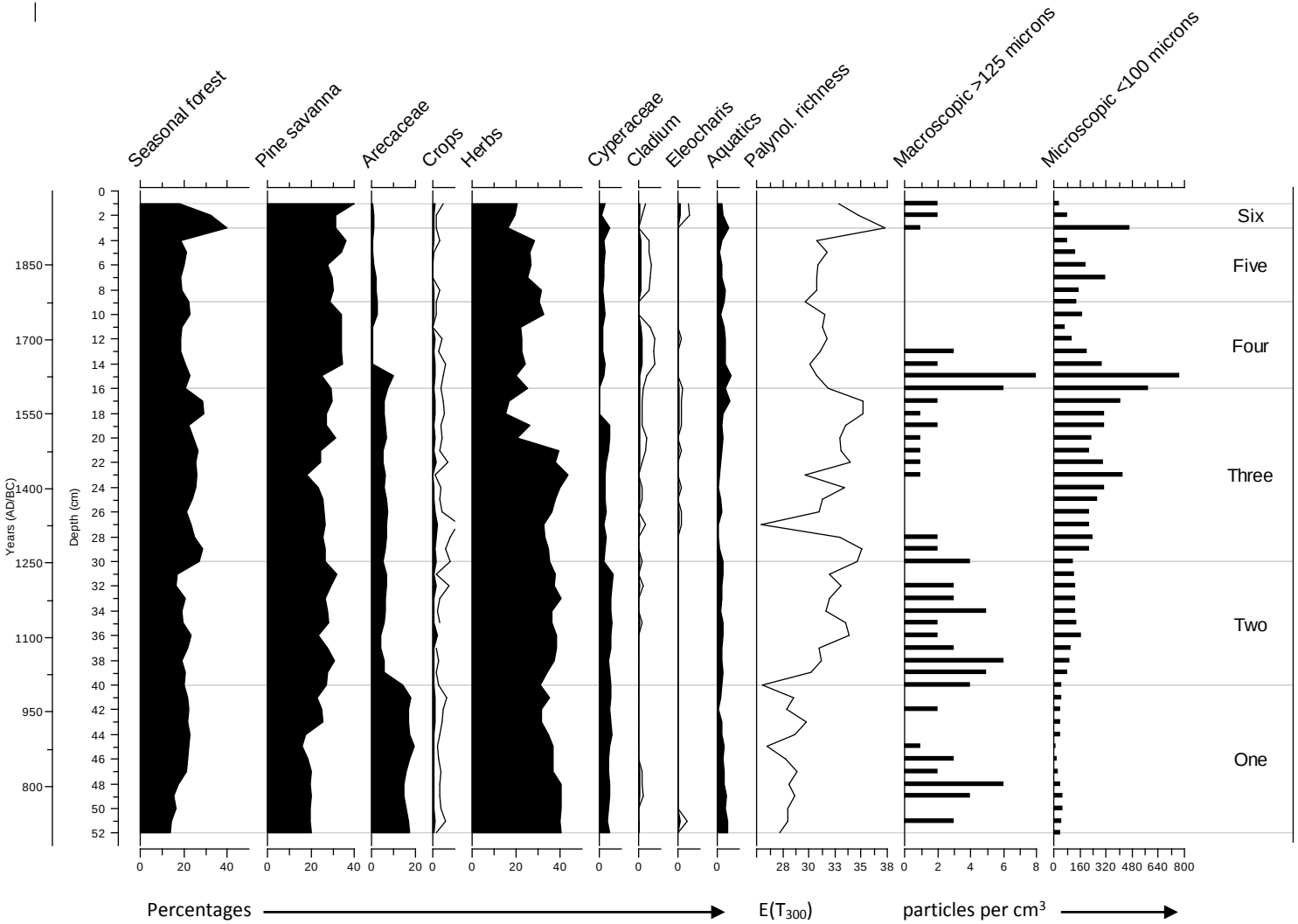

Figure 4.5 Summary pollen percentage and palynological richness diagram, with charcoal concentration (presented with pollen zones) for the Lamanai II (2010) core, NRL. ('Seasonal forest' represents 'Seasonally dry tropical forest or SDTF. Fine black line on the 'Crop' taxa reflects x10 exaggeration of pollen percentage)

Palms peak in this zone (average 16.4%), ranging between 14.1 - 19.5%. Herb taxa peaks in this zone (36.7%) and an equivalent peak is also found in Zone Two (c. 900 BC – AD 350; 220 – 100 cm) of the Lamanai I (1999) core (46.2%). Chenopodiaceae/Amaranthaceae (5.3 - 28.2%), Poaceae (3.5 - 9.6%) and Asteraceae (1.6 - 8%) comprise the herb signal of zone one of Lamanai II (2010) core. Crop taxa include *Capsicum*, *Cucurbita*, *Ipomoea batatas* type and *Z. mays*, with *Ipomoea batatas* type and *Z. mays* the most consistently present throughout this zone. Cyperaceae and semi-aquatic taxa feature in small amounts (<5%).

Zone Two: 40 – 30 cm

Seasonal forest values average 20.5% in Zone Two, ranging between 16.3% and 27.2%, and increases from the base of this zone (40 cm) to the top (30 cm). Morticaceae/Urticaceae (3.4 - 8.2%), *B. simaruba* (1 - 3.1%), *M. brownei* (1.2 - 2.8%) and *M. zapota* (0.7 - 2.7%) are the most abundant taxa in this zone, with *Acalypha* type, *Brosimum* type, *Spondias* type, *Swietenia* type, *Maclura* type, *Talisia* type, *Ulmus* and *Vitex* type found in lower amounts (<3%). Pine savanna averages 27.9%, and has a range of 26.5 - 32.2%. *Pinus* dominates in this zone (5.9 - 15.5%), with Combretaceae/Melastomaceae (0.2 - 6.2%) and *Byrsonima* (3.4 - 5.9%) also present. *Cecropia*, *Curatella* and *Quercus* are present (<4%), as are *H. campechianum*, *Mimosa*, *Myrica* and *Myrtaceae* (<2%). *Cecropia*, *Quercus* and Combretaceae/Melastomaceae increase from the base of the zone (40 cm, combined value of 3.5%) towards the top (30 cm, combined value of 13%), whereas *Pinus* has the opposite trend, decreasing from 15.5% at 40 cm to 5.9% at 30 cm.

Palms average 5%, with a range of 1.2 - 14.1%, decreasing from the bottom of the zone (40 cm, 14.1%) towards the top (30 cm, 1.2%) of this zone. Herb taxa have a secondary peak in this zone (36.6%), with Asteraceae (2.1 - 11.1%) and Poaceae (3.5 - 12.4%) increasing from the bottom of this zone (40 cm) and, conversely Chenopodiaceae/Amaranthaceae (16.9 - 25%) decreasing from the base of zone two. Crops include *Z. mays* (0.1 - 2.3%) and *Cucurbita*, *Capsicum* and *Ipomoea batatas* type in smaller amounts (<1%). Cyperaceae has the highest average value in this zone (5.5%) and decrease from 35 cm to 30 cm (2.1 - 6.6%) whereas semi-aquatic increases during 34 - 30cm (1.8 - 2.7%).

Zone Three: 30 – 16 cm

Average seasonal forest signal has a secondary peak in this zone (25.3%) with a range of 20.6 - 29.5%, peaking at 18 cm. Seasonal forest taxa comprise Morticaceae/Urticaceae (2.2 - 8.2%), *Brosimum* type (0.7 - 3.4%), *Talisia* (0 - 3.1%) and *M. zapota* (1.8 - 3%). *M. brownei*, *B. simaruba*, *Acalypha* type,

Luehea type, *Swietenia* type and *Guazuma* type present in smaller amounts (<3%), as well as *Spondias* type, *Cnidoscolus*, *Croton*, *C. pentandra*, *Sweitenia type*, *Celtis* and *Vitex* (<2%). *M. brownei*, *B. simaruba* and Morticaceae/Urticaceae decrease with increasing depth, whereas *Maclura* type, *Brosimum* type and *Luehea* type increase from the base of this zone (30 cm) to the top (16 cm). Average pine savanna signal is the second lowest in Zone Three (26.3%), and has a range of 18.7 - 31.5%. *Pinus* (1.6 - 12.7%) and Combretaceae/Melastomaceae (6.1 - 10.7%) dominate this zone, with *Mimosa* (0.8 - 4.9%) and *Byrsonima* (0 - 4.3%) also present. *Cecropia* and *Quercus* are observed in lower amounts (<4%) and *Dalbergia glabra*, *H. campechianum* and *Myrica* are also present in small amounts (<2%). Palms average 4.7%, increasing from 1.1% at 30 cm to 7.6% at 16 cm. Herb taxa average 31.7%, featuring Chenopodiaceae/Amaranthaceae (4.4 - 27.5%), Poaceae (6.1 - 12.1%) and Asteraceae (3.11 - 8.8%). The average combined crop signal peaks in this zone, with *Z. mays* present throughout the zone, peaking at 2.3% (25 cm). *Capsicum*, *Cucurbita* and *I. batatas* type are also present (<1%). Cyperaceae ranges between 0 and 4.7%, and semi-aquatic taxa increases between 24 and 17 cm (ranging between 0.62% and 5.7%).

Zone Four: 16 – 9 cm

Seasonal forest taxa average 20.8% in Zone Four, ranging between 18.5 and 23.1%. Morticaceae/Urticaceae has a range of 1.9 to4.8%, with *Luehea* type, *Sweitenia* type, *Brosimum* type, *Maclura* type and *M. zaopta* present in lower amounts (<4%). *M. brownei*, *Spondias* type, *B. simaruba*, *Acalypha* type, *C. pentandra*, *Talisia* type, *Phyllostylon* type, *Ulmus*, *Vitex* and *Guazuma* are also present, but in small amounts (<2%). Zone Four has the second highest average pine savanna values, with *Pinus* (3.8 - 12.7%), *Mimosa* (1 - 10.6%) and Combretaceae/Melastomaceae (5.8 - 10.1%) featuring strongly. *Cecropia*, *Curatella*, *Quercus* and *H. campechianum* are also present (<5%). Palms have an average of 3.2% in Zone Four, with a range of 0.4 - 10.1%. Herbs average 25% which is the second lowest for this core, and has a range of 20.1 - 32.7%. Taxa include Chenopodiaceae/ Amaranthaceae (5.8 - 17.9%), Poaceae (6.9 - 9.8%) and Asteraceae (5.2 - 9.5%). Average combined crop taxa are 0.6%, with no single crop higher than 0.5% at any sample point within this zone. *Capsicum*, *Cucurbita* and *Ipomoea batatas* type are absent between 9 and11 cm. Cyperaceae has the lowest average value in this zone (1.8%) and semi-aquatic taxa averages 3.6%, with a range of 1.5 - 6.1%.

Zone Five: 9 - 3 cm

In Zone Five, seasonal forest signal has a second lowest average value for the Lamanai II (2010) core (20%) and is in the main comprised of Morticaceae/Urticaceae (3.5 - 5.8%), *Brosimum* type (1.5 - 3.94%) and *M. brownei* (0.82 - 2.4%). *Spondias* type, *B. simaruba*, *Acalypha* type, *C.*

pentandra, *Swietenia* type, *Maclura* type and *M. zapota* are present in lower amounts (<2%). The pine savanna signal has a range of 27.9 - 36.1% and an average of 31.6%. Dominant taxa include Combretaceae/Melastomaceae (7.1 - 13.6%), *Pinus* (3.2 - 13.5%), *Mimosa* (3.3 - 10.6%) and *Cecropia* (1.1 - 5.2%). *Curatella* and *Byrsonima* are present in lower amounts (<3%), and *H. campechianum*, *Quercus* and *Myrtaceae* are observed in small quantities (<2%). Palms have the second lowest average value in this zone (1.5%), and crops have the lowest average value (0.3%) with no *Cucurbita* or *I. batatas* type present, and *Capsicum* only present once (8 cm). Herbs have an average value of 28.2%, with Chenopodiaceae/Amaranthaceae (14 - 17.4%), Poaceae (3.6 - 8.6%) and Asteraceae (4.7 - 6.9%) present. Cyperaceae has an average value of 2.2% (range: 1.6 - 2.5%) and semi-aquatic taxa have an average value of 2.4% (range: 1.23 - 3.5%).

Zone Six: 3 - 0 cm

The seasonally dry tropical forest signal has the greatest abundance and variety of taxa in Zone Six, in comparison with the rest of the short core, with values ranging between 18.2 and 40% (average 30.3%). Forest taxa, as a whole peak in this zone at 3 cm (40%) and this is the peak for the whole core. Values decrease across this zone, falling to 32.6% at 2 cm and 18.2% at 1 cm. Taxa comprise Morticaceae/Urticaceae (3.6 - 7.6%), *M. brownei* (2.8 – 4.0%), *M. zapota* (2.7 - 5.7%), *Acalypha* type (0.5 - 4.5%), *Brosimum* type (2 - 3.2%) *Swietenia* type (1.7 - 3.7%), *B. simaruba* (0.3 - 2.9%), *Talisia* type (0 - 3.2%) and *Guazuma* type (0 - 2.4%). The following taxa are found in small amounts (<2%): *C. pentandra*, *Celtis* type and *Vitex* type. *Spondias* type, *Croton* type, *Luehea* type, *Maclura* type, *Drypetes* type and *Phyllostylon* type are found at <1% throughout this zone. Pine savanna values peak (39.7%) at the top of Zone Six (1 cm) and this is the peak for the Lamanai II (2010) core. Pine savanna values average 34.3% and range between 31.6% and 39.7% in this zone. The greatest abundance and diversity occurs at the topmost part of this core (1 cm), where values are similar to those observed for modern pine savanna. Highest levels of *Pinus* (15.9%), Combretaceae/Melastomaceae (12%), *Mimosa* type (4%), *Byrsonima* (2.6%), *Quercus* (2.5%), *Myrica* (2.1%) and *H. campechianum* (2%) are observed. *Pinus* (10.8 - 15.9%) and Combretaceae/ Melastomaceae (9.6 - 12%) dominate in this zone and the following taxa are present in lower amounts (<3%), *Byrsonima*, *Cecropia*, *Curatella*, *Dalbergia*, *H. campechianum*, *Mimosa*, *Quercus* and Myrtaceae. Palms are present in the lowest average amount in this zone (0.9%), as are herb taxa (18.7%). Crops are present (combined crop average 0.5%), as is Cyperaceae (5.5%). Semi-aquatic taxa peak in this zone at 3.4%.

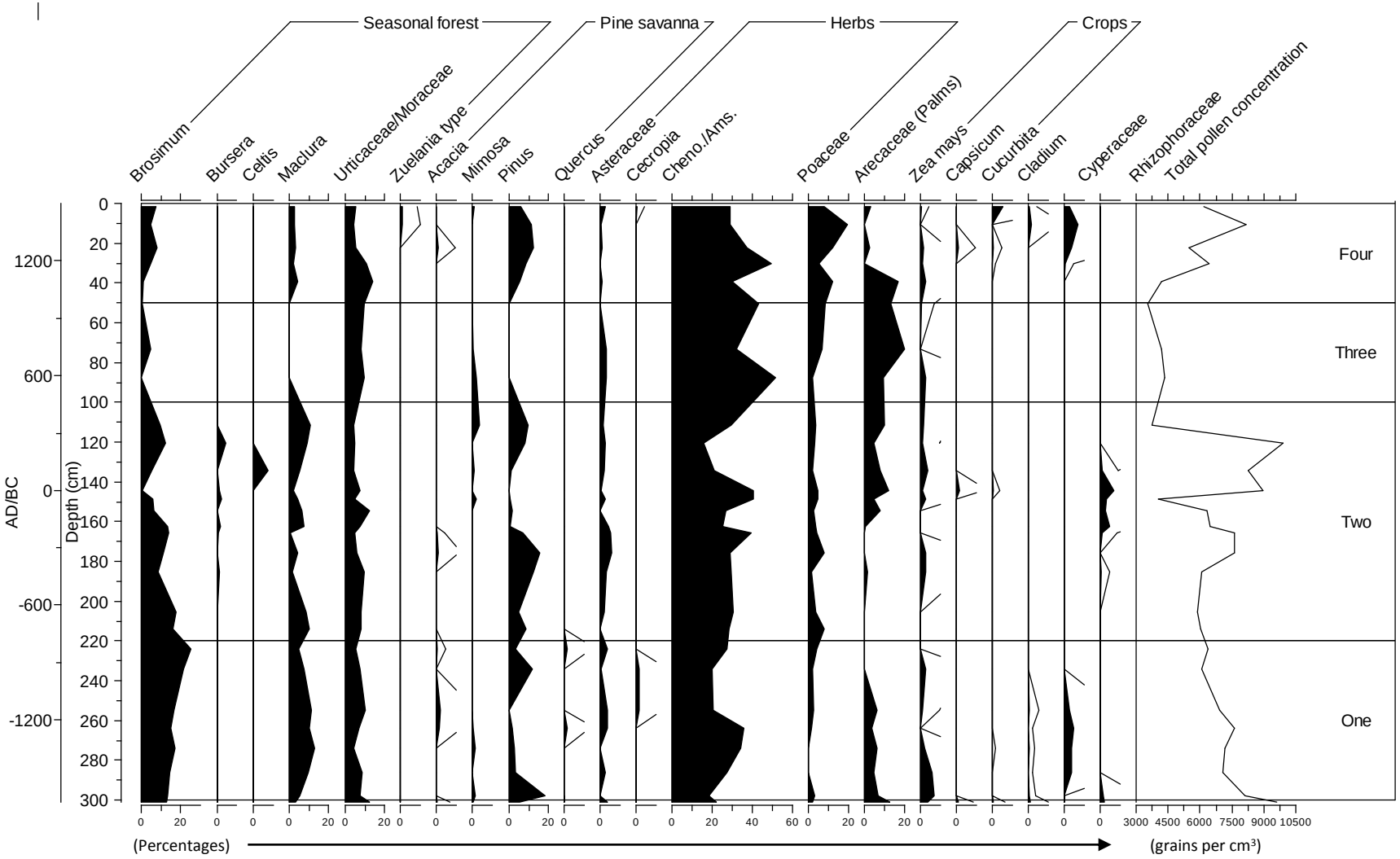

Figure 4.6 Detailed pollen percentage diagram and summary pollen concentration for the Lamanai I (1999) core, NRL ('Seasonal forest' represents 'Seasonally dry tropical forest or SDTF. 'Cheno/Ams': Chenopodiaceae/Amaranthaceae; the fine black line reflects x10 exaggeration of pollen percentages.)

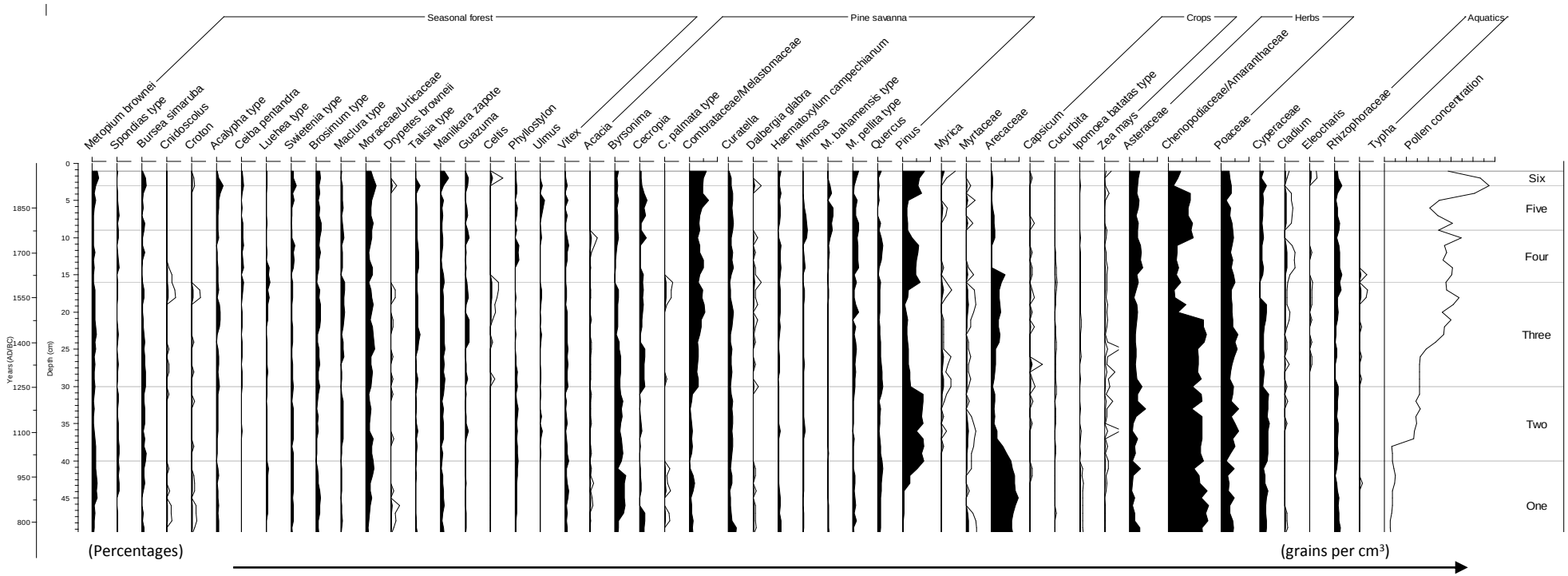

Figure 4.7 Detailed pollen percentage diagram for the Lamanai II (2010) core, NRL, with total pollen concentration data. (The fine black line on the percentage data reflects x10 exaggeration of pollen percentages. 'Seasonal forest' represents Seasonally Dry Tropical Forest or SDTF)

4.4.4 Pollen concentration

Broadly, pollen concentration is lower in the Lamanai I (1999) core (Fig.4.6) than the Lamanai II (2010) core (Fig.4.7). Zones One and Two of the Lamanai I (1999) core have an average pollen concentration of over 7,000 grains per cm^{-3}. This decreases in Zone Three to 4,000 grains per cm^{-3}, increasing to almost 5,500 grains per cm^{-3} in Zone Four. Zone One of the Lamanai II (2010) core has the lowest pollen concentration of this core (4300 grains per cm^{-3}) and the second lowest value across both cores. Pollen concentration increases throughout the Lamanai II (2010) core, rising to 6,300 grains per cm^{-3} in Zone Two, 9,200 grains per cm^{-3} in Zone Three and to over 10,000 grains per cm^{-3} in Zones Four and Five. Zone Six contains the highest average pollen concentration of all zones in both cores (13,150 grains per cm^{-3}), peaking at 3 cm (14,950 grains per cm^{-3}).

i) Rarefaction analysis

Palynological richness values are low in the Lamanai I (1999) core (Fig.4.4) with averages of 26.6 $E(T_{300})$ and 25.3 $E(T_{300})$ respectively. Average palynological richness in these zones is lower than the lowest average values found in the Lamanai II (2010) core (Fig.4.5: Zone One, average 28.1 $E(T_{300})$). Palynological richness increases in zone three (average 28.1 $E(T_{300})$) and peaks in Zone Four (32.1 $E(T_{300})$), with peak palynological richness at 6 cm (32.5 $E(T_{300})$). In the Lamanai II (2010) core the lowest average palynological richness value is 28.1 $E(T_{300})$. This increases through Zone One and continues to increase through Zones Two and Three, which have palynological values of 31.4 $E(T_{300})$ and 32.7 $E(T_{300})$ respectively. After a tertiary peak (35.1 $E(T_{300})$ at 29 cm, values fall sharply in Zone Three, decreasing to 25.4 $E(T_{300})$ at 25 cm. Values broadly increase throughout Zone Three. Zone Four values remain constant, with an average of 32.1 $E(T_{300})$, a range of 29.7 - 31.9 $E(T_{300})$. This trend continues into Zone Five, with an average of 30.7 $E(T_{300})$. Zone Six contains the peak average palynological richness value (34.9 $E(T_{300})$) and the core peak (37.3 $E(T_{300})$) at 3 cm.

4.4.5 Linking the Lamanai I (1999) and the Lamanai II (2010) cores

The description of the sediment unit at the base of the Lamanai II (2010) core (39 – 52 cm) and the Lamanai I (1999) core (200 – 90 cm see Metcalfe et al., 2009) suggests that these two cores contain sediments from the same stratigraphic unit. The date at 50 cm from the Lamanai II (2010) core of AD 686-873 (1240 ± 30 ^{14}C yr BP), and the confirmation that the top of the core is modern suggests that this core both overlaps with the Lamanai I (1999) core from c. AD 700 and continues to capture the sediment record until the modern period (c. 2010). The palm pollen signal provides significant evidence that the second unit of the Lamanai II (2010) core overlaps with the Lamanai I (1999) core. A high palm pollen signal is observed in Lamanai I (1999) during the

period 100 BC – AD 1100 (range 4.7 - 19.7%; average 10.6%), with a peak at c. AD 740 of 19.7%. A similar signal is found in Lamanai II (2010) core during 36 – 52 cm (range 4.1 – 19.5%; average 14.2%), with a peak of 19.5% observed at 50 cm (AD 686-873). This suggests that Zone One of Lamanai II (2010) core overlaps with the Lamanai I (1999) core, and an examination of the pollen concentration levels also support the overlap of these two cores. Average pollen concentrations in Zone One, Lamanai I (1999) core are observed as 4,432 grains per cm^{-3} with a concentration of 4,343 grains per cm^{-3} at 50 cm (calibrated date AD 686 - 873). Average pollen concentrations in Zone Three, Lamanai II (2010) core are similar, with a concentration of 4,020 grains cm^{-3}. The similarity of these average pollen concentrations across zones from both cores is increasingly important as it may suggest there is an overlap in the basal sediment unit from Lamanai II (2010) core and the top unit of the Lamanai I (1999) core.

Table 4.3 compares the pollen percentages, concentrations, loss-on-ignition, carbonate content and charcoal concentrations of the Lamanai I (1999) core c. AD 740 (39.5 cm) with the Lamanai II (2010) core c. AD 686 - 873 (50 cm). This demonstrates that the seasonal forest, palm and herb signals at these two points are very similar, as are the loss-on-ignition percentages. The pine savanna signal from the Lamanai I (1999) core at c. AD 740 (39.5 cm) is approximately three times smaller than that observed in the Lamanai II (2010) core c. AD 686 – 873 (50 cm), and the carbonate content of the Lamanai I (1999) core at the same point is almost twice that of the Lamanai II (2010) core. The sediment description pollen (Seasonal Forest, Palms, Crops, Herbs and overall pollen concentration) and loss-on-ignition signals and the radiocarbon evidence broadly suggest that there is overlap between the two Lamanai cores, and that together these cores represent the period 1500 BC – modern.

Table 4.3 Comparing two sample points from Lamanai I (1999) and Lamanai II (2010) cores

Core	**Pollen (%)**						**LOI (%)**	**$CaCO_3$ (%)**	**Charcoal (particle per cm^3)**
	SF	**PS**	**Palms**	**Crops**	**Herbs**	**Conc. (particles per cm^{-3})**			
Lamanai I (1999) core c. AD 740 (39.5cm)	19.5	6.5	19.7	2.4	42.4	4343	5.8	33.8	279
Lamanai II (2010) core	16.5	19.8	19.5	0.7	40.6	4180	2.6	17.8	59

c. AD 686-873 (50cm)									

4.5 Results summary

In this section of the chapter, the stratigraphy and chronology of the two cores (Lamanai I (1999) and Lamanai II (2010)) have been described. A detailed account of the charcoal and pollen analyses undertaken on the two cores from the NRL, Lamanai have been presented. In addition, loss-on-ignition analyses have been presented to support the primary proxies of pollen and charcoal. The following section will explore the key themes and ideas that have emerged from these analyses.

4.6 Discussion

4.6.1 Pollen source

The modern core top sample from the Lamanai II (2010) core reflects the dominant ecosystem types around the site at Lamanai, and the wider New River Lagoon catchment. Seasonal forest is found to the west of the New River Lagoon and surrounding the present archaeological site, and pine savanna is found to the east of the lagoon (see section 2.1.2). Seasonal forest (SDTF) includes ecological dominants such as *B. alicastrum, B. simaruba, M. zapota* and *S. macrophylla* that are reflected in the modern pollen assemblage. However, compared with modern pollen spectra from forested sites in this region that report Moraceae/Urticaceae comprising >40% of the pollen assemblage (Bhattacharya et al., 2011), the modern core sample has a relatively low arboreal signal (18%). Correa-Metrio et al. (2011) reported that it was not possible to distinguish evergreen seasonal, tropical semi-deciduous and tropical deciduous using their modern pollen spectra, and that these subcategories had to be grouped as tropical seasonal forest. This large group of taxa meant that the pollen signal was wide (‘fuzzy’), and this could account for the comparatively low arboreal signal in the modern assemblage from the NRL.

Savannas dominated by *P. caribaea* are represented in the modern pollen assemblage by abundant *Pinus* pollen. Pines are prolific producers of wind-dispersed pollen, thus regional sources, such as high elevations from Mexico/Guatemala, may contribute some pollen to the *Pinus* signature in the NRL record. However, source plants located nearer to deposition sites contribute a substantially larger proportion of pollen compared with regional or ‘background’ pollen where vegetation patches in a heterogeneous environment are larger than the lake area, as in the case of Belizean pine savanna (Sugita, 1994). Therefore, we can be confident that nearby pine savannas east of the NRL, contribute the greatest proportion of pine pollen in NRL, and past variations in the abundance of pine in these savannas are

reflected in the pollen signature. *Byrsonima crassifolia* is also a characteristic taxon found in Belizean pine savannas and, although of low abundance in the modern pollen assemblage at NRL, *Byrsonima* has been identified as an important indicator species of pine savanna in the modern pollen rain from northern Belize, as it was exclusively found in the modern pollen spectra of pine savanna sites (Bhattacharya et al., 2011). Ledru (2002) and Gosling et al. (2009) have both demonstrated that *B. crassifolia* is a good indicator species of savanna (or cerrado) in the Neotropics, and the presence of the less prolific *Byronsima* (of which there is only one additional species found in Belize), combined with *Pinus* pollen, is indicative of local pine savanna.

The presence of *H. campechianum* and *M. brownei* most likely indicate the logwood fringe that surrounds the NRL today. Palms are not abundant in the modern pollen record, and this underrepresentation is possibly due to both the large grain size (>60 µm) and the large catchment of the New River Lagoon (13.5 km^2). Large grains may not get transported far into a lake. Crop taxa were only represented by a small amount of *Z. mays;* however, it has been demonstrated in both field and laboratory settings that, because of its large size (50–120 µm), *Z. mays* grains are poorly dispersed from the source plants (Raynor et al., 1972; Jarosz et al., 2003). In addition, the condition of the pollen grain has been used as a proxy for taphonomy (Cushing, 1967; Lowe, 1982; Tipping, 1987). In experimental investigations into the preservation of pollen grains, Twiddle and Bunting (2010) reported that mechanical damage (i.e. crumpling and folding of grains) was more prevalent in grains of a larger size. The presence of multiple, undamaged *Z. mays* grains most likely represent a distinctive local signal of economic or agricultural taxa within a regional record of vegetation change, and therefore provides an opportunity to examine both local and regional change within this record.

Before continuing with this discussion of the palaeoecological record, a table summarising the key taxa of each of the major ecological groups presented in Figs.4.4 - 4.7 are outlined, with details of their common and Maya names and possible uses.

Table 4.4 Key taxa from seasonally dry tropical forest, pine savanna, herbs, palms and crop ecological groups, with summary information concerning their potential uses

Key species (Family)	**Common (Maya) name**	**Uses** (text in bold are uses identified by Peña-Chocarro and Knapp, 2012)
SEASONALLY DRY TROPICAL FOREST		
Metopium brownei (Anacardiaceae)	Black poisonwood (Chechem)	Known for its poisonous properties, on contact with the skin causes intense itching, blistering and swelling (Schlesinger, 2001). **Building, fuel, forage, poison**.
Spondias mombin (Anacardiaceae)	Hog plum (kinim**)**	Coe (1994) suggests a ritual use. **Building, fuels, fruits, medicines, forage**.
Tabebuia rosea (Bignoniaceae)	May flower	**Building, fuels, medicines**
Bursera simaruba (Burseraceae)	Gumbolimbo/ Tourist tree (Chacah)	Schlesinger (2001) suggests that it is one of the most common trees in the Maya home garden, used for food, medicine, fodder, building material, fuel, tools, religious. Red resin used for varnish and glue.
Cnidoscolus (Euphorbiaceae)	Spinach tree	Edible leaves, similar to spinach. Also used as a tea. Leaves often used as wrappers for tamales in the Yucatan. Sap used as a purgative to 'clean out' kidneys and bladder (Schlesinger, 2001).
Ceiba pentandra (Bombacaceae)	Cotton tree/ silk cotton tree (yaaxché)	The ceiba tree was sacred to the Maya (Grube, 2001), its trunk thorns were depicted on Maya ceramics for centuries. Silk fibres used for beds, pillows, packing materials, insulation (Schlesinger, 2001). Not used for timber but for some building e.g. canoes (Schlesinger, 2001). Bears fruit after 7-10 years, may only produce on alternate years (Baker, 1983). **Forage, fuel, medicines, building materials**.
Luehea speciosa (Malvaceae form. Tiliaceae)	Mountain moho (Balmax)	**Building, fuel, forage**

Swietenia type (Meliaceae)	Mahogany (uch)	Expensive decorative hardwood. Ancient Maya probably used mahogany for canoe building and carving (Schlesinger, 2001). **Building and medicinal**.
Brosimum alicastrum (Moraceae)	Breadnut tree/ramón (ujushte)	One of the most useful trees of the Yucatán forest (Schlesinger, 2001). Fresh seeds can be boiled and eaten or dried and then ground into a meal from which a sort of bread can be made, hence the name breadnut. Breadnut often found around maya ruins either because the Maya actively cultivated them and/or because this species grows well in the limestone rich soils found in archaeological sites (Lambert and Arnason, 1978; 1982). Edible fruit the most important aspect of this tree. Today the Maya cultivate ramón around their homes – a single tree can produce 12,000 fruits per fruiting. Fruit may be mixed with maize as an extender. Wood is strong but rots so has little commercial value. **Building, food, forage, medicine.**
Maclura tinctoria (Moraceae)	Fustic (chak ox)	**Food, forage, medicine, building.**
Drypetes brownie (Euphorbiaceae)	Bull Hoof	**Building**
Talisia (Sapotaceae)	(Guaya)	**Edible fruits, building, fuel, forage**.
Manilkara zapota (Sapotaceae)	Zapote/ chicle tree (Ya)	The wood is hard, heavy, durable, and resistant to decay, has a wide variety of applications, including fencing posts, general construction, furniture (Schlesinger, 2001). One of the few woods known to have been used in the construction of Maya temples, for example as elaborately carved door lintels (Lentz and Hockaday, 2009). The fruits are edible, and latex obtained from the bark yields chicle, the original base for natural chewing gum. De los Angeles La Torre-cuadros and Islebe (2003) – *M. zapota* most valuable for modern locals – chicle (latex) and wood for construction. Found in SDTF and secondary vegetation. **Building, food, medicine**.
Guazuma ulmifolia (Sterculiaceae)	Cedar/ pixoy	The bark of many trees of the Malvaceae family has a strong fibre. Stems used for rope and wood used for making small boats (Schlesinger, 2001). Sweet fruit consumed by many animals, but numerous seeds make it unattractive to humans. **Building, fuel, food, medicine, forage, honey**.
Celtis (Ulmaceae)	(Muc)	Edible fruits (Schlesinger, 2001)

Vitex gaumeri (Verbenaceae)	Fiddlewood/walking lady (yaknik)	Schlesinger (2001) suggests that it was used for medicine, fodder, building material and firewood. The elastic and resistant wood of *Vitex* is used as building materials, especially where the supply of harder woods has been depleted. Carved for instruments (Roys, 1931). **Building materials, fuel, medicines, forage (fruits).**
Zuelania (guidonia) Salicaceae (Formerly Flacourtiaceae)	Drunken bayman wood (Tamay)	This tree has been called 'the liquid-amber tree of this land' (Roys, 1931). Liquid amber (sweetgum), so named because of its brownish sap which is sometimes used for gum. Young leaves used to cure asthma and coughs. Roots for snakebite and headache (Roys, 1931). **Building, fuel, medicine, forage**.
PINE SAVANNA		
Acacia (Fabaceae)	e.g. Acacia collinsii/Cockspur/ (subin) e.g. Acacia dolichostachya/ wild tamarind e.g. Acacia glomerosa/ jimcrow (sapiche)	**Fire, medicine**. **Building and fuel**. **Building, fuel, honey**.
Byrsonima crassifolia (Malpighiaceae)	Craboo/nance (Zacpan)	Schlesinger (2001) suggests that the modern Maya stew the fruit to make jam, eat it raw or ferment it for wine. Birds and mammals eat the fruit. *Byrsonima* are a key feature of the pine savannas and are fire-resistant trees that can also survive drought and flooding. **Building, fuel, food, medicines, foraging**.
Cecropia (Urticaceae)	Trumpet tree (a' kl/ cho-otz/ po-hór)	Fast growing disturbance tree. Grows in abandoned milpas; can cover land in 3-5 years then die in 30 (Schlesinger, 2001). Medicinal: leaves used in tea as a diuretic or to draw out fevers. May also be used as tobacco (Schlesinger, 2001). **Medicinal/building/religious-cultural**.
Combretaceae/ Melastomaceae	e.g. Bucida buceras (Combretaceae) bullet tree(puk-te) e.g. Conocarpus erectus	**Building**.

	(Combretaceae) – white mangrove (kanche) e.g. Terminalia Amazonia (Combretaceae) Bully tree (canxún**)** e.g. Laguncularia racemosa (Combretaceae) white mangrove (but-nuut)	**Building and fuel**. **Building**. **Building and fuel**.
Curatella (Dilleniaceae)	Sand paper tree (saha)	**Building, fuel, food, medicine.**
Dalbergia (Fabaceae)	Dalbergia stevensonii/ Rosewood	**Building**.
Haematoxylum (Fabaceae)	Logwood (Ek)	Central use – heartwood used as a dye. Lentz and Hockaday (2009) – H.campechianum L. with zapota was most common trees used for lintels in the temples of Tikal. H. campechianum was dominantly used during AD 766 -806. Lentz and Hockaday (2009) suggest that this period of use of H. campechianum was to enable the restocking of M. zapota. Tree found in seasonally inundated savannas. **Building, fuel, medicine**.
Quercus oleoides (Fagaceae)	Live Oak	Schlesinger (2001) suggests the thick bark protects the oak from fires in the savannas. **Building and fuel.**
Pinus (Pinaceae)	Caribbean pine (huhub)	Archaeological evidence suggests that the ancient Maya burned pine as torches in ceremonial and utilitarian contexts. Modern Maya cut shards of Caribbean pine into small torches, burning them like candles

		(Schlesinger, 2001). The species is v fire resistant with tough cones and thick outer bark (Schlesinger, 2001). **Building, fuel, medicine, cultural/religious.**
HERBS		
Chenopodiaceae/Amaranthaceae	Schlesinger (2001) suggests that herbs including chenopods and amaranths are used for edible greens and seeds. Herbs found in milpas are not necessarily only weed/disturbance related, they may be cultivated.	
Cucurbita (Convolvulaceae)	Gourds	Key Maya food crops grown in the Yucatán.
Ipomoea batatas (Convolvulaceae)	Sweet potato	
Zea mays (Poaceae)	Maize	
Capsicum (Solanaceae)	Pepper	
Arecaceae 1) Thrinax radiate; 2) Sabal yapa; 3) Acoelorraphe wrightii; 4) Orbigyna cohune; 5) Roystonea olerecea; 6) Desmoncus schippii; 7) Saval morrisiana 8) Acrocomia aculeata	**Palms** 1) Fan palm (chit) 2) - 3) Palmetto (tasiste) 4) Cohune (chun-kuy) 5) - 6) - 7) - 8) Cocoyal (mop)	De los Angeles la Torre-cuadros and Islebe (2003) suggest palms, especially *Thrinax radiate* and *Sabal yapa* are used in the construction of roofs and walls of palapas and brooms. Trunks of *Acoelorraphe wrightii* used for palapa walls (transition forest dominant). Schlesinger (2001) suggests that *Orbigyna cohune* is used for thatching when *T. radiate* and *S. yapa* are less abundant.

4.6.2 Maya land clearance for agriculture and construction

The exact date of origin of a Maya settlement at Lamanai is unknown, but it has been suggested as being c. 1500 BC (Pendergast, 1981; 1982a&b; 1986) (see section 2.2.1). The pollen data from the Lamanai I (1999) core shows that *Z. mays* and *Cucurbita* were being cultivated near the NRL by 1630 BC, indicating that the Maya were established and practising agriculture at Lamanai before 1500 BC. Agriculture is also indicated by the presence of economically important plants in other records from Northern Belize c. 2000–1000 BC, including Laguna de Cocos, Albion Island (Hansen, 1990); Cobweb Swamp (Jones, 1994) and Cob Swamp (Pohl et al., 1996) (See Fig.2.6). At c. 1240 BC synchronous increases in charcoal, herb taxa and Z. *mays*, coincident with a decrease in forest and savanna taxa provides strong evidence for Maya land clearance for field-based agriculture. Throughout the record there is a clear and consistent *Z. mays* signal, with multiple pristine grains observed, and only two periods where *Z. mays* is absent (830 - 640 BC and 220 - 100 BC).This concentration of *Z. mays* is not found in other records from the region. By comparison, Hansen (1990) and Jones (1994) identify the presence or absence of large grain cultigens, such as *Z. mays, Manihot* and *Cucurbita* in some parts of their records using one or two grains. The high level of *Z. mays* observed in the record from Lamanai indicates the extent and close proximity of maize fields to the coring site.

4.6.3 Periods of pine clearance for use in construction and ceremony

i) Pinus as a source of fuel and building material

Abrams and Rue (1998) and McNeil et al. (2010) have suggested that the Maya selectively used *Pinus* for construction and fuel, with vast quantities needed to produce the limeplaster for stucco work. Schlesinger (2001) suggests that at the Maya city of Copán, Honduras, the Maya burned pine as torches, and that the modern Maya cut shards of caribbean pine (*P. carribea*) into small torches, which burn like candles. In the Lamanai I (1999) (Fig.4.6) record *Pinus* has periods where it is much reduced (170 BC – AD 150) or completely absent (AD 600 – 980), and this later period of very low *Pinus* (<1%) from the Late classic/ Early Post-Classic Maya is also visible in the Lamanai II (2010) at 52 - 42 cm. Both of these periods of a substantial or complete absence of *Pinus* are consistent with periods of construction and development of the site in the archaeological record, and the pollen record is consistent with the heavy exploitation of *P. caribaea* for timber in nearby savannas. Construction began on the largest known temple (High Temple or Str. N10-43) c. 100 BC and there was significant early Classic building in various areas of the site during AD 100 – 400 (Pendergast, 1981). Between AD 500 and 600, masks were added to the terraced faces of the Mask Temple (Str. N9-56, Pendergast, 1981), and

between AD 600 and 700, a number of buildings around the main plazas were added to and expanded, including the addition of stelae (Pendergast, 1981, 1988; Graham, 2004). During the Terminal Classic (AD 800 – 1000) the construction of masonry platforms continued and the only ball court at the site dates from this period (Pendergast 1982c, 1986). The charcoal record (Fig.4.6) is also consistent with *P. caribaea* being used for fuel, with the primary (AD 590), secondary (1250 BC) and tertiary peaks of charcoal coincident with very low or absent *Pinus*. A secondary peak in silica, iron, aluminium and magnetic susceptibility c. 170 BC to AD 270 (Metcalfe et al., 2009) indicates increased erosion from the NRL catchment which could be associated with increased building at Lamanai. The palaeolimnological evidence is therefore in agreement with the palynological and archaeological records.

At the top most part of the Lamanai I (1999) (Fig.4.6) core (c. AD 1500), the decrease in arboreal signal is dominated by a reduction in *Pinus*, which could indicate the continued use of pine as a source of fuel and in construction, as it was a familiar resource to the European settlers, and easily accessible in the pine savannas. The early Spanish colonial period at Lamanai dates from c. AD 1544 - 1641, with the construction of two churches (YDL I and YDL II) during this period (Graham, 2011; Pendergast, 1975); this further supports the use of pine at Lamanai as a source of fuel and a building material. Further evidence for a link between pine and construction in the European period can be found in a reduced pine signal (<5%) observed in Zones Three and Five of the Lamanai II (2010) core (Fig.4.7). The radiocarbon date of 143 yr BP (± 36) at 15 cm suggests that this is a signal of clearance during the 19th century. This was a period of substantial clearance and construction at Lamanai, as the first known Belizean sugar mill was built in the mid 1850s within the modern day archaeological site, and was in operational use during c. 1860 – 1875 (Fig. 2.9). Pendergast (1982a) suggests that land clearance for sugar cane plantations began in and around Lamanai as early as the 1830s, with an *Indian Church Plantation Grant* issued by the British Government in 1837. Morris (1883) describes the use of pine torches during overnight trucking of mahogany logs from the forest to the river bank during the 19th century.[16] The recovery of the *Pinus* signal in the Lamanai II (2010) core from 5 cm suggests that as the population of the Lamanai area reduced to a small hamlet at Indian Church, the pine savanna ceased to become a significant source of timber for construction and fuel, and regrew.

This is the first record which demonstrates that *Pinus* can be used as a proxy for periods of construction, because it is possible to distinguish between the extraction of *Pinus* for timber in savannas from clearance for agriculture in the broadleaf forest. This distinction is possible due to the edaphic controls on the distribution of these vegetation types (Furley, 1994, 2007). At Copán, Honduras, McNeil et al. (2010) reported the most substantial deforestation of pine (*Pinus*) during the Preclassic period (c. 1800 BC – AD 250), during

[16] See Chapter 5 for a more detailed description of mahogany production in the 19th and 20th centuries.

periods of clearance for agriculture, and, that pine levels increased during the Classic period as a result of management by the Maya. At Lamanai, *Pinus* increases post AD 1000 after the end of major construction at the site, whereas broadleaf seasonal forest species do not (e.g. *Brosimum* type, *Maclura* type). In the European period, *Pinus* continues to be selectively felled, and in the most recent decades the *Pinus* signal increases, coincident with a decline in clearance activity in and around Lamanai.

ii) The use of Pinus in ritual and ceremony

Morehart et al. (2005) suggest that the Maya had two central uses of *Pinus*: domestic (e.g. fuel and as a building material) and ritual (e.g. ceremonial burning of incense and/or torches). Archaeologists have demonstrated the ubiquity of *Pinus* found at assemblages from cave sites including in the Belize River Valley (Graham et al., 1980; Morehart, 2002) and the Sibun River Valley (Pendergast, 1974; Graham et al., 1980; Reents-Buder and MacLeod, 1997; Stone, 1997). Surface sites include Caracol (Chase and Chase, 1998) and La Milpa (Hammond et al., 2000), both in northwest Belize, and two sites from the Belize River Valley, Pook's Hill (Morehart, 2001) and Xunantunich (Lentz et al., 2003) (Fig.1.5). Pine needles and charcoal have also been found in caches (a collection of objects that are intentionally gathered together and ritually buried) in Caracol (Chase and Chase, 1998); La Milpa (Hammond et al., 2000), Xunantunich (Lentz et al., 2003) and Pook's Hill (Morehart, 2001) (Fig.1.5). This frequency, geographical and contextual variety of *Pinus* assemblage demonstrates the important of *Pinus* as a Maya resource.

The utilitarian function of *Pinus* as a torch has been reinforced by the association of *Pinus* charcoal assemblages and ceramic torch holders in cave sites (Graham et al., 1980; Brady, 1989; Stone, 1995; Reents-Budet and MacLeod, 1997). However, Morehart et al. (2005) suggest that pine torches were also part of an important longstanding ritual, with the burning of pine wood and resin an offering to deities a common motif in Classic Maya icongraphy (Schele and Miller, 1983; Stuart, 1998; Martin and Grube, 2000). One ritual use proposed by Morehart et al. (2005) was the burning of pine torches associated with 'a symbolic complex of offering food sacrifices to deities, proposing that the role of pine torches in the past may have been similar to the modern-day ceremonial use of candles…the burning of pine may have been as essential, symbolic act necessary to establish the validity of ritual performances' (p.269). Although *Pinus* is one of the most common features of charcoal assemblages from the Maya Lowlands, demonstrating its widespread use, *Pinus* is not a resource frequently found locally to Maya sites as the ecological distribution of *Pinus* is restricted to upland regions such as the Maya mountains and pine ridges, as well as pine savannas (Bridgewater, 2012). The widespread use of pine, coincident with its limited ecological distribution, further emphasises the cultural significance of *Pinus* for the Maya (Morehart et al., 2005). Furthermore, some archaeologists have suggested that *Pinus* or pine charcoal may have formed part of a Maya trade network

which stretched across the Lowlands (Thompson, 1970; Lentz, 1999; Morehart, 2002; Lentz et al., 2003).

For the Maya, the site at Lamanai had the advantage of an extensive local source of pine found in the savanna on the east side of the New River Lagoon. In an as yet unpublished study of charcoal found in the Classic/ Postclassic structures and caches from the Ottawa Group of structures at Lamanai, Elizabeth Graham identified five *P. caribbea* deposits from structural contexts and thirteen caches which contained *P. caribbea* charcoal fragments. One cache dating from the Classic period (AD 601 - 662) containing *P. caribbea* charcoal also included jade fragments, *Spondylus* and obsidian (N10-77/2); a Late Classic cache (N10-77/3) also contained obsidian and pottery sherds alongside *P. caribbea* charcoal. Caches were also placed as an offering in a room before the final floor was laid (e.g. N10-77/10, c. AD 670 - 859). Of the fourteen caches examined by Graham, thirteen contained *P. carribea* charcoal fragments, and date from the Late Classic/Terminal Classic period (AD 600 - 900), which demonstrates the importance of the use of pine in a ritual context at Lamanai. In both the Lamanai I (1999) (Fig.4.6) and Lamanai II (Fig.4.7) (2010) cores *Pinus* is present in very low levels (<1%) during this period, which may further attest to the high levels of extraction of pine from the savanna adjacent to the New River Lagoon. Perhaps *Pinus* became increasingly in demand as an important part of rituals and ceremonies associated with food in the Maya Lowlands, as some settlements across the region faced ‘collapse’ through periods of Late Classic/Terminal Classic drought (Hodell et al., 1995, 2005, 2007; Curtis et al., 1996; Haug et al., 2003; Neff et al., 2006). The only cache that did not contain *Pinus* but instead contained burnt *Z. mays* seeds, kernels and stalks dated from the Postclassic period (AD 1055 – 1255). The Lamanai I (1999) and Lamanai II (2010) cores both reflect a period of slightly increased *Pinus* levels in the Postclassic period, with an average of 4.7% during c. AD 975 – 1180 (Lamanai I (1999) core) and an average of 4.3% in Zone Two of the Lamanai II (2010) core. This recovery in *Pinus* as indicated by the palynology and the absence of *P. carribea* charcoal in cache N10-2/2 (AD 1055 – 1255) may suggest a shift in the importance of *Pinus*, or perhaps that a declining regional population may have reduced demand for pine wood and/or charcoal.

4.6.4 Multifaceted Maya management of vegetation resources

i) Palms

Palms have long been recognised as an important vegetation resource used by the Maya in the construction of their homes, called ‘palapas’ (Schlesinger, 2001; de los Angeles la Torre-Cuadros and Islebe, 2003) (Fig.4.8). Schlesinger (2001) suggests that the modern Belizean Maya favour *Thrinax radiate* and *Sabal yapa* for thatching, but often use *Orbigyna cohune* as the previous two species are often less abundant. Trunks of the *Acoelorraphe wrightii* palm are used for palapa walls, with *T. radiate* and *S. yapa* used for

the construction of roofs and other household implements such as brooms (de los Angeles la Torre-cuadros and Islebe, 2003). The pollen records from both the Lamanai I (1999) and Lamanai II (2010) cores (Figs.4.4 – 4.7) suggest evidence of palm cultivation. Palms including *Acrocomia aculeate*, *Attalea cohune* and *A. wrightii* form part of the forest cover at the modern site of Lamanai (Meerman and Sabido, 2001) and palms are present in the modern pollen assemblage at low levels (1%), however, in the pollen record there are three periods where the palm pollen signal is much higher (4 - 20%). During 1630 - 1150 BC (Lamanai I (1999) core) (Fig.4.4) the palm signal is much increased (4 - 13%), and again to an even higher level during 100 BC - AD 1100 (5 - 20%). This second period of elevated palm signal is found in both the Lamanai I (1999) core c. 100 BC - AD 1100, and also in the Lamanai II (2010) core between 52 and 36 cm (4 - 19.5%). The last period of increased palms occurs during 24 and 15 cm (Lamanai II (2010) core), with levels slightly lower than the previous two periods of increased palm signal (5.3 - 10%).

Figure 4.8 A modern reconstruction of a Maya dwelling or ‘palapa’ with a palm roof in the gardens of the Musuem of Maya Culture, Chetumal, Mexico (Photo: Rushton, 2012)

These three periods of abundant palms are separated by periods where the palm signal is similar to the modern assemblage (1 - 2%) (Fig.4.4). The first two periods of high palm values are separated by a c. 700 year period (c. 930 – 200 BC). In Lamanai II (2010) the period of elevated palm signal (4 - 19%) at

52 – 36 cm is followed by a period of reduced palm signal during 35 and 25cm, before increasing (5 - 10%) during 24 – 15 cm. The second period of increased palm values (100 BC – AD 1100) is one of substantial construction at Lamanai (Pendergast, 1981) and such disturbance might be associated with an increase in the palm signal. A substantial increase in palms also occurs during a period without significant clearance, during the earliest known Maya settlement at Lamanai (1630 – 1100 BC). This suggests that these periods of increased palm pollen may be due to Maya cultivation. Jones (1994) also recorded increases in the palm signal during periods of Maya occupation and attributed this to Maya cultivation. The most recent period of palm cultivation occurs during the Spanish colonial period, with the palm signal declining sharply post 15 cm in the Lamanai II (2010) core (c. AD 1800) (Fig.4.5). Graham (2011) suggests that Lamanai was an important centre for Christianised Maya in Belize (see section 2.2.2).This suggests that Lamanai had an increasing population throughout the Spanish colonial period, with this population needing housing and other infrastructure that would, in the vast majority of cases, have used palms to construct dwellings, as well as church buildings. Graham (2011) suggests that although the two 16th century churches (YDL I and II) had foundations and some walls made of stone, the majority of the walls and the roofs would have been thatched. This Spanish Christian mission centred in Lamanai further supports the interpretation of an increased palm signal as owing to cultivation, as palms remained an important commodity, even used in the construction of Christian churches.

ii) Late Classic Maya forest gardens

Modern managed forests or ‘forest gardens’ where arboreal species are selected and promoted for their particular useful properties (see section 2.3.1) have been recognised by ecological and ethnobotantical researchers working in the Maya Lowlands (Nations and Nigh, 1980; Alcorn, 1983; Gómez-Pompa et al., 1987; Atran, 1993 and Ross, 2011). Maya managed forests produced trade goods including cacao, copal and rubber (Wiseman, 1978; Healy et al., 1983; Gómez-Pompa, 1987; Lentz, 1991; 2000; Ford and Fedick, 1992; Fedick, 1995 McKillop, 1994; Crane, 1996; Ross, 2011) and McNeil (2012) suggests that forest products such as jaguar pelts, feathers, medicines and decorative woods ‘played critical roles in the accumulation and maintenance of elite power and in the construction of elite identities’ (p.28). The following plants and plant families have been identified in the wider literature as being an important component of Maya forest gardens: Arecaceae, *B. alicastrum*; *B. simaruba*; *C. petandra*, *M.zapota*; *Spondias*; *Swietenia*; *Vitex gaumeri*; *Zuelania Guidonia* (Turner and Miksicek, 1984; Lentz, 1991; Rico-Gray et al., 1991; Lentz et al., 1996; Campbell et al., 2006).

The pollen record from the Lamanai I (1999) core has a low arboreal signal at c. AD 590 (Fig.4.5), with an absence of *Pinus*, reflecting heavy timber extraction from the savannas, and a reduction in pollen reflecting high forest, such as *Brosimum* type and *Maclura* type. This is associated with high herb

taxa, a peak in charcoal concentrations and a strong *Z. mays* signal. This record indicates that this is a period of substantial agricultural activity at Lamanai, and is consistent with both the interpretation of a reduction in pine as a signal for increased construction, as well as the archaeological record described above. After c. AD 590 in the Lamanai I (1999) core (Fig.4.5), there is a slight increase in seasonal forest taxa; *Z. mays* is present between c. AD 970 and AD 1100, and palms peak c. AD 740. In the Lamanai II (2010) core (Fig. 4.7), the seasonal forest signal increases from the base of zone one (52 cm), rising from 14% to 22.5% at 42 cm. Forest taxa that increase throughout zone one include *M. broweni*, *Spondias*, *Luehea*, *Brosimum*, *M. zapota*, *Talisia* and *Vitex*. *Sponidas*, *Brosimum* and *M. zapota* are trees central to the Maya forest (Ford, 2008; Schlesinger, 2001) providing edible fruit as well as timber for construction. *M.broweni*, *Luehea*, *Talisia* and *Vitex* all provide durable timber which was widely used as a source of building materials (Schlesinger, 2001). Palms also peak (19.5%) at 45 cm (zone one) and *Z. mays* and *I. batatas* type are present throughout Zone One. This increase in seasonal forest cover observed after AD 590 in the Lamanai I (1999) core (Fig.4.5) and from the middle of zone one of the Lamanai II (2010) core (Fig.4.7) could represent an increase in diversification by the Maya, with management of forest resources alongside the cultivation of palms and field based agriculture, providing multiple resources, from a 'managed mosaic' (Fedick, 1996).

Figure 4.9 The fruits of (left) the *Brosimum alicastrum* ('breadnut') and (right) *Manilkara zapota* ('sapodilla') trees (Photos: www.tropicos.org 2013)

Brosimum alicastrum (Fig.4.9) has been particularly identified as a multi-purpose tree favoured by the Maya as it provides: a starch and nutrient rich fruit (Puleston, 1982; Schlesinger, 2001), shade (Schlesinger, 2001) and medicine (Roys, 1931). Lambert and Arnason (1982) suggested that the high density of *B. alicastrum* trees at Maya archaeological sites was due to an ecological relationship – that *B. alicastrum* favoured the limestone rich soil, rather than being selectively promoted by the Maya. In contrast, Schlesinger (2001) suggests that it was because the Maya specifically grew *B. alicastrum* in close proximity to their homes, this species was well placed to expand when populations declined in the Terminal Classic period. Furthermore, the modern

Belizean Maya grow *Brosimum* (rámon) in the gardens surrounding their homes, with a single tree providing 12,000 fruits in one fruiting season (Schlesinger, 2001). Turner and Misksicek (1984), Lentz (1991) and Lentz and Hockaday (2009) have demonstrated that *M. zapota* was extensively used by the ancient Maya for their edible fruits, latex rich sap (chicle) and the hard, heavy, durable timber which was resistant to decay, and was used as lintels in Maya temples (Schlesinger, 2001) (Fig.4.9). Analysis of the door lintels from the Maya city of Tikal, Guatemala suggests that the seasonal forest remained in close proximity during the Late Classic period, and that some *M. zapota* trees were preserved (Harrison, 1999; Lentz and Hockaday, 2009). During AD 766 - 806 *H. campechianum* was exclusively used for door lintels, and Lentz and Hockaday (2009) suggest that this switch was due to the depletion of *M. zapota*. *M. zapota* was again used c. AD 806, possibly after a period of abstinence to enable it to restock, suggesting that the ancient Maya actively undertook agroforestry. de los Angeles la Torre-cuadros and Islebe (2003) suggest that *M. zapota* is the most valuable tree for the modern Maya due to its latex sap and timber for use in construction.

At Lamanai, the *Brosimum* and *M. zapota* signal increases during the Late/Terminal Classic period alongside other fruit trees (*Spondias*), whereas other non fruiting trees remain constant (Moraceae/Urticaceae), or decrease slightly (*Acalypha* and *Maclura*); this suggests that the Maya were promoting the cultivation of species of trees which provided edible fruits. Ford (2008) has suggested that palynological records derived from lake cores do not contain a significant proportion of the tree species selectively encouraged by the Maya as they are animal pollinated, and that this has led to the misinterpretation of the decline in Moraceae pollen (which is wind pollinated and so more abundant in lake records) as an indicator for general forest cover change. Ford and Nigh (2009) suggest that this misinterpretation of the Moraceae record (in particular *B. alicastrum*) has led to an understanding of the Late Classic Maya period as one of increased deforestation and disturbance as a result of increased population (Binford et al., 1987; Rice, 1996; Dunning and Beach, 2000); they suggest that this period was one of ‘renewed cultural and ecological stability’ (Ford and Nigh, 2009, p.227). The record from Lamanai does reflect fifteen of the thirty-seven forest garden species that Ford (2008) identifies, including Arecaceae, *Ceiba*, *B. simaruba*, *Cecropia*, *Bucida*, *Curcurbita*, *Cnidoscolus*, *Acacia*, *Quercus*, *Byrsonima*, *Brosimum*, *Talisia*, *M. zapota* and *Guazuma*, which suggests that the palynological proxy is more sensitive than Ford (2008) claims. Indeed, published pollen records from the Maya lowlands contain at least four taxa listed by Ford (2008) in addition to *Brosimum*, including those from Lamanai (Rushton et al., 2013); Punta Laguna (Leyden et al., 2002); Cobá (Leyden, 2000) and the wider Petén region (Islebe et al., 1996) (Fig.1.3). Furthermore, this thesis has interpreted the pollen signal using an approach that examines the landscape as a whole: rather than selecting individual pollen types, different vegetation formations and land-use practises are examined.

This pollen record of management of vegetation resources at Lamanai is consistent with the archaeological record of continued occupation throughout the Terminal Classic (AD 800 - 1000), and Graham (2004) suggests that there was continuous dense settlement along the NRL, and that although Early post Classic rulers 'may have had different cultural, political, religious and perhaps economic priorities than the classic period….[the Early Post Classic] kick started a vibrant period of economic revival in commerce and long-distance trade' (p.223). Papers from the wider Yucatán region have observed a period or periods of drought associated with the 'collapse' of Maya polities during the Terminal Classic (Curtis et al., 1996; Hodell et al., 1995, 2007; Neff et al., 2006). Metcalfe et al. (2009) report that there is some isotopic enrichment c. AD 970 in Lamanai, NRL, which could be indicative of a drying event, however this could be reflecting a regional drying signal and the resilience of the NRL system. The local pollen record of large immobile grains (*Z. mays*, palms) and archaeology demonstrate that a regional-scale drying event found in other records c. AD 900 (Hodell et al., 2007) does not impact upon the settlement at Lamanai, and this may be due to continued access to abundant water resources, as well as effective management of vegetation resources during the Late /Terminal Classic period.

4.6.5 Forest recovery after periods of disturbance[17]

Three periods of sustained forest recovery after periods of disturbance are visible in this record. The first occurs from 1150 BC until c. 800 BC (Lamanai I (1999) core) (Fig.4.4), with the highest arboreal levels found at c. 900 BC. This increase in arboreal taxa is accompanied by a decrease in herbs and a decrease in particulate charcoal. This possible period of forest recovery is also visible in the C/N values, as the peak at c. 1300 BC (44.6) declines to an average of 32.7 until c. 900 BC when values increase to 39.2 (Metcalfe et al., 2009). The second period occurs at c. AD 1400 and is demonstrated in both the Lamanai I (1999) and II (2010) cores; the latter suggests that this period of recovery ends c. AD 1800 (Figs.4.4 and 4.6). In the Lamanai I (1999) core the arboreal signal increases, with a great variety of taxa including *Z. Guidonia* (Fig.4.7). There could also be a recovery of fringing marsh that may have encircled the NRL as it does today, with the highest levels of Cyperaceae in this core found at AD 1400 alongside a complete absence of crops (including palms), and low charcoal concentrations together suggesting decreased Maya activity. At the bottom of zone three of the Lamanai II (2010) core (30 – 28 cm) (Fig.4.7), there is a marked increase in arboreal taxa, with increased diversity including *Cnidoscolus*, *Croton*, *Luehea*, *Talisia*, *Celtis*, *Ulmus*, *Guazuma* and *Drypetes*. The palynological richness for Zone Three is over 37.3 E(T_{300}) (Fig.4.7), which is even greater than the Lamanai I (1999) core peak value observed at the top of Zone Four of that core (32.5 E(T_{300})) (Fig.4.6). As with the Lamanai I (1999) core, the increase in quantity and variety of arboreal taxa in the Lamanai II (2010) core is accompanied with a decline in the pine

[17] For discussion on the wider significance and interpretation of the term 'disturbance' see Chapter 8.

savanna and herb signal and low micro charcoal concentration (Figs.4.4 and 4.5). However, a macro-charcoal signal is observed in the second core at the bottom of Zone Three, which may indicate continued local burning events.

These two pollen records are consistent with the record of Metcalfe et al. (2009), which also suggested reduced anthropogenic activity at Lamanai in the topmost part of the core, indicated by low magnetic susceptibility and $\delta^{13}C$ values. The first (3.5 cm) and second (8.5 cm) samples from the top of the core have the lowest C/N values (15.3 and 16.8 respectively) with all other values ranging between 21.6 and 44.6 (Metcalfe et al., 1999). This is consistent with aquatic material comprising the majority of the organic matter deposited in the sediment core (Brenner et al., 1999; Metcalfe et al., 2009). There are no diatoms found in the period c. AD 1100 – 1400, which could suggest increased evaporation and increased alkalinity. Pollen evidence of forest recovery post-AD 1000 appears in other records from Northern Belize. Hansen (1990) observes forest recovery at AD 1000, indicated by a fall in *Ambrosia* pollen and an associated increase in arboreal taxa, and links this to a switch to less intensive farming methods consistent with a fall in population post-Collapse period. Jones (1994) also reports an increase in forest cover post-AD 900, which is consistent with the abandonment of the nearby site of Colha at c. AD 850. Brenner et al. (1990) date forest regeneration in the Petén region c. AD 1600, although other studies have suggested that it occurred c. AD 1000 (Curtis et al., 1998; Islebe et al., 1996) and c. AD 1000 – 1200 (Mueller et al., 2010). Mueller et al. (2010) suggest that in the absence of human populations and associated farming the Petén forests recovered within a period of 80 – 260 years.

The third period of forest recovery is evident at the top (3 – 2 cm) of the Lamanai II (2010) core, with the highest seasonal forest value across both cores occurring at 3 cm, accompanied with low herb, palm and crop signals. Rarefaction analysis indicates that the top of this core has the highest palynological richness across both cores (see section 4.4.4). This suggests that the biodiversity of the land surrounding Lamanai is greater in the modern era compared to previous periods, including that of the Late Classic Maya forest gardens. This may be due to a low population at Lamanai, with the archaeological remains of the Maya city and its environs under Government legislative protection preventing much development, with just one small population located in the village of Indian Church. Chazdon et al. (2009) suggest that in order to understand the current and future status of Neotropical diversity, researchers need to understand patterns of biodiversity in the context of actively managed lands and explore how biodiversity is affected by such management practices. This three thousand year old palaeoecological record from Lamanai enables the comparison of such different management practices, comparing those of the Maya with those of European cultures who utilised vegetation resources post c. AD 1500. Proponents of the ‘forest garden’ model of Maya management (Ford, 2008; Ford and Nigh 2009) suggest that modern forest conservators should look to late Classic Maya management practice however, the evidence from the Lamanai record is

equivocal. Certainly the Maya do seem to have managed resources during the Late Classic/ Terminal Classic period, and such a model would be useful in understanding the best way to promote seasonal forest cover whilst growing field based crops, arboreal resources and cultivating palms. However, the most recent portion of the record demonstrates that in the absence of such a model (and in the context of a low population) seasonal forest cover and diversity increased within a century, to levels previously unknown in over three thousand years of human interaction.

4.6.6 European encounter and colonial forestry: periods of logwood and mahogany extraction from the forests of Northern Belize.

As discussed above, some pollen records from the Maya Lowlands have demonstrated substantial forest recovery during and after the Terminal Classic period that has been linked to a much reduced Maya population after a period of 'collapse' (Hansen, 1990; Jones, 1994, Curtis et al., 1996; Islebe et al., 1998). In the Lamanai II (2010) record (Fig.4.5) there is no substantive evidence of forest recovery until the most recent modern period, which suggests that the forest continued to be utilised by the indigenous and European populations from the earliest established Maya presence at Lamanai c. 1630 BC. The decline in the palm signal at 35 – 25 cm (Lamanai II (2010) core) (Fig.4.5 and 4.7) is not associated with any other palynological indicators of declining Maya use of the land around Lamanai, as there is a high field based crop signal, high levels of herbs and low seasonal forest and pine savanna cover. At 30 cm (Fig.4.5) there is a secondary peak in microscopic charcoal particles, a peak in loss-on-ignition and high levels of macroscopic charcoal particles which further indicate burning at Lamanai, and in the region; this could reflect land clearance and construction associated with European contact. In the absence of a coherent radiocarbon date between 49 – 16 cm in the Lamanai II (2010) core (Fig.4.1) it is not possible to construct a more detailed chronology, and so it is unclear when the changes observed at 30 cm occurred.

Documentary sources (see Chapter 6) have suggested that during AD 1660 – 1910, European logging focused upon extracting logwood from the coastal and riverine regions across the north of Belize. They also demonstrate that during AD 1800 - 1945 the predominant forestry product was mahogany. These two distinct periods of European colonial forestry are visible in the most recent pollen record from the NRL, in the Lamanai II (2010) core (Fig.4.7). During Zone Three (30 – 16 cm) the seasonal forest signal is high, the secondary peak across both zones and field based crops peak; however, the pine savanna signal is the second lowest. Between 23 cm and 16 cm there is a fall in pine savanna species such as *Byrsonima* type, *Cecropia*, *Quercus* and *Pinus*, and a corresponding increase in *H. campechianum* (logwood), with this peak in logwood extending beyond Zone Three to 11 cm. This shift in the composition of the pine savanna suggests that *H. campechianum* is being selectively promoted and extracted in the pine savannas surrounding the NRL,

and may reflect the colonial economic interest in logwood as a dyewood, used in the textile industry in the 16th and 17th centuries. Between 17 and 15 cm, at the transition between Zone Three (30 – 16 cm) and Zone Four (16 cm – 9 cm), there is a cluster of increased loss-on-ignition (>11%) and increase micro and macro-charcoal concentration, with the peak of both size fractions at 15 cm, and a tertiary peak at 16 cm. This suggests anthropogenic burning and clearance both locally and regionally, with the regional signal possibly reflecting increased British colonial presence in northern Belize. The local burning signal may reflect the construction of the British sugar mill at Lamanai in the mid 19th century, which began in c. AD 1857 (Pendergast, 1982a).

Between 16 and 9 cm (Zone Four) of the Lamanai II (2010) core (Fig.4.5 and 4.7) seasonal forest decreases and pine savanna cover increase. Seasonal forest taxa that decrease during this zone include *Metopium*, *B. simaruba*, *Luehea*, *Maclura*, *M. zapota* and *Guazuma*, and all of these species are those identified as being commonly used by the Maya for various purposes including timber, fuel, and medicine (Schlesinger, 2001). At the same time, *Swietenia* (mahogany) increases, and the change in the cover and composition of the seasonal forest may reflect the increasing impact of European mahogany extraction. Furthermore, the recovery of pine savanna cover may reflect the decline of logwood extraction from the pine savanna found to the east of the NRL, and from across the region, as both the species with the more localised pollen signal (insect pollinated species e.g *Acacia* and *Curatella*) and regional signal (wind pollinated species e.g. *Pinus* and *Quercus*) increase during this period of pine savanna recovery. Although it is not possible to define the chronology of European periods due to the dating limitations in the Lamanai II (2010) core (Fig.4.7), two distinctive periods of seasonal forest and pine savanna cover and composition are visible in this record; this may reflect the shift from the dominance of logwood extraction until the mid 18th century to mahogany post AD 1750. This is accompanied by both a local and regional signal of burning at 15 – 17 cm (Fig.4.5), which further suggests that this is a shift driven by changes in anthropogenic use of the vegetation.

4.7 Summary

The pollen and charcoal record from the NRL, near Lamanai, reflects a continuous vegetation history for the period c. 1630 BC – AD 2010. Crops, including *Z. mays* found from c. 1630 BC indicates cultivation of maize throughout the occupational history of Lamanai (Pendergast, 2002), and crops are also found c. 1600 BC in other records from Northern Belize (Hansen, 1990; Jones, 1994; Pohl et al., 1996). The almost continuous and abundant local *Z. mays* signal from the NRL highlights the potential for a dual regional/local signal within the same record. This may improve our understanding of site-specific responses to human disturbance and land management strategies, within a regional context. The effects of distinct periods of Maya construction during the Preclassic and Late Classic are visible in this record, with *P. caribaea* extracted from the pine savannas for

timber and fuel. The palaeoecological evidence concurs with the archaeological record of continuous occupation and development throughout these periods at Lamanai. The importance of the ritual use of *P. caribaea* torches is evident from the widespread identification of *P. caribaea* charcoal in caches from across the Maya Lowlands (Morehart et al., 2005), and previously unpublished archaeological evidence from Lamanai demonstrates that *P. caribaea* was widely used in ceremonies during the Late/ Terminal Classic transition (Graham, 2013 Pers. Comm.). Although *P. caribaea* is ubiquitous at cave and surface Maya sites, *P. caribaea* is ecologically restricted, which suggests that *P. caribaea* was an important article of trade (Thompson, 1970; Lentz, 1999; Morehart, 2002; Lentz et al., 2003.) Furthermore, the extensive and local source of *P. caribaea* found in the pine savanna to the east of the New River Lagoon may have provided the population at Lamanai with both a source of *P. caribaea* for their own use, and something to trade for goods such as obsidian and jade, which feature alongside *P. caribaea* in Late Classic caches (Graham, 2013 Pers. Comm.). This new palaeoecological record, combined with the previous record of Metcalfe et al. (2009) demonstrates that Maya management of resources continued into the Late Classic. Palm cultivation during the Classic, Late Classic and Postclassic periods perhaps formed part of a suite of managed vegetation resources which also included arboreal and field-based crops. This evidence of continued palm cultivation and previous palaeolimnological (Metcalfe et al., 2009) and archaeological (Pendergast, 1975; 1981; 1982a-c; 1986; 1991; Graham, 2001; 2004; 2011) records do not demonstrate any impact of the 'Maya collapse' found in other records from the region (Curtis et al., 1996; Hodell et al., 1995).

After a period of forest recovery between c. AD 1250 and 1400 there is some evidence of European contact c. AD 1500, with a reduction in palms and *P. caribaea* signal. At c. AD 1800 there is a subtantial decrease in seasonal forest signal associated with peaks of charcoal concentration. This could represent British industrial development at Lamanai during the 19th century, with the construction of one of first Belizean sugar mills. During the British colonial period two distinct periods of forestry are visible in the record, with a period of logwood extraction followed by the extraction of mahogany. The most substantial seasonal forest recovery occurs in the most recent period which raises questions about whether the proposed vegetation management strategies of 'forest garden' (Ford, 2008; Ford and Nigh, 2009) or 'managed mosaic' model (Fedick, 1996) actually are the most effective methods of conservation of the Maya seasonal forest. This palaecological record, which has documented a vegetation history for the last three thousand years, demonstrates the different impacts the Maya and European cultures had upon the vegetation, and, that the seasonal forest and pine savanna recover repeatedly after periods of disturbance. That the most substantial recovery in terms of percentage abundance and diversity occurs in the last sixty years suggests that Maya lowland seasonal forest is resilient, and able to recover in less than a century in the absence of a substantial population and industrial development

Chapter Five

Reconstructing the meteorological history of Belize, 1865 - 2010

5.0 Introduction

This chapter focuses on the instrumental record from Belize City which, as with many early meteorological records, has temperature and precipitation as the most consistent and continuously observed variables (Mock, 2012). Central to this instrumental proxy is the Belize Public Hospital record which has daily temperature and precipitation data for >95% of the period 1866 - 1947 (see 3.2.7 for a more detailed account of the composition of the record). This record presents a unique opportunity to examine the daily long term climate variability in the region where records were taken at virtually the same location. Annual and seasonal (May - November and December - April) minimum and maximum temperature values are reconstructed and precipitation amount, frequency and intensity are also presented. The instrumental record (in particular precipitation) is examined in light of historical accounts of yellow fever. These accounts of yellow fever have been reconstructed to form a chronology of outbreaks in Belize using primary archival and secondary published sources and this chronology has then been compared with the meteorological record. Yellow fever years (YFY) have higher than average total precipitation days (TPD), even when the overall amount of precipitation is lower than average. This high frequency, low volume pattern of rainfall provides optimum water availability necessary for the yellow fever vector the mosquito *A. aegypti* to breed. Diaz and McCabe (1999) have noted how, in the 18th and 19th centuries, major outbreaks of yellow fever in the southern and eastern United States have coincided with El Niño episodes. Although the extent of the impact of ENSO activity on precipitation in the region is far from clear (see section 5.3.2) there is some evidence from the meteorological record from Belize City, 1866 – 1946 that extreme El Niño events coincide with increased precipitation in the year following the event and decreased precipitation in the year following an extreme La Niña event. The impact of hurricane activity in Belize upon the instrumental record is also examined. This eighty year instrumental record from mid-19th to mid-20th Century Belize is a substantial contribution to our understanding of past weather in the region, as prior to this record there was no published data from the Central American region before the early 20th century.

Instrumental weather records from Belize date from the early 19th century, with the earliest meteorological record keepers bringing British instruments and knowledge of undertaking meteorological observations with them when they travelled to Belize. The first known record comes from an early 19th century volume titled ‘An account of the British Settlement of Honduras, being a view of its commercial and agricultural resources, soil, climate and natural history’,

written by a British man Alexander Henderson and published in London in 1811. At the back of the volume, Henderson includes a daily record of meteorological observations for the months of February - August 1806 which he describes as being recorded at Balize [sic] in the Bay of Honduras; this is almost certainly the early settlement at modern day Belize City. The record comprises twice daily temperature measurements (˚F) taken in 'the morning' and at noon, with the wind direction and a daily comment regarding the 'general state of the weather'. These comments usually contain information about the presence and absence of clouds and precipitation, and sometimes described the extent or intensity of either. Unusual or extreme weather such as storms were also noted. At the end of each month, a general overview of the weather of the previous month was given, with an attempt to put the observed events of that month into a more long-term context. For example, the comment for February 1806 states that:

> 'Heavy rain generally during the night; frequent heavy showers in the day. This month, being included in what is denoted the *dry season*, the rains that have fallen have, therefore, been considered unusual.' (p. iii)

The temporal extent of this early record reported by Henderson (1811) beyond that described here is unknown. It is clear however, that some British born residents in Belize City continued to keep individual personal meteorological records. This reconstruction benefits from the observations of one such individual, the Revd Richard Dowson; he kept a meteorological record for approximately nine years in the 1860s, which only survives in summary form for the years 1865 - 1868 (see section 3.2.7). The surviving record (at the Public Hospital in Belize) of formal, institutional meteorological observations dates from 1866, and there is nothing in the archival record to suggest that observations began earlier than this. The modern instrumental record for Belize City dates from 1973 and is based on daily observations of temperature and precipitation measurements (see section 3.2.7). British and American newspaper articles contain references to weather conditions at Belize and provide a useful source of information, particularly for the period prior to the meteorological record. However, these observations concerning precipitation and temperature are in the vast majority of cases linked to economic impacts, particularly concerning the logging industry, where the timing of the dry and wet season was linked to the level of timber extracted. These accounts are considered in relation to the mahogany and logwood export records presented in section 6.2.3.

5.1 The temperature record

Analysis of the quality of the temperature record in section 3.2.7 has demonstrated that the historical record (1865 - 1946) has some limitations related to a change in exposure in the late 1890s. Burnette et al. (2010) have used regression analysis of spatially and temporally overlapping records to provide an empirical method for correcting some sources of exposure error:

however, as this record from Belize is the first of its kind from both the country and the wider Central American region, it is not possible to use this method to correct the historical temperature record for 1865 – 1946. Even with these limitations, the record from Belize is temporally the most extensive record from Central America (Mock, 2013 Pers. Comm.) and provides a predominantly daily record of minimum and maximum temperatures. During 1865 – 1946 the minimum temperature range is 18.4 - 25.9˚C with a mean value of 22.9˚C (Fig. 5.1). The maximum temperature range is 26.8 - 32.1˚C and has a mean value of 29.2˚C. The maximum temperature observations are more consistent with a range of 5.3˚C compared to more fluctuating minimum observations which have a range of 7.5˚C. The modern record (1973 – 2010) has a minimum temperature range of 21.3 - 24.0˚C, with a mean value of 23.0˚C (Fig.5.2). Maximum temperature ranges have a mean value of 30.2˚C, and a range of 29.0 - 31.1˚C. The modern observations have a much smaller value ranges of 2.7˚C and 2.1˚C for the minimum and maximum observations respectively.

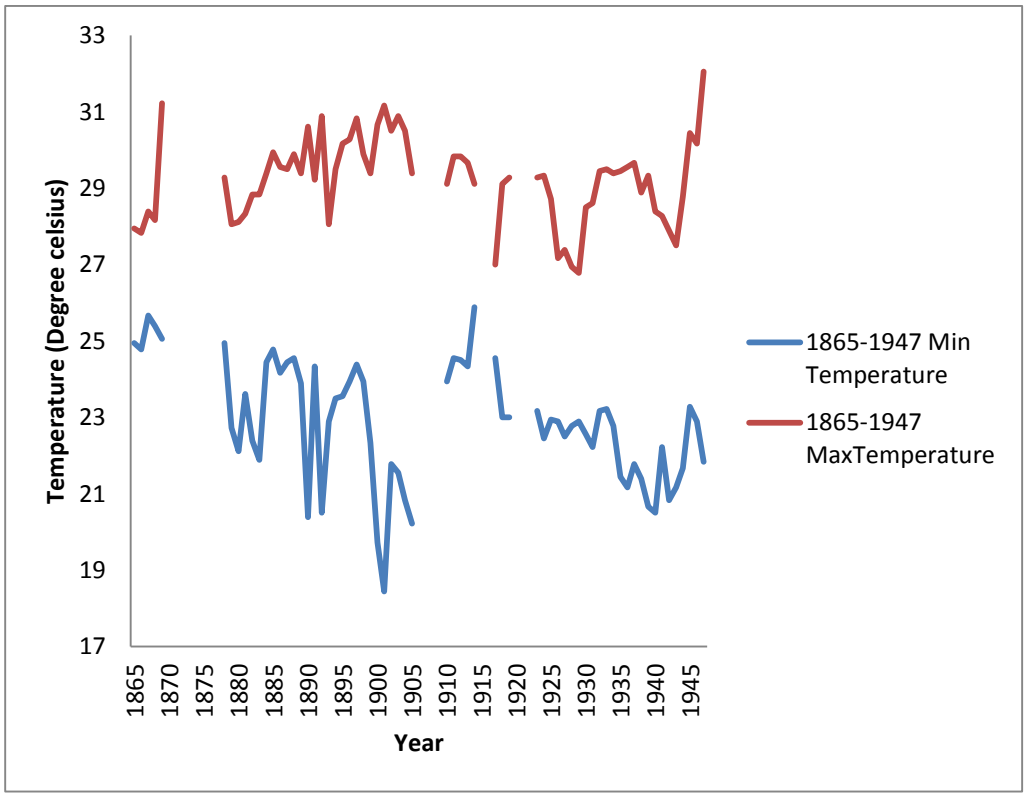

Figure 5.1 Annual mean and maximum temperatures from Belize City, Belize for 1865 – 1947 (Values are missing because there was no surving data available)

When comparing the monthly means of minimum and maximum temperatures for the historical (1865 – 1946) and modern (1973 – 2010) periods, the minimum temperature observations are very similar, with the greatest difference 0.8˚C in October (Fig. 5.3). The largest differences in minimum temperatures occur during August - December, ranging between 0.4˚C and

0.8˚C. This close similarity in monthly mean minimum temperatures between the two meteorological data sets is important given the concerns which surround changes in thermometer exposures during the 1890s (Mock, 2012).The maximum temperature observations show a similar trend across the two periods of observation, however the modern temperatures are consistently higher than the historical record (Fig.5.3). These two records show that modern monthly mean temperatures are recorded as between 0.6 and 1.2˚C higher than the historical record, with an average 1.0˚C higher in the modern record. This increase in the modern record maximum temperature could reflect a difference in instrumentation or exposures, or could be the product of the different locations of the weather stations. It is clearly difficult to disentangle climatic change from changes in measurement when examining these two records; temperature records are the more susceptible to data quality variability (Mock, 2013 Pers. Comm.). Precipitation, the second part of the meteorological record, provides a further opportunity to examine the climate of Belize from the mid 19th century to the present, using data which has been established as high resolution (see section 3.2.7).

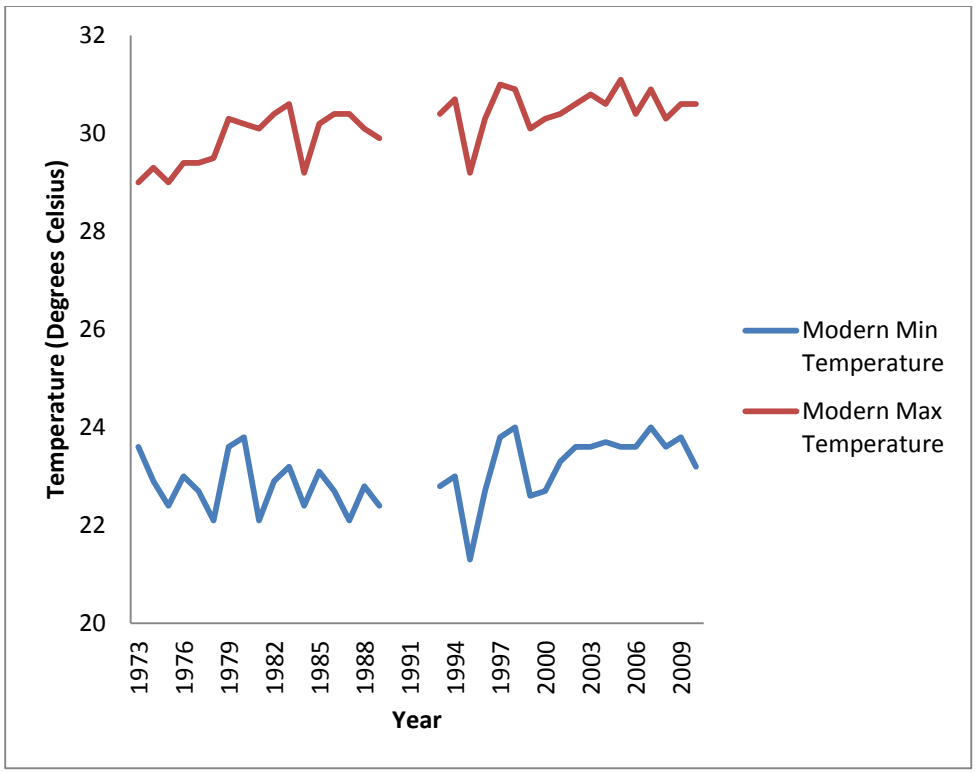

Figure 5.2 Annual mean maximum and minimum temperatures from Belize City, Belize for the period 1973 – 2010 (Values are missing because there was no surviving data available)

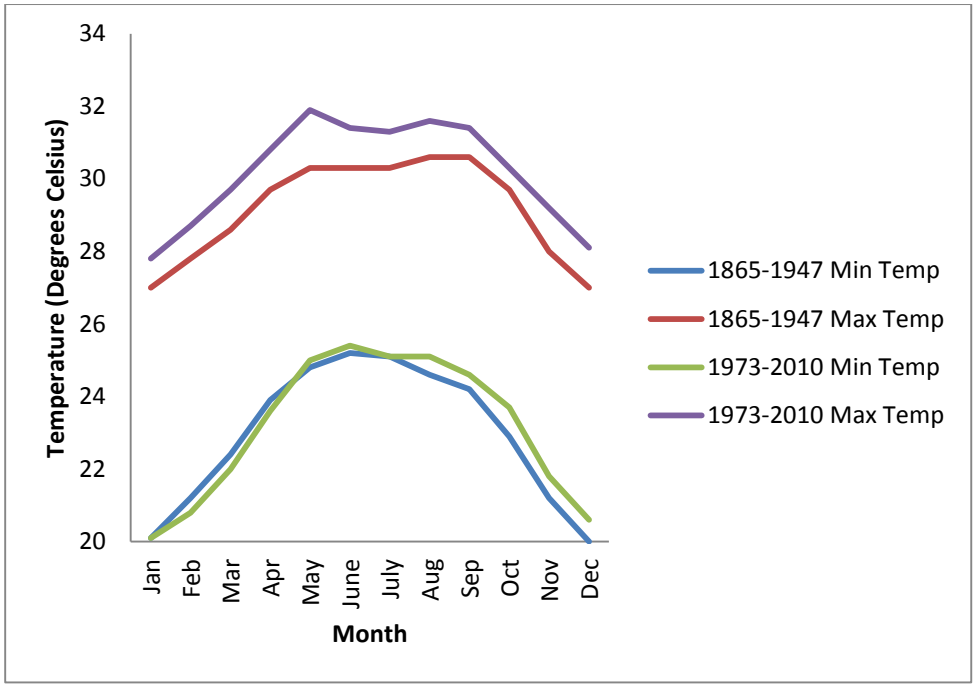

Figure 5.3 Comparing minimum and maximum monthly temperatures from Belize City, Belize for the periods 1865 - 1947 and 1973 – 2010

5.2 The precipitation record

Fig. 5.4 displays precipitation totals (inches) derived from monthly averages in three categories; annually, May – November and December – April for 1865 - 2010. Totals were derived from monthly means of daily data wherever possible; where daily sources were unavailable, monthly means were used (see Table 3.3). Where there are missing values on the graphs this is because there was no available data. Broadly speaking, the annual precipitation totals suggest that the mid/late 19th century (mean 80.7 inches/ 2050 mm) was drier than the early 20th century (mean 99.3 inches/ 2522 mm), with a peak in precipitation in the early 20th century (1906). Total annual precipitation values have a range of 13.1 - 198.7inches/ 323 mm – 5047 mm (mean 77.6 inches/ 1970 mm); however, with the exception of the maximum and minimum of the entire range, values fall between 41.8 and 134.6 inches (1062 – 3418 mm). Peak precipitation occurred in 1906 (annual total 198.7 inches/ 5047 mm), with the driest year in 1975 (annual total 13.1 inches/ 323 mm). December - April precipitation values are broadly consistent, with a range of 7.9 – 54.6 inches/ 201 mm, and the majority of values falling between 7.9 and 35.5 inches/ 201 – 902 mm (mean 19.4 inches/ 493 mm). Dry/winter season precipitation totals rise above 40 inches/ 1016 mm on three occasions during 1866 – 1946, twice in the early 20th century, with the peak in 1906 (54.6 inches/ 1387 mm), a tertiary peak in 1907 (42.05 inches/ 1068 mm), and once in the late 20th century with a secondary peak (43.8 inches/ 1113 mm) in 1990.

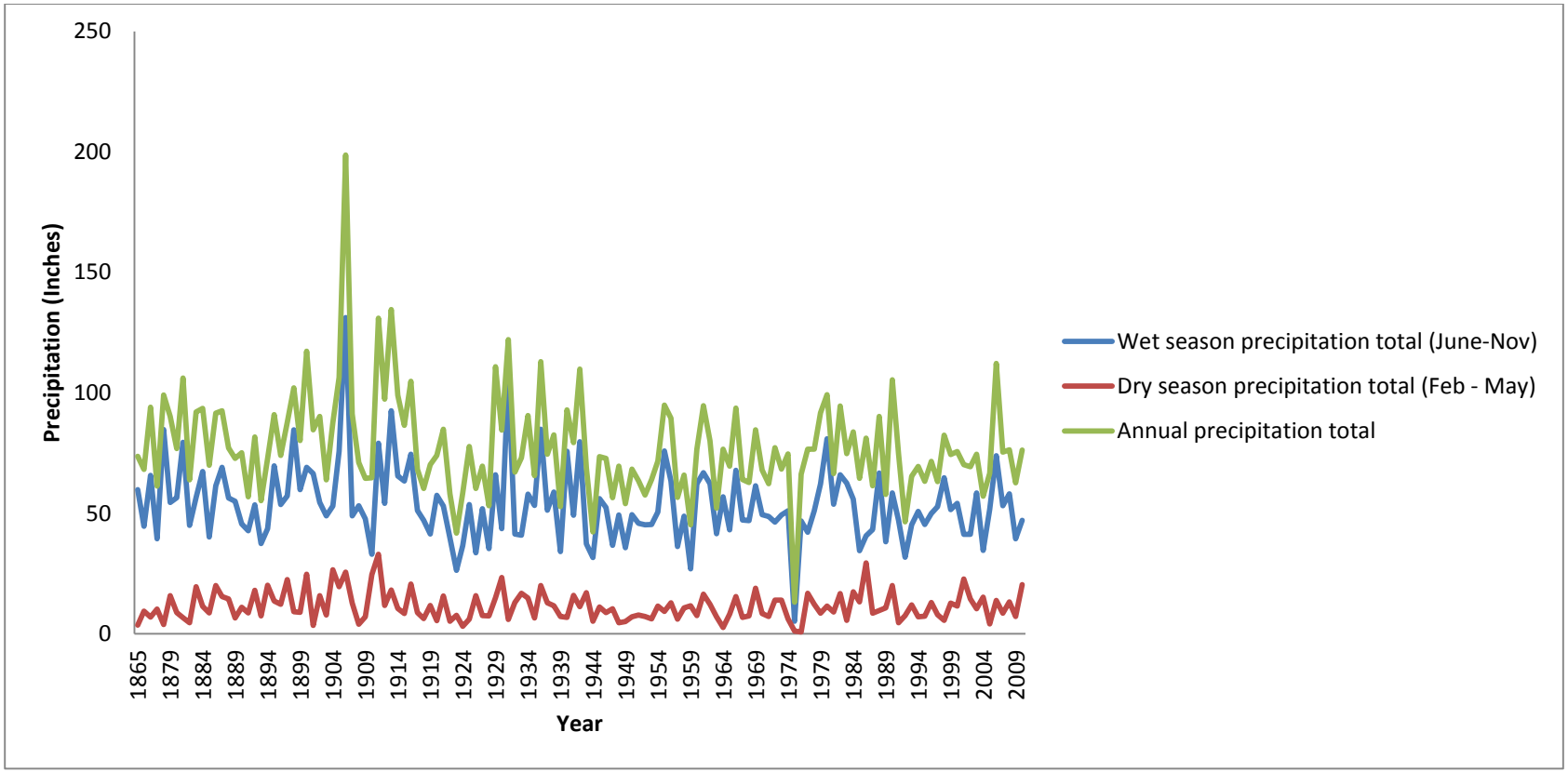

Figure 5.4 Precipitation totals derived for monthly averages for Belize City, Belize for 1865 - 2010

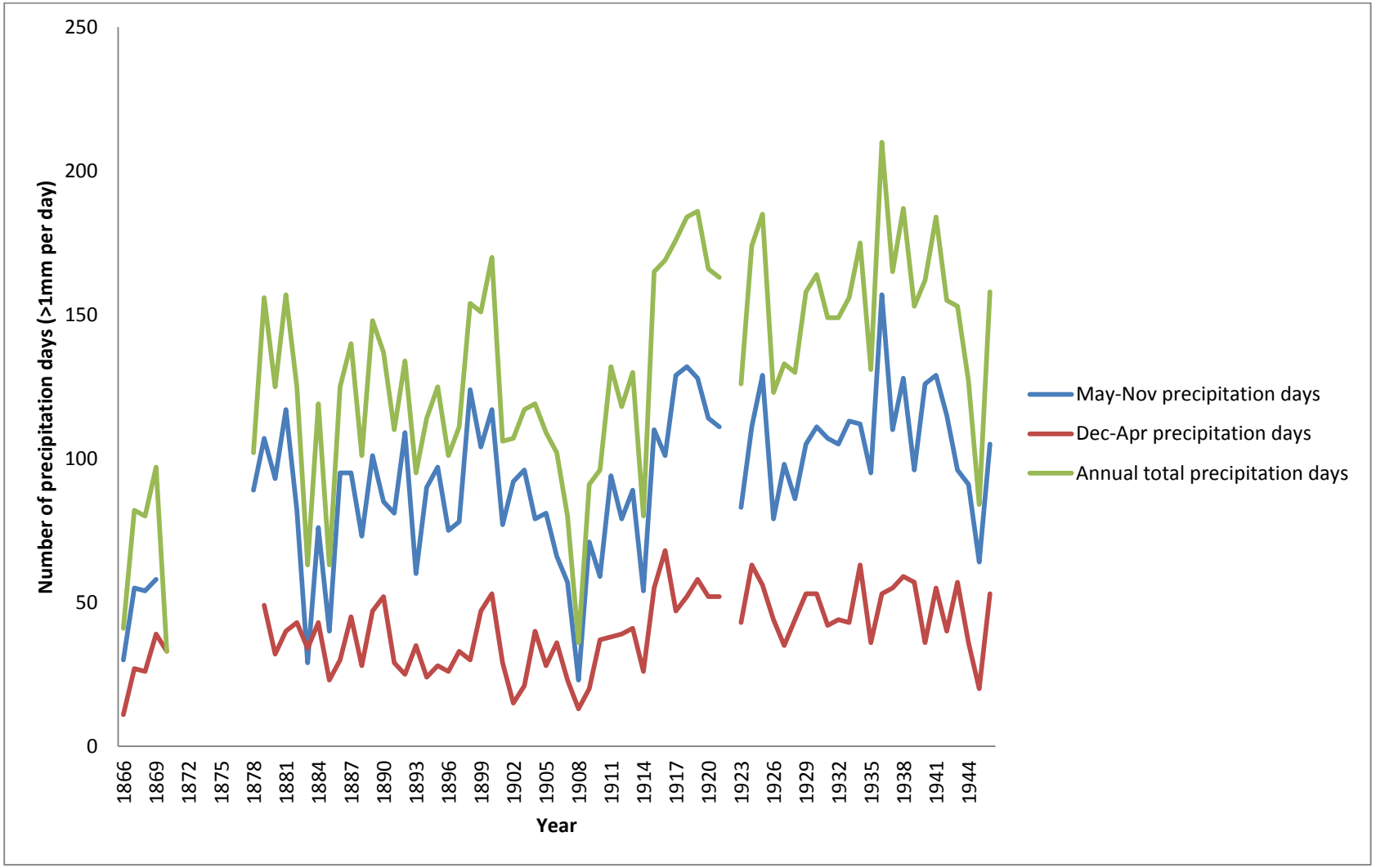

Figure 5.5 Number of precipitation days from Belize City, Belize for 1866 - 1946 (Values are missing because there was no surviving data available)

There is more variability in the May - November precipitation figures, with precipitation in this period following the general trend of annual precipitation totals. May - November precipitation is lower in the mid/late 19th century, with an average total rainfall for the period 1865 – 1900 of 61.0 inches (1549 mm) compared with 71.9 inches (1826 mm) for the period 1900 – 1915. All three precipitation totals demonstrate that the early 20th century was a period of high precipitation, with all 5 years with annual totals over 115 inches and May – November over 95 inches occurring during the period 1900 – 1936. Within this early 20th century period of high precipitation, the 1920s was a very dry decade (annual total mean value 68.9 inches/ 1750 mm), second only to the 1950s (annual total value mean 67.7 inches/ 1720 mm).

All available daily data were analysed and the number of precipitation days (days with rainfall > 1mm, or TPD) was reconstructed for the period 1866 - 1946 (Fig.5.5). This shows that the number of precipitation days follows a similar trend to that in Fig.5.4, with lower average TPD during the mid/late - 19th century (mean 113 days) compared with an average 141 days in the period 1900 - 1946. Unlike Fig.5.4, the December - April precipitation days also show a drier 19th century/wetter 20th century trend. The decade with the highest average precipitation days is the 1930s (164 days); however, the second highest average is found in the 1920s, in direct contrast with the 1920s having the least average precipitation for any decade during the period 1866 - 2010 (Fig.5.4). Fig.5.8 shows the number of days of rainfall >2 inches during May - November for the periods 1866 – 1946 and 1973 – 2010. Precipitation intensity is greatest in the historical period, with the number of days with precipitation >2 inches ranging between 4.4 and 9.7 days, with an average of 7.4 days. The decade with the highest average precipitation intensity is the 1880s (mean 8.7 days), and the lowest average value in the historical period occurs during the 1920s (mean 4.4 days). The low precipitation intensity value for the 1920s is consistent with the low precipitation values and high number of precipitation days (Fig.5.4 and Fig.5.5). The modern period (1973 – 2010) precipitation intensity ranges from zero days >2 inches (1973, 1975-6, 1982 and 1990 – 1992) to 10 days (1987, 2006), with a mean value of 4.1 days. Years with 15 or more >2 inch days are all found in the historical period, including 1878 (15 days), 1886 (21 days), 1911 (19 days) and 1931 (15 days). In the modern period there are no years with more than 10 days of >2 inch precipitation. This May – November precipitation intensity record for both the historical and modern periods shows that while total precipitation amounts were lower in the mid – late 19th / early 20th century (Fig. 5.4), more intense periods of rainfall occurred in this earlier period than in the more recent period.

Figure 5.6 A comparison of monthly mean precipitation values from Belize City, Belize for the period 1865 - 1946 with the modern period (1973 - 2010)

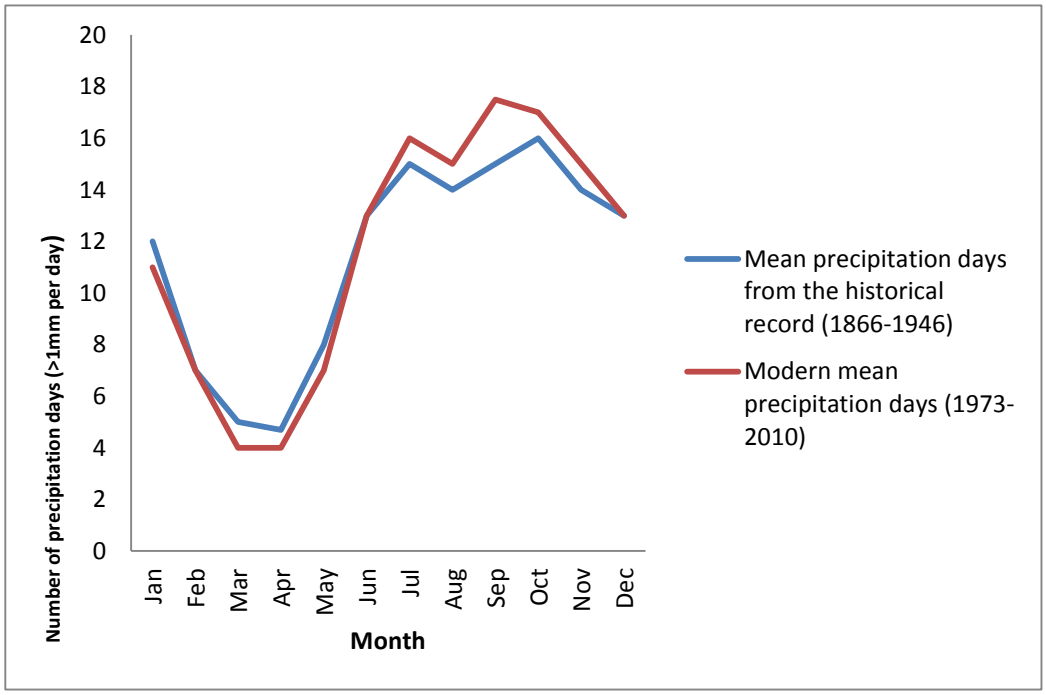

Figure 5.7 A comparison of mean precipitation days from Belize City, Belize for the period 1866-1946 with the modern period (1973-2010)

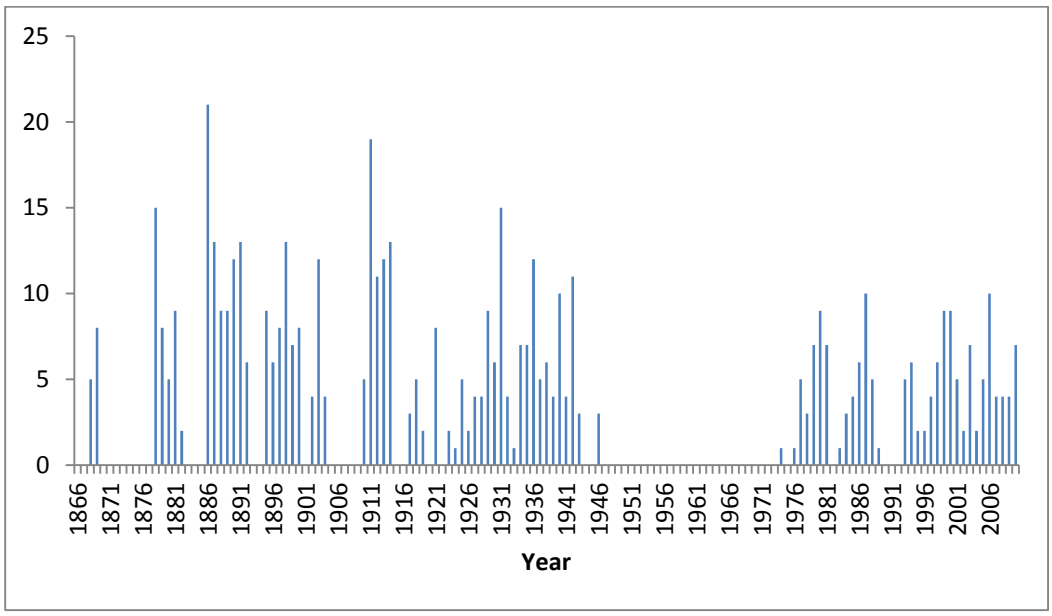

Figure 5.8 Total number of days in May - November with precipitation >2 inches; Belize City, Belize, for the periods 1866 - 1946 and 1973 – 2010 (Values are missing because there was no surviving data avaible)

Fig.5.6 compares the monthly mean precipitation totals from the historical period (1865 – 1946) with the modern period (1973 - 2010), and Fig.5.7 compares the TPD for the same periods. Precipitation totals are very similar across the two periods, with slightly higher rainfall in the historical period during the months of October - January. TDP values are also similar, with a slight increase in TPD in the modern record during the months of July - November. The close similarity between the records from two different periods suggests that the observations on which the historical record is based are of high quality, and provide an accurate reconstruction of the meteorological record of Belize during the period 1865 – 1946. The precipitation record from Belize suggests that the mid – late 19th century was drier than the early 20th century. O'Hara and Metcalfe (1997) observed dry conditions in the Yucatán during the 1890s, and across north and central Mexico 1892-1896. In contrast Mendoza et al. (2007) observe drier conditions across the Yucatán during the early to mid-19th century and wetter conditions in the mid to late-19th century. The variations observed in these records reflect the spatial complexity of precipitation regimes across Central America. Furthermore, the record from Belize comes from observations made at Belize City, a coastal site with higher average annual rainfall (1800 – 2500 mm p.a.) than rainfall at Lamanai (< 1800 mm p.a.) (Fig.1.3) which may account for the different patterns observed in this record compared to that of Mendoza et al. (2007). In spite of the absence of a precipitation record from the north of Belize, this record is thus far the only source of information for the mid-19th century – early 20th century period, as other records do not have the spatial range (tree ring records do not

extend to Belize), the temporal coverage (Webster et al., 2007) or reliable proxies (Kennett et al., 2012) during this period. The implications of the precipitation record for the logging industry, where the timing of the 'wet season' and the quantity of rains was of special interest, will be examined as part of economic logging record in 6.2.3. Some other implications of the meteorological record are considered in the following section of this chapter, with particular consideration given to the precipitation record and the occurrence of yellow fever.

5.3 Discussion

5.3.1 1866 - 1946 meteorological record and yellow fever

As has been previously demonstrated in section 2.2.3, Diaz and McCabe (1999) have linked the climatic factors associated with the warm phase (El Niño) ENSO episode of 1877 - 1878 with a severe outbreak of yellow fever in the southeast United States that resulted in approximately 20,000 deaths in Memphis and New Orleans during the summer of 1878. Warmer temperatures in the spring and summer months of April – July, accompanied by a high number of precipitation days, provided the optimum conditions for the yellow fever vector, the mosquito *A. aegypti* to breed and propagate (Diaz and McCabe, 1999). Availability of water in mosquito breeding areas is critical, with an extended period of precipitation days preferable to high intensity/low frequency storm derived precipitation, as mosquitoes lay eggs in shallow, still bodies of water (Diaz and McCabe, 1999). Temperature is of less importance in the Belizean context. Mosquitoes thrive in temperatures of 27˚ - 31˚C and are able to exist and breed in a temperature range of 20 - 39˚C (Smith and Gibson, 1986; Diaz and McCabe, 1999). In Belize, the mean minimum and maximum temperatures during the period 1865 - 1947 are 22.9˚ and 29.2˚C, respectively, and the lowest recorded temperature of 46˚F (7.8˚C, which occurred on 31st December 1894) while by no means optimum, is substantially above the 0˚C threshold for the survival of adult mosquitoes. Therefore, when looking at any possible link between the meteorological record and incidence of yellow fever, the amount, duration and intensity of precipitation are the most important variables.

By examining the archival record from Belize for the period 1866 - 1946 it is possible to identify seven years as having multiple reports of cases of yellow fever. Table 5.1 sets out these YFY and presents the number and type of archival sources which document each YFY. Three precipitation variables for each year are also displayed, including the total rainfall (inches), total number of precipitation days and total number of days with rainfall >2 inches, all for the period May – November. By using these three different measures of precipitation it is possible to assess the intensity of the rainfall and the duration of intense rainfall, as opposed to broad changes in total rainfall amounts. In each precipitation measurement, the difference from the mean value for the May – November season over the course of the entire historical daily record

(1866 – 1946) is displayed in brackets. Years with all three precipitation measures higher than the average are highlighted in bold.

Table 5.1. Yellow fever years in Belize as identified by archival and meteorological records.

YFY[1] (months in which yellow fever was reported)	**Archival evidence for YFY**	**Total rainfall (inches) May - Nov (difference from mean)**	**TPD[2] May - Nov (difference from mean)**	**PI[3] May – Nov (difference from mean)**
1860 (May-Oct)	Colonial Office reports x4 Naval medical records x3 Newspaper reports x7 Missionary letters and reports x7 Bristowe (1894) Eyles (1898) Boyce (1906)	No meteorological data available		
1869 (May-Nov)	Colonial Office report x1 Eyles (1898) Bristowe (1894)	51.1 (-10.6)	97 (-2.3)	6 (-1.5)
1878 (Nov) (ENSO+1)	**Naval medical report x1 Missionary letter x1**	**88.6 (+26.9)**	**125 (+25.7)**	**15 (+7.5)**
1886 (May-Oct)	**Colonial Office report x1 Bristowe (1894) Eyles (1898) Boyce (1906)**	**76.8 (+15.1)**	**119 (+19.7)**	**21* (+13.5)**
1887 (May-Oct)	**Newspaper report x1 Bristowe (1894) Eyles (1898)**	**73.99 (+12.29)**	**119 (+19.7)**	**13 (+5.5)**
1889-90 (Nov-Jan) (ENSO+1)	Newspaper report x1 Bristowe (1894) Eyles (1898) Boyce (1906)	52.7 (-9)	125.5 (+26.2)	10.5 (+3.0)
1891 (May-Oct)	Newspaper report x2 Boyce (1906)	46.8 (-14.9)	145 (+45.7)	13 (+6.5)

*= peak value for the period 1866-1946; [1]YFY = Yellow Fever Year; [2]TDP = Total number of precipitation days; [3]PI = Total number of days with >2inch precipitation.

Of the seven YFY identified in the archival record from Belize (Table 5.1), 1860 produced the highest number and diversity of accounts. All YFY had at least one primary and secondary source account of yellow fever, and only 1878 had less than three sources in total. Only six of the seven years are within the span of the archival record, and it is extremely unfortunate that there is no surviving meteorological record from Belize for 1860; however, the history of this epidemic and the societal impacts will be considered in Chapter 7. Three of the six YFY with meteorological data available have higher than average rainfall (1878: 43%, 1886: 24.5% and 1887: 16.6%). The three other years – 1869, 1889/1890 and 1891 have between 11.4 and 24.1% lower than average rainfall. The TPD are 18 - 45% higher in every YF year, apart from 1869, and precipitation intensity is 20 - 64% higher in the same years. There are two YFY, 1878 and 1890, which also coincide with ENSO+1 years. 1878 has a 43.6% increase in total precipitation, a 20.6% increase in TPD and a 50% increase in days with precipitation >2inches. In contrast, 1890 has a 23.4% decrease in total precipitation, but has a 25.3% increase in TPD and a 37.5% increase in rainfall intensity.

The archival evidence suggests that the yellow fever outbreak in Belize was in no way comparable to that observed in the US during the summer of 1878 in terms of the socioeconomic impacts (Diaz and McCabe, 1999). It is clear however, that during 1878 there was increased precipitation in terms of volume, precipitation days and intensity to Belize, and this could be a contributing factor to the outbreak of yellow fever in Belize in 1878. As outlined above, *A.aegypti* breed in small, shallow bodies of water and are often found in urban areas where water is contained in pots and guttering, which provide ideal breeding conditions (Diaz and McCabe, 1999). The constant availability of water bodies such as these is critical to the survival of the species, and this relies both on a certain amount of total rainfall throughout May – November, plus a high number of TPD; a high annual rainfall total may be the result of a few periods of high intensity rainfall due to storm events, and may mask long periods of dry weather (Diaz and McCabe, 1999). When examining the record of YFY apart from 1869, the remaining five years with meteorological data (1878, 1886, 1887, 1889-90, 1891) all have above average TPD and precipitation intensity; however, three of these five years have higher than average total rainfall. This suggests that YFYs had extended periods of consistent rainfall which provided the optimum breeding habitats for *A. aegypti*. Daily meteorological data is available for the sixty year period 1878 – 1947 (Table 3.2). The archival record is incomplete or entirely missing for nine years (1905 – 1909, 1920, 1922, 1944 and 1947) during this sixty year period. When examining the remaining fifty-one years, ten years have precipitation values across all three indices (presented in Table 5.1) that are higher than the mean values (1879, 1881, 1895, 1898, 1900, 1929, 1931, 1936, 1940 and 1942). There are no recorded outbreaks of yellow fever during any of these ten years despite favourable precipitation intensity, which

suggests that the relationship between precipitation and incidences of yellow fever may be less certain in the context of Belize City.

In 1887 Dr Alexander Hunter, Belizean Public Medical Officer, sent a report to the Colonial Office concerning the causes of yellow fever in Belize City and includes case studies from 1860 and 1886. The conclusions that Hunter draws as to the causes of yellow fever and how it might be prevented in the future are considered in 7.2.3. His narrative account of the 1886 outbreak includes descriptions of the meteorological conditions at Belize City during the period May – August 1886. These can be compared with the precipitation and temperature data. Hunter's report is mixed, with some highly detailed, accurate accounts of high precipitation in May 1886 and elevated temperature in June 1886, coupled with an account of rainfall and temperature in July and August 1886 that is inconsistent with the meteorological data. Hunter reported that May 1886 saw high rainfall in what was expected to be a dry month. The precipitation total for May 1886 was 15.35 inches, seven times the average for the period 1865 -1885, and more than three times the average for the period 1865 - 2010. Total precipitation days were also unusually high, with 12 days recorded in 1886, compared with an average of 4.8 days for the period 1866 - 1885 and 7.8 days for the period 1866 - 1946. The Public Hospital meteorological record supports the account of Hunter that May 1886 was unusually wet, both in terms of his twenty years prior experience of the weather of Belize City, but also in the context of an 80 year record. Hunter stated that June 1886 was 'intolerably hot and oppressive, the temperature rising to a degree unprecedented in the records of meteorology of this place'.[18] He recorded that the peak temperature occurred on 10th June (93.5˚F/ 34.2˚C) and, during the period 8 - 25th June, temperatures were over 90˚F (32.2˚C), averaging 90.8˚F (32.7˚C). This account of high temperatures in June exactly matches the Public Hospital meteorological record, but this is hardly surprising as Hunter was personally involved in making meteorological observations at the Public Hospital for twenty years (1866 - 1886).

What is more surprising is the second part of Hunter's account of the summer of 1886 as he says, 'the months of July and August [1886] were also unusually hot, while the rainfall was very inconsiderable, and the drought was thus occasioned',[19] yet this is not consistent with the meteorological record. The meteorological data demonstrates that both July and August 1886 had higher than average precipitation, with 13.8 and 9.6 inches, respectively compared with an average for the period 1865 - 1885 of 7.5 inches in July and 7.8 inches in August. The precipitation totals for July and August 1886 were also higher than average values for the period 1865 - 2010, with precipitation in July for this period averaging 8.0 inches and August 7.5 inches. Precipitation during July and August 1886 was not 'very inconsiderable', but actually 54% and 17% higher respectively than the average totals for these two months during the previous twenty years. TPDs in August 1886 (16) were higher than the average across the period 1866 - 1885 (12) and two days higher than the

[18] TNA_CO_123_188_p.20
[19] TNA_CO_123_188_p.20

average for the nineteen years prior to 1886 (14). In July 1886, TPDs were also higher than the previous nineteen years, with a value of 14 days in 1886 compared with an average 8.5 days during the earlier period. Average TPDs across the period 1866 - 1946 (13 days) is a day lower than the 1886 July total. There is therefore no indication in the meteorological data to suggest that precipitation was vastly reduced during July and August 1886.

Temperatures in 1886 were also unremarkable, with an average maximum value of 87.5˚F (30.8˚C) for July compared with an average value of 86.5˚F (30.3˚C) during 1865 - 1946. August 1886 had an average maximum value of 87.4˚F (30.8˚C) compared with an average value of 87˚F (30.6˚C) during 1865 - 1946. The temperature and precipitation record for July and August 1886 is therefore entirely inconsistent with Hunter's report which suggests that 'drought' occurred during these two months. Furthermore, the daily records from July and August 1886 do not show extended periods of dry days, with longest sequences of consecutive zero precipitation days of five in July and three in August. July and August 1886 also had a higher than average precipitation intensity, with two days in July and one day in August 1886, compared with an average of 0.8 days in July and 0.6 days in August, respectively, during the period 1866 - 1946.

It is interesting to explore why there would be an inconsistency between a meteorological record and a governmental report compiled in the main by the same person. It is clear that even an individual who was actively engaged in accurate weather record keeping for two decades gave a narrative account of the conditions in July and August 1886 (perceived high temperature and low rainfall) and impacts (drought) that is inconsistent with the meteorological record. As part of the report, Hunter included a summary table of monthly averages of temperature, precipitation totals and precipitation days. The entries for July and August are consistent with the daily record of temperature; however, the precipitation record was inaccurate, listing 11 inches TPD in July 1886 and 6 in August 1886. There was also a discrepancy in the total rainfall values with 10.7 and 2.3 inches listed for July and August 1886, respectively. These discrepancies could be due to human error in copying out data from the originals, or a misreading of the figures. It could also be caused by a change in the position of the rain gauge or physical conditions surrounding the rain gauge; however, this information has not been found in any notes accompanying the records, and it would not explain why two different accounts of the same record have different figures for the same month. Hunter's narrative account may reveal how different conditions were perceived at the time rather, than the actual numeric record. A substantial increase in rainfall in May followed by a hot June (the average temperature in June 1886 was 32.0˚C, the average for 1865 - 1885 was 29.8˚C); this may have meant that July and August were perceived as hot and dry. The unusually hot weather in June may have meant water supplies were in greater demand, so that in July and August there was not sufficient even with greater than normal rains.

A further aspect is that the meteorological conditions of 1886 were cited as a cause of a yellow fever outbreak in a report that sought to identify preventable and unpreventable causes, with meteorology classed as an 'unpreventable cause'. As Public Medical Officer, answerable to the Colonial Office in London, Hunter may have wished to identify high temperature and low rainfall as part of a suite of conditions which were conducive to disease that were ultimately out of his (the local government of Belize's) control. Whatever the cause(s), this inconsistent report demonstrates the importance of using daily data wherever possible and, when summary monthly data are used, cross referencing sources (particularly secondary sources) to be sure of the figures given. This report also shows that even when dealing with climate within the sphere of meteorological observation, undertaken by professionals of longstanding within their community, perceptions of climate and health may indeed have an impact on the recording and interpretation of 'primary data'. The relationship between, climate, perceptions of health and disease, in particular yellow fever, will be further considered in Chapter 7.

5.3.3 Hurricanes

Hurricanes are a feature of the climate of Belize and usually occur during August - October, although the hurricane season begins officially on 1st June (Bridgewater, 2012). Using information from databases, including the National Hurricane Centre (USA) database of tropical cyclones in the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea since 1851 (HURDAT) and the Belize Meteorological Service (BMS), Table 5.4 lists all hurricanes that have made landfall in Belize since 1851. The information from the databases is supplemented with newspaper accounts of hurricanes and secondary published sources. The use of documentary accounts alongside information from databases and meteorological record enables the identification of events outside of the temporal scope of the meteorological record and the exploration of the impacts of hurricane events. The hurricane record is compared with the meteorological record of precipitation.

Table 5.4 Hurricanes to make landfall at Belize since 1787 with details of the event, sources and the annual average total precipitation record for each event year

Date	Description of event	Sources	Meteorological record (annual average precipitation total, inches)
2nd September 1787	High winds and flooding reported at Belize City. No wind speeds recorded due to the age of the event. Damage reported to >500 houses in Belize City which is approximately one third of the settlement. Tens of deaths. Livestock killed, vessels destroyed and crops damage. Estimated modern equivalent cost is US$ 1.7 million.[20]	>1300 word report published on January 8th 1788 in both *The Morning Chronicle*[21] and *The London Advertiser.*[22] Bristowe (1894).	No data.
1st August 1813	No detail.	Bristowe (1894) lists this event as one of four to affect Belize.	No data.
19th August 1827	No detail.	Bristowe (1894) lists this event as one of four the affect Belize.	No data.
7th September 1864	Category 1 hurricane which passed over Belize City doing 'considerable damage and destroying six vessels lying in the harbour'.[23]	HURDAT Reported in *The New York Weekly Herald* 6th October 1864[24] and *The Dundee Courier and Argus* on 15th October 1864.[25] Bristowe (1894)	No data.
12th October 1892	Category 1 hurricane which affected the south and coastal regions of the country. Houses blown down, plantations destroyed and vessels damaged.	HURDAT Reported in *The New York Times* on 24.10.1892;[26] *Los Angeles Times* on 24.10.1892[27]	(81.64)
6th July 1893	Category 1 hurricane which affected the	HURDAT	(55.22)

[20] BLNOL_The London Advertiser_5823_8.01.1788
[21] BLNOL_The Morning Chronicle_8.01.1788
[22] BLNOL_The London Advertiser_5823_8.01.1788
[23] BLNOL_The Dundee Courier and Argus_3491_15.10.1864
[24] LOC_The New York Weekly Hearld_6.10.1864
[25] BLNOL_The Dundee Courier and Argus_3491_15.10.1864
[26] GBNA_The New York Times_24.10.1892
[27] GBNA_Los Angeles Times_24.10.1892

	coastal regions and the south of the country. Removed doors, roofs and windows, flooding in low lying regions, damage to southern plantations.	Report in Colonial Office Blue Book by Rev LC Casartelli.[28]	
12th October 1906	Category 1 hurricane, 90 mph winds affecting NE Belize.	HURDAT	(198.65)
10th September 1931	Category 4 hurricane, 135 mph winds, 2500 deaths in Belize City and the surrounding areas. Buildings, boats, churches, schools destroyed. Flooding surges up to 15 feet.	HURDAT Newspaper reports include: *The Washington Post* on 12.09.1931.[29] *The Times*, daily between 14-17.09.1931; 21.09.1931; 4.11.1931.[30] *The Economist* on 26.09.1931.[31] *The Guardian* on 12.09.1931.[32] *The New York Times* on 12, 13 and 16.09.1931[33]	(122.06)
13th September 1933	Category 1 hurricane, area of impact northern Belize.	HURDAT BMS	(73.0)
9th September 1942	Category 1, winds 95 mph over northern Belize.	HURDAT BMS	(109.9)
4th October 1945	Category 1 hurricane impacted south Belize.	HURDAT BMS	(73.5)
27th September 1955	Hurricane Janet, category 5, 175 mph, Corozal town, north Belize destroyed, 20,000 homeless, 16 deaths, flooding.	HURDAT BMS *The New York Times* on 02.10.1955[34]	(94.9)
15th July 1960	Hurricane Abby, category 1, south/central Belize.	HURDAT BMS	(76.6)
24th July 1961	Hurricane Anna, category 1, ten foot tides and damages to roofs and buildings reported.	HURDAT BMS	(94.6)

[28] TNA_CO_128_75
[29] GBNA_The Washington Post_12.09.1931
[30] BLNOL_The Times_14.09.1931; 15.09.1931; 16.09.1931; 17.09.1931; 21.09.1931; 4.11.1931
[31] EOL_The Economist_26.09.1931
[32] BLNOL_The Guardian_26.09.1931
[33] GBNA_The New York Times_12.09.1931; 13.09.1931; 16.09.1931
[34] GBNA_The New York Times_02.10.1955

		The Washington Post and *The New York Times* on 25.7.1861[35]	
31st October 1961	Hurricane Hattie, Category 5, sustained winds of 155 mph, gusts of 200 mph. Half of the buildings in Belize City were destroyed by winds and flood surges. 400 fatalities. The damage resulted in the relocation of the administrative and governmental capital 80 km inland to Belmopan.	HURDAT BMS Reported in: *The New York Times* on 4 and 5.11.1961;[36] *The Washington Post* on 2, 6 and 9.11.1961;[37] *The Guardian* on 4 and 5.11.1961.[38]	(94.6)
4th September 1969	Hurricane Francelia, category 1, impact south Belize, flooding on the Belize River, up to 36 ft higher than normal.	HURDAT BMS Reported in *The New York Times* on 5.9.1969;[39] *Los Angeles Times* on 5.9.1969[40]	(84.6)
19th September 1974	Hurricane Fifi, category 2, 120 mph winds at Belize City and tides up to 12ft higher than normal.	HURDAT BMS Reported in *The New York Times* on 21 and 23.09.1974;[41] *Los Angeles Times* on 21.09.1974;[42] *The Washington Post* on 20 and 22.09.1974.[43]	(74.6)
19th September 1978	Hurricane Greta, category 2, impact in south Belize, four deaths reported. Entire grapefruit crop destroyed.	HURDAT BMS Reported in the *Los Angeles Times* on 20.09.1978[44] *The Times* on 21.09.1978[45]	(76.6)
29th October 1998	Hurricane Mitch, category 5, damage to crops and roads. This hurricane was the first to make landfall in Belize since 1980.	HURDAT BMS Reported in *The Guardian* on 31.10.1998;[46] *The New*	(82..4)

[35] GBNA_The Washington Post_25.7.1961 and GBNA_The New York Times_25.7.1961
[36] GBNA_The New York Times_4.11.1961; 5.11.1961
[37] GBNA_The Washington Post_2.11.1961; 6.11.1961; 9.11.1961
[38] BLNOL_The Guardian_4.11.1961; 5.11.1961
[39] GBNA_The New York Times_5.09.1969
[40] GBNA_The New York Times_5.09.1969
[41] GBNA_The New York Times_21.09.1974; 23.09.1974
[42] GBNA_Los Angeles Times_21.09.1974
[43] GBNA_The Washington Post_20.09.1974; 22.09.1974
[44] GBNA_Los Angeles Times_20.09.1978
[45] BLNOL_The Times_21.09.1978
[46] BLNOL_The Guardian_30.10.1998

		York Times on 30.10.1998.[47]	
2rd October 2000	Hurricane Keith, category 4, 135 mph winds, north Belize and Cayes suffered greatest impact.	HURDAT BMS Reported on the BBC News website on 3, 10 and 21.10.2000.[48]	(75.7)
8th October 2001	Hurricane Iris, category 4, 145 mph winds, 3718 homes destroyed, 14 foot storm surge, 31 killed. Infrastructure damage estimated at US$ 8.15 million, cost to agricultural industry US$ 74.5 million.	HURDAT BMS Reported in *The New York Times* on 12.10.2001;[49] *The Guardian* on 10.10.2001;[50] the BBC News website on 10.10.2001.[51]	(70.1)
21st August 2007	Hurricane Dean, category 5, north Belize, 2,000 made homeless. Damage estimated as costing US$ 10 million.	HURDAT BMS Reported in *The New York Times* on 22.08.2007[52] and on the BBC News website on 22.08.2007.[53]	(75.4)
24th October 2010	Hurricane Richard, category 1 Roofs blown off and electricity supply temporarily disrupted. 3 deaths reported. 80 mph winds over Belmopan, 831 buildings damaged.	HURDAT BMS Reported on the BBC News website on 25.10.2010[54]	(76.2)

In the period 1787 - 2010 twenty three hurricanes made landfall at Belize, once per decade on average. The decade 1960 - 1969 contained four hurricanes, which is the highest of any decade in this record. No tropical cyclone activity of any sort was observed at Belize during the period 1980 - 1998 until Hurricane Mitch in October 1998. When the record of hurricane activity is compared with the meteorological record, it is unclear whether hurricanes have an impact upon precipitation amounts. Of the twenty three hurricanes outlined in Table 5.4, 19 occurred within the temporal frame of the meteorological record. Of these nineteen, ten hurricanes (1892, 1906, 1931, 1942, 1955, 1961, 1961, 1969 and 1998) occurred in years with higher than average annual precipitation, ranging between 5.2% (1892) to 155.9% (1906). The other nine hurricanes (1893, 1933, 1945, 1960, 1974, 1978, 2000, 2001, 2007 and 2010) occurred in years with lower than average annual

[47] GBNA_The New York Times_30.10.1998
[48] Available at: www.news.bbc.co.uk/1/hi/world/americas/953791.stm
[49] GBNA_The New York Times_12.10.2001
[50] BLNOL_The Guardian_10.10.2001
[51] Available at: www.news.bbc.co.uk/2/hi/world/americas/982451.stm
[52] GBNA_The New York Times_22.08.2007
[53] Available at: www.bbc.co.uk/2/hi/6955163.stm
[54] Available at: www.bbc.co.uk/news/world-latin-america-11615973

precipitation. 1893 and 2001 respectively had annual rainfall 28.8% and 9.7% lower than average. All other years had rainfall <6% lower than average.

Twelve hurricanes occurred in years when daily meteorological data are available and this enables the examination of the PI. The number of days with precipitation >2inches was 7.5 per year on average for the period 1878 - 1947 and 4.9 for the period 1973 - 2010. Six hurricanes occurred in years with daily data during the period 1878 - 1947 and three of these have higher than average PI including 1931 (15), 1942 (11) and 1945 (10). In the modern period (1973 - 2010) four hurricanes occurred in years with a higher than average PI including 2000 (10), 1998 (6), 1978 (5) and 2001 (5). Across both historical and modern precipitation records, there are four years with a PI of 15 days or higher; 1886 (21), 1911 (19), 1878 (15) and 1931 (15). Of these years, only in 1931 did hurricanes made landfall at Belize. This suggests that increased PI is not linked to hurricane activity. When the hurricane record is examined at a decadal level, the 1960s had the highest number of hurricanes (4), and this decade had lower than average rainfall (2.7% below average). Of the thirteen decades which contained hurricanes, only two had higher than average rainfall; the 1900s (25.6%) and the 1930s (6.4%). This suggests that the rainfall associated with hurricane activity at Belize did not make up a significant component of average rainfall at an annual or decadal level.[55] Similarly, there did not appear to be an increased PI in hurricane years.

5.4 Summary

The record of temperature and precipitation from Belize dating from 1865 represents the first such reconstruction from the country, and the oldest instrumental record from Central America. The predominantly daily observations provide the opportunity to examine more than monthly averages, reconstructing total precipitation days and precipitation intensity. The record of precipitation is more reliable than the temperature record. The latter suggests that in the modern period, monthly average maximum temperatures were 1˚C higher than the period 1973 - 2010; however, this could be due to the use of different exposures after the early 20th century. The precipitation record demonstrates that the mid-late 19th century was drier than the early 20th century, with each of the three measures of precipitation (average amount in inches, TPD and PI) higher on average during the latter period. Examination of the archival record identified seven years where yellow fever was present and even prevalent in Belize City. Of the six years where meteorological data was available, five had higher than average TPD and PI. This suggests that the persistent, low intensity rainfall may have created ideal conditions for the yellow fever vector *A. aegypti* to breed and this may have contributed to the outbreak of yellow fever. It should also be noted that ten further years were identified during the period 1878-1947 where ideal precipitation conditions

[55] Although it should be noted that rainfall associated with annual tropical storm acitivity does contribute a significant (as yet unquantified) amount of precipitation to the annual total.

occurred for breeding A. aegypti, yet there were no yellow fever epidemics recorded in the archival record. The report by Hunter (1887) demonstrates that the impacts and perceptions of climate can conflict with numerical meteorological data, even when the two types of account (narrative and numerical) were written by the same person. This demonstrates the importance of an interdisciplinary approach that seeks to compare (wherever available) high quality daily data with narrative accounts of the causes, perceptions and impacts of climate.

The hurricane history of Belize has been reconstructed using both narrative accounts and meteorological records. Analysis of the hurricane record derived from archival sources shows little visible impact of these events upon the precipitation record in terms of average monthly amounts. The PI increased in seven of the twelve years with hurricane events (and corresponding daily meteorological records), which could be due to the high intensity short duration precipitation associated with hurricane events. Newspaper reports gave insight into the socioeconomic cost of each event. The reconstructions of precipitation and hurricane activity presented in this chapter provide an important context for discussion in the following chapter (Chapter six). Chapter six focuses on the economies of the Belizean environment by exploring the history of two economic exports: mahogany and logwood. The role of these natural resources in shaping the economic history of Belize is examined, as is their impact upon the forests of northern Belize. The precipitation and hurricane reconstructions presented in Chapter 5 are considered alongside economic records of mahogany exports, and section 6.2.3 considers the role of climate variability in the production of mahogany in the 19th and 20th centuries.

Chapter Six

Economies of the Belizean environment, 1650 – 1950

6.0 Introduction

This chapter forms part of a 'poltical' environmental history which predominantly explores the impact of economic activities of the British in northern Belize during the 17th, 18th and 19th centuries, placing these activites in their political and social contexts. A reconstruction of the methods of logwood and mahogany production and export histories are presented using narrative accounts and export records from the British Colonial period. This 'political' aspect of an integrated environmental history builds upon the political, economic and social contexts explored in sections 2.3.3 and 2.3.4. These reconstructions of mahogany and logwood production and export enable the exploration of various impacts of the timber industry upon the landscape of Belize, in particular the SDTF and pine savanna ecosystems. This chapter also draws on the meteorological records presented in the previous chapter (Chapter 5), particularly concerning precipitation and hurricane reconstruction. These economic and meteorological records are considered together in order to examine the possible relationships between climatic conditions and the production of mahogany. In the final section, the established periods of intensive logwood and mahogany production are considered alongside the summary pollen record presented in Chapter 4, to discern whether periods of timber extraction and recovery since the 17th century are visible in the palaeoecological record. This chapter focuses on how economic activities, specifically the British since the 17th century, have affected their environment; this is the second central dimension of environmental history (Fig.1.2). In addition, this record of economic activity, centred on timber extraction, is brought together with meteorological and palaeoecological records to better understand the causes and extent of changes to the forests of northern Belize since the 17th century.

6.1 Logwood

6.1.1 The production of logwood

Much of the information surrounding the 17th and early 18th century logwood production comes from three naval travelogues. The first is, 'A new voyage around the world' (1699) was written by Somerset born privateer William Dampier (1651 - 1715) who visited Belize in the 1670s, and the second, 'A history of the voyages and travels of Capt. Nathaniel Uring' (1726) who travelled across northern Belize in 1719. The third is an account from John Atkins (1735), who visited the logwood cutters in northern Belize in 1730.

Dampier (1699), Uring (1726) and Atkins (1735) suggest that the logwood cutters built a camp of wooden huts in the logwood rich coastal and river bank regions called a 'barcaderas', and here the men would live and grow food on small agricultural plots. Atkins (1735) reports that logwood was stored at the barcaderas, and Uring (1726) also suggests that people came to purchase logwood there, as he himself did in 1719. Dampier (1699) suggests that the extraction of logwood began in the dry season and that cutters selected mature logwood trees 4.5 – 6 m tall and less than half a metre thick. The bark and outer grey/white layer were chipped away on site and the red heart wood removed; this was then dragged by the cutter to the coast or river bank (Dampier, 1699). Dampier (1699) describes the work of logwood cutters he observed in 1676, and notes the different roles performed by each man:

> 'Some fell the trees, others saw and cut them into convenient logs, and one chips off the sap…and when the tree is so thick that after it is logged, it remains still too great a burthen [sic] for one man…[they] blow it up with gunpowder.' (p.80)

Uring (1726) describes how logwood was transported from the river bank to the barcadares by loading chipped logwood into canoes; Bristowe (1894 p.214) suggests that larger logs had to be loaded into 'bark rafts' or 'cradles made of cabbage palm' as logwood did not float. Morris (1883) reported that up to two tons of logwood could be transported using these rafts, describing an 'immense train of these heavily-freighted bark-logs is often met with on its way down the river, or anchored at night in the middle of the streams' (p.42). Logwood cutters did not need substantial equipment, Dampier (1699) records that when cutting logwood in Campeche, Mexico he only required axes, machetes, saws, a gun, and a tent or 'pavilion' to sleep in. Bulmer-Thomas and Bulmer-Thomas (2012) suggest that it is likely that the cutters of Belize would have needed similar equipment. All three accounts suggest that cutting logwood needed little investment in equipment, labour or infrastructure, with rivers rather than roads used to transport logwood to the camps.

Contemporary accounts of logwood cutting give a detailed picture of the transitory nature of the production of logwood, with little if any profit re-invested in the infrastructure of a permanent settlement. The following section will explore in detail the logwood economy during the period 1680 - 1950, and the impacts of different periods of production upon the landscape of northern Belize will also be examined.

6.1.2 The logwood economy: 1680 - 1950

Annual exports from Belize to Britain of logwood and other valuable commodities such as mahogany, cedar and rosewood, were recorded by the British more than sixty years before Belize became a Crown Colony in 1871 (see section 2.3.3 i). The first records were made in ships logs (1809 - 1812). From 1822 to 1943, annual Colonial Office Blue Books of Statistics[56] recorded the export and import data for British Honduras, as well as population figures and other miscellaneous data. These records were consulted at TNAUK, and were supplemented with secondary data for the years 1750 - 1805: these were graphed with amount exported (tons[57]) plotted against the year of export (Fig.6.1). Data was available for almost every year during the periods 1802 - 1805, 1809 - 1812 and 1822 - 1943. In the period 1750 - 1802 data was available for 1750, 1755, 1756, 1765, 1771 and 1783. Broadly speaking, Fig.6.1 shows exports were high during the mid 18th century and peaked during the late 19th and early 20th centuries. These trends will be explored in greater detail in the following section.

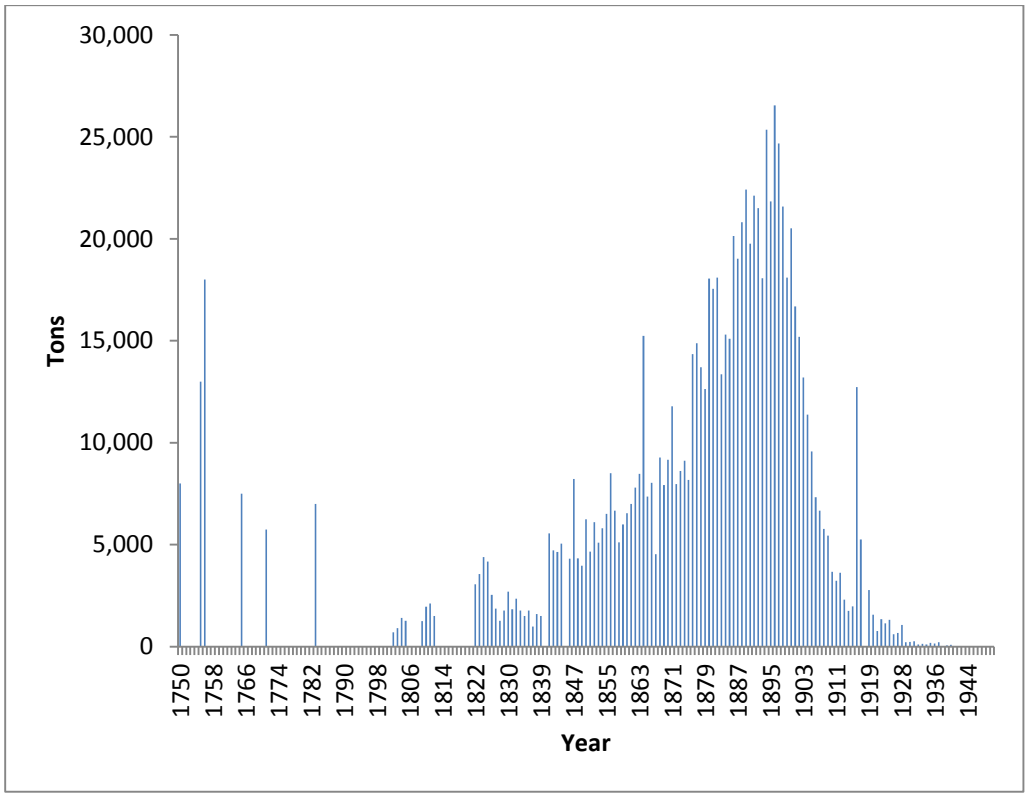

Figure. 6.1 Annual exports of Belizean logwood to Great Britain, 1750 - 1950[58]

[56] TNA_CO_128_1-117

[57] Tons = the imperial ton which is equivalent to 2000lbs 2240lbs according to Wikipedia, as opposed to 1 metric tonne which is equivalent to 1000kgs, or 2204lbs.

[58] TNA_CO_128_1-117

i) 1650 - 1800

By the mid-17th century, logwood cutting was extremely profitable (the peak value (in 1650) was £100 per ton in today's prices; the dyes derived from the heartwood were in great demand for use in the expanding European woollen industry (Camille, 1996). The price of logwood fell from 1650 to1750, to £50 per ton in 1670,[59] £25 per ton in 1749,[60] and £3 per ton[61] in 1800 (Camille, 1996; Bulmer-Thomas and Bulmer-Thomas, 2012). Although highly profitable during the 17th century, logwood cutting was undertaken during a period of geopolitical turbulence, with British activities in Belize considered illegal by the Spanish Crown, which laid claim to the region (Camille, 1996; Bulmer-Thomas and Bulmer-Thomas, 2012) (section 2.3.3 i). The contested and illegal nature of early logwood cutting placed limits on markets where the exported logwood could be sold legally; the vast majority of logwood was shipped via North Atlantic merchant shipping routes to Boston, New England and Port Royal, Jamaica. Logwood exported from Jamaica to Britain was subject to a tax (or duty) of £5 per ton[62] which, in the mid-18th century, reduced profit margins at a time of falling prices. The majority of logwood was shipped directly from Boston and Port Royal to European markets (including Germany and Holland), avoiding British duty; the British government received little benefit as they did not play any part in the profitable merchant shipping routes, nor did they have the opportunity to purchase high quality logwood direct from source and evade the Spanish monopoly.[63]

There are no figures for logwood exports to Britain during the 17th century and only six annual figures available for the 18th century (1750, 1755, 1756, 1765, 1771, 1783) (Fig.6.1), all dervived from secondary sources,[64] suggesting exports were at a low level. However, as has been demonstrated above, Fig.6.1 does not accurately document the scale of logwood extraction from Belize during this period. The amount of logwood exported during the late 17th and 18th century can only be estimated using contemporary narrative accounts and some limited export data. These suggest that from c. 1680 - 1740 logwood extraction was approximately 2,000 tons per year, undertaken by a small population (150 - 500 individuals) of mainly white British settlers and some slaves. Logwood exports increased during the second half of the 18th

[59] Equivalent to £4150 in 2005. All currency equivalents cited in this thesis were calculated using the currency converted on The National Archives UK website at www.nationalarchive.gov.uk/currency

[60] Equivalent to £2130 in 2005.

[61] Equivalent to £100 in 2005.

[62] Equivalent to £220 in 2005.

[63] Governor of Jamaica Thomas Lynch (1603-1684) reported that in 1682 logwood exported from Belize cost £15 per ton compared to Spanish logwood which was £100 per ton (Bulmer-Thomas and Bulmer-Thomas, 2012).

[64] Values for the 18th century have been compiled from secondary sources including MMS_AR_1871; Gibbs (1883); Bolland (1977) and Bulmer-Thomas and Bulmer-Thomas (2012).

century, with an average 9,500 tons per year exported to Britain alone in the period 1750 - 1800. Exports peaked at 18,000 tons in 1756. This was made possible by a substantial increase in the number of African slaves brought from Caribbean slave markets to cut logwood. In 1745 the number of slaves totalled 120, but by 1800 there were 3,000 working and living in Belize, ten times the number of white Europeans (Bolland, 1988). By 1765, the quantity and value of logwood exports from Belize was declining rapidly, as other sources of cultivated logwood became available, including those grown by the British in Jamaica and the Bahamas, the Spanish in Mexico and Cuba and the French in Guadeloupe, Haiti and Martinique (Bulmer-Thomas and Bulmer-Thomas, 2012). This decline in price came at the same time as the logwood cutter's labour costs increased,[65] so that by 1770 the Belizean logwood industry was no longer profitable.[66] At this point the Spanish and British governments came to an agreement over British settler's rights to cut and export Belizean logwood in the Treaty of Paris (1763), and an expansion of the agreed cutting area in The Convention of London (1786). These political agreements came at a time when logwood was no longer profitable and cutters had already begun to export mahogany.

ii) 1800 - 1950

The first forty years of the 19th century were a time of significant change in the British settlement at Belize (see section 2.3.4). After their defeat at the Battle of St George's Caye in 1798 (King, 1991) the Spanish no longer held any active claim over Belize, although it wasn't until 1862 that Belize was given the legal status of 'The British Settlement in the Bay of Honduras' (Bolland, 1988).The abolition of the slave trade in 1808 and of slavery in 1834 also brought changes to Belizean society and increased both the cost and the shortage of labour for the forestry industry. During this period, logwood was of minimal value as an export as European demand had reduced dramatically, and even that was available more cheaply from Jamaica and St Domingo (Bulmer-Thomas and Bulmer-Thomas, 2012). Export amounts to Britain in 1800 - 1840 averaged less than 2000 tons per year, which was less than exports one hundred earlier (Fig.6.1). Mahogany became an increasingly important export; by 1780 it had overtaken logwood as the primary export from Belize, and in the early 19th century logwood cutters shifted towards mahogany as their main source of income. During the following thirty years (1840 - 1870), logwood exports did recover slightly, averaging over 4,000 tons per year (Fig.6.1). A British newspaper article from 1857 suggested that the increase in logwood exports during this period was due to the higher quality of the Belizean product:

[65] Henderson (1811) states that slaves from Jamaica cost £40 to purchase and £25 per year to maintain.

[66] In 1750 slave purchase and maintenance costs made up 13% of the total value of exports, this rose to 61% in 1765 and 148% in 1771 (Bulmer-Thomas and Bulmer-Thomas, 2012).

> 'The Honduras logwood trade has greatly increased of late years, owing to the dye being much superior to the dye of the logwood which is cut in Jamaica and St. Domingo. The price of the former is 40 per cent higher than that if the latter…The Jamaica and St. Domingo wood is used in the dyeing of carpets and other coarse cloths; but the Honduras wood is used in dyeing all kinds of woollen, cotton and silken fabrics.'[67]

This trend of increasing logwood exports accelerated sharply during the period 1870 - 1910, with an average 8,650 tons exported per year, peaking at 26,500 in 1896 (Fig.6.1). The trend occurred after the introduction of synthetic aniline dyes in Europe post 1860 which were an alternative to dyewoods (Camille, 1996). Initially however, the artificial dyes proved costly to produce (Camille, 1996) and Belizean logwood exports had a strong resurgence in the late 19th and early 20th centuries, providing up to 50% of domestic exports during this period. After 1910, the export industry collapsed, with average annual exports 1,800 tons in 1910-1940; this included a brief revival during WWI (the combined exports of 1916 and 1917 account for 17% of total exports for the period 1910-1940) (Fig.6.1). Exports were non-existent after 1941 (Fig.6.1), and this marked the end of logwood as a significant component of Belize's economy.

6.1.3 Assessing the impact of the logwood economy on the landscape of northern Belize

Accounts of logwood production from the 17th (Dampier, 1699) 18th (Uring, 1726; Atkins, 1735) and 19th (Morris, 1883; Bristowe, 1894) centuries demonstrate that methods of production of logwood remained remarkably constant throughout the period 1680 - 1950. What did change was the scale of production for export, with two distinct periods of high exports, during 1680 - 1760 and 1870 - 1910. Here, the impacts of the different periods of logwood extract upon the landscape of northern Belize will be explored, bringing together the histories of logwood production and of the logwood economy.

Logwood cutting began in the mid-17th century along the coast of Belize, where it was abundant, and Caribbean ports were easily accessible. Dampier (1699) reports that in 1676, logwood was so abundant that all the wood cut in Belize was felled within 300 yards of the coast. However, less than fifty years later John Atkins (1735) reports that by 1730, cutters were moving beyond the immediate locale of their camps in order to cut more logwood:

> 'They [logwood cutters] are about 500 (merchants and slaves), and have taken up their residence at…a barcaderas, about 40 miles up a narrow river..at the season (once a year) they move their pavilions…better to attend the logwood cutting, which carries them sometimes many miles from this principal residence, to follow the wood, which runs in a line or vein…of some miles perhaps…'(p.227)

[67] BLNOL_The Daily News_3328_15.01.1857

Even with this expansion of cutting in the mid 18th century, logwood was still a small scale venture that had an extremely limited impact upon the landscape of Belize. Logwood was the first global Belizean export, extracted in the main by settlers of British origin who, in the mid-17th century, made the transition from privateers to logwood cutters. This transition was, in physical geography terms, a simple one. The coastal reefs and lagoons that had provided a base for piracy were also highly suitable locations for logwood camps and required only small scale clearance for dwellings and domestic agricultural plots, which were adjacent to the strips of coastal vegetation that contained the indigenous logwood thickets (Camille, 1996). The ecological distribution of logwood in riverine and coastal regions meant that the four major river systems of north and central Belize (Fig.1.5) provided water borne highways, which substantially reduced the financial cost and land clearance required to transport logwood from the north of the country to the port of Belize City (Fig.1.5). Although the late 17th and early 18th centuries were profitable for the logwood cutters and merchant ships that brought the Belizean logwood to a global market, this period of extraction had a minimal impact upon the landscape of Belize.[68]

The legalisation of logwood cutting came at the end of the 18th century, when the vast majority of settlers had made the switch to mahogany. This first recognition of the legal status of British activities in Belize may also have encouraged the settlers to document and record the boundaries of their 'logwood works'. Hooper (1886) records that the regulations set out on 10th April 1765 in Belize established that:

> 'When a person finds a spot of logwood unoccupied, and builds his hut, that spot shall be deemed his property, and no person shall presume to cut or fell a tree…less than one thousand paces or yards of his hut…with the course of the river or creek on both sides…' (p.30)

The formal international agreements between Britain and Spain and the local regulations of the Belizean logwood cutters reveal that by the end of the 18th century, the extraction of logwood had extended into the riverine areas of the northern and central interior of Belize. This was far beyond the late 17th century cutting limit of 300 yards from the coast and suggests that a much greater expanse of land was covered by the logwood cutters in order to extract mature trees. This greater coverage was coupled with a substantial increase in the enslaved population (who needed housing and feeding), and both

[68] One important impact was the absence of the indigenous Maya from the forests of northern and central Belize. By the beginning of the 18th century the vast majority of the Maya had already moved (sometimes forcibly by the Spanish) to the west and northwest of Belize, beyond the limits of the early British settlers. By the end of the 18th century the Maya that remained in locations used by the logwood cutters (e.g. along the New River, Hondo River) they were in such small numbers that they were unable/unwilling to prevent the advancement of the British (Camille, 1994; Mayfield, 2009; Bulmer-Thomas and Bulmer-Thomas, 2012)

factors contributed to the probable increased clearance of the forests of northern Belize during the second half of the 18th century.

As demonstrated by the record of exports (Fig.6.1), minimal quantities of logwood were cut during the first forty years of the 19th century. A species indigenous to Belize and therefore, well suited to the tropical climate and inundated savanna and coastal regions, logwood reaches a harvestable height in 10 to12 years (Bridgewater, 2012). A period of forty years would arguably enable significant re-growth of logwood in previously exploited regions. Furthermore, the period of peak extraction in 1870 - 1910 came more than two hundred years after logwood was first exported from Belize, which suggests that a period(s) of re-growth would be required in order for such a small area to support this sudden and late resurgence in the export market. Camille (1996) suggests that by 1910, the decreasing demand for logwood, 'merely compounded the fundamental problem of a dwindling supply, which was the result of centuries of over extraction' (p.83). This further supports the idea that logwood needed a substantial period (decades) of recovery after consecutive decades of high extraction. Today, logwood is still a common sight along the river banks and in the pine savannas of northern Belize, so whilst arguably its incidence may be lower than in the past (Camille, 1996) it still forms a significant component of these ecosystems. This recovery of logwood comes after a period of more than seventy years since the last year of export to Britain and demonstrates that, with a substantial period of minimal extraction, logwood continues to form part of the landscape of northern Belize in spite of being extracted as part of Belize's global export economy for nearly three hundred years.

6.2 Mahogany

6.2.1 The production of mahogany

There are multiple accounts of the production of mahogany (see section 2.1.2 ii) from the 19th and early 20th centuries, including contemporary newspaper reports and accounts written by British men who travelled to Belize, including Henderson (1811), Gibbs, (1883), Morris (1883) and Gadsby (1911). These describe how trees were felled in the forests of the interior northern region and were then transported by river to the sea port of Belize City. Writers also document the nature of the mahogany camps and the workforce who resided in them for some eleven months of the year. The mahogany cutting season began in mid-January when the 'woodsmen' left the main settlement of Belize City with their families for the mahogany 'works' or 'camps' of the northern forests (Henderson, 1811; Gibbs, 1883). Small boats called 'pitpans' were loaded with provisions to maintain the workers and their families during the long cutting season, as most would not return to Belize City until November. Key aspects of the production of mahogany will be explored in detailed, using contemporary accounts, beginning with the roles and composition of the mahogany workforce.

i) The 'mahogany hunters'

As has been shown in the previous account of the production of logwood, African slaves were first brought to Belize in substantial numbers in the mid-18th century, and by the end of the century outnumbered the white population by ten to one (Bolland, 1988). As the transition from logwood to mahogany occurred in the late 18th century, more African slaves were brought to Belize from the Caribbean slave markets. Henderson (1811) describes the mahogany workers as 'negroes' and Gibbs (1883) says that they were divided into groups of between ten and fifty men, with defined roles such as captains or huntsmen, carpenters, foremen, book-keepers and managers who oversaw multiple work gangs. Perhaps the most important individual in each cutting gang was the 'huntsman' who was tasked with cutting a path through the forest using his machete and identifying with an individual mark the mahogany trees to be felled (Henderson, 1811; Gibbs, 1883; Morris, 1883). Henderson suggests that huntsmen were valued at £500 (modern equivalent) as they were 'the most intelligent of fellows and his chief occupation is the search of the woods…to find labour for the whole' (p.57). Within the broad mahogany season of mid-January to November there was a second season which began in August, when 'the leaves of the mahogany tree are invariably of a yellow reddish hue which enables an eye accustomed to this kind of exercise to discover, at great distance, the places where the wood is most abundant' (Henderson, 1811, p.58). The huntsman would climb the highest tree in the vicinity and identified the mahogany trees within the territory of the mahogany works with which he is associated (Gibbs, 1883). As mahogany trees are rarely found in clusters or groups, but as individual trees dispersed over an area of approximately two hectares (Bridgewater, 2012), the huntsman's role was invaluable (Henderson, 1811; Gibbs, 1883; Morris, 1883). Gibbs (1883) identifies the challenges the huntsman faced in working with uncertain property boundaries of mahogany works, 'he is compelled to proceed craftily, so as not to be overreached, especially in placing his marks for recognition by a rival' (p.120). Hunters were paid for each individual tree they identified that was suitable for cutting (Morris, 1883).

ii) Felling, floating and trucking mahogany

Mahogany trees were commonly cut at about 3 – 4 m from the ground, usually on wooden platforms built and attached to the tree by the 'axe-men', so that they were able to cut above the buttressed roots, leaving a stump approximately 3 m high (Henderson, 1811; Gibbs, 1883). Gadsby (1911) writes that the axe-man 'wields the large axe with dexterity and strength gained by experience. Blow follows blow, until the forest resounds with the music of industry, breaking a silence which for countless years has reigned supreme' (p.53). Gibbs (1883) acknowledges the 'firm nerve and quick eye' needed in order to avoid accidents at the moment the tree falls which 'despite

the care taken, do sometimes occur' (Gibbs, 1883, p.53). Felling a single tree is the work of one day for two men, and once the tree is cut it is 'lopped, cleaned and sawn to the available length, ready to be hauled to the works' (Morris, 1883, p.68). Once roughly cut into a four sided log, 'they lie, like giant-warriors, stripped of their armour and left dead and naked on the field of battle' (Gadsby, 1911, p.54).

Two principal methods were used to transport felled mahogany to the river bank mahogany works. The older method, that of 'rolling', dates from the earliest period of cutting in the mid 17th to early 18th centuries, when mahogany trees felled were located closes to the works, and logs were rolled along cleared paths to the river bank (Gibbs, 1883; Gadsby, 1911). A second version of rolling was also continued throughout the 19th century during the wet season when the ground was soft. Mahogany logs were pulled on 'slides, or a kind of sleigh' over 'skids' which consisted of a path of 'long, hard wood posts, about 3 inches [7.5 cm] in diameter, placed across the track about a yard [1 metre] apart…sometimes mahogany logs…were drawn a distance of 8 or 10 miles [13 – 16 km]' (Morris, 1883, p.64). The most common method of transporting mahogany logs was that of 'trucking' (Gibbs, 1883; Morris, 1883), although Gibbs (1883) suggests that all three methods (two versions of rolling and trucking) were used in the course of a mahogany season, depending on the local conditions. In the trucking process, cut logs were loaded onto wooden trucks and hauled out of the forest by oxen along cut tracks and paths. Gibbs (1883) suggests that for a gang of forty hands there would be six trucks, each with two drivers and a team of six or eight pairs of oxen. Trucking was undertaken during the dry season months of April and May, when the ground was hard after a long period of dry weather (Morris, 1883; Gibbs, 1883). The trucks were a rudimentary construction, 'mounted in four broad wheels about three feet [1 m] in diameter…made in a most primitive fashion by sawing pieces across from a log of Santa Maria' (Morris, 1883, p.67). A report from 1890 described the trucks as 'clumsy and antiquated contrivances, the wheels are of solid wood, made by sawing off the end of a log a fitting iron boxes in the centre'.[69] The oxen used to pull the trucks were fed 'on the leaves and twigs of the breadnut tree,[70] which gives them more strength and power of endurance than any other obtainable food'.[71] Morris (1883) and Gibbs (1883) both reported that logs were removed from the forest or 'trucked out' at night, as the oxen are unable to work in the high daytime temperatures.[72] Morris (1883) says:

> 'It is a picturesque and striking scene, this midnight trucking. The lowing of the oxen, the creaking of the wheels, the shrill cries of the men, the resounding

[69] BLNOL_The Birmingham Daily Post_31_2134_27.12.1890

[70] Breadnut is the common name for the tree Brosimum alicastrum which is abundant in the seasonally dry tropical forests of the north of Belize and was also cultivated by the Maya for their starch rich fruits Ford (2009).

[71] BLNOL_The Birmingham Daily Post_31_2134_27.12.1890

[72] See Chapter 5 for the meteorological history of 19th and 20th century Belize. Average maximum daily temperatures during the 19th century were 29.4˚C.

> cracks of their whips, and the red glare of the pine torches[73] in the midst of the dense, dark forest, produce an effect approaching to sublimity' (p.67).

Once logs were trucked or rolled to the river bank they were piled high until the middle of June or July when the seasonal rains raised the level of the largest rivers and on all rivers by October, so the logs could be 'tumbled' into the water and floated to the mouth of the river (Morris, 1883). At the river mouth a 'boom' or iron chain was fixed which collected the logs as they were floated down, and it was here that 'several owners selected the logs by their respective marks, formed them into rafts and so float them down to the sea…whence they are shipped abroad' (Morris, 1883, p.69). Workers followed the logs down the larger rivers to release those which got caught up by fallen trees or other obstacles in the river.[74] If the logs were damaged in transit they were relined and re-hewn by the workmen who gave them 'a smooth and even surface. The logs are then measured, rolled back into the water at the mouth of the river and made into rafts'.[75]

iii) The mahogany works

The main mahogany works or 'banks' were the headquarters of the mahogany cutting operation and were situated on or close to the banks of the largest rivers of Belize, including the New River, the Belize River and the Rio Hondo (Fig.1.5). A central path was opened up from the camp into the forest and this was cleared and levelled by members of the gang, with individuals cutting approximately one hundred yards per day (Gibbs, 1883). The palm thatched store-houses, cattle sheds and accommodation for the gangs and their families were all located in the main camp on the river bank (Gibbs, 1883). The thatched huts used by the workers were sometimes called 'waltas' and were often raised to protect the workers and their provisions from 'prowling creatures', with 'hammocks hung…for beds, any convenient logs serve well for tables and chairs, and the cook makes an excellent range by filling a hole in the ground with hot stones'.[76] The trimming and rough squaring of the logs sometimes occurred at the river bank camps however, this manufacturing also took place at the river mouths after the logs had been floated from the camps (Gibbs, 1883). Morris (1883) identifies the temporary and transitory nature of the mahogany works:

> 'When the mahogany in the district was exhausted, the works were abandoned, the huts in the course of time tumbled to pieces, and the place eventually would become so overgrown as to be hardly distinguishable from the neighbouring forest. The name, however, lives in the memories of the inhabitants, and is handed down until it becomes mere tradition.' (p.62)

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[73] This is an interesting reference to the use of pine as torches and is discussed in Chapter 4.
[74] BLNOL_The Birmingham Daily Post_31_2134_27.12.1890
[75] BLNOL_The Birmingham Daily Post_31_2134_27.12.1890
[76] BLNOL_The Bristol Mercury_221_331_7.10.1896

The procurement of mahogany from the forests of Belize and its production into logs shipped to Britain was a substantial endeavour, requiring the clearing of paths and trucking roads, investments in workers, equipment, camps and livestock over an eleven month cutting season. Compared to the cutting of logwood, which could be undertaken by men on an individual scale, mahogany production required the investment and oversight of well resourced operations, which needed to require substantial areas of forest to fund their investment. By the beginning of the 19th century this new, large scale economy replaced logwood as Belize's leading global export; the economy of mahogany exports will be considered in the following section.

6.2.2 The mahogany economy: 1780 - 1950

As with logwood, annual exports from Belize to Britain of mahogany were recorded by the British from the beginning of the 19th century. The first formal British records were made in ship's logs (1809 - 1812) and then in Colonial Office Blue Books of Statistics (1822 - 1950).[77] These records were supplemented with secondary data for the years 1799 - 1808, and were graphed with amount exported (cubic meters[78]) plotted against the year of export (Fig.6.2). Annual export figures are available for every year during the periods 1799 - 1805, 1809 -1812 and 1822 - 1943. Figures for the period 1799 - 1805 come from secondary sources.[79] Fig.6.2 shows that during 1825 - 1865 exports were broadly high, and that this was followed by a period of decline in the late 19th century. The first thirty years of the 20th century saw peak mahogany exports, before a sudden and permanent collapse.These broad periods of the mahogany economy will be explored in greater detail in the following section.

[77] TNA_CO_128_1-117

[78] In the original records exports of mahogany were measure in 'board feet' (bd ft), a North American unit of measure for the volume of timber. For ease of comparison with modern measurements these values have been converted into cubic meters where 1 board-foot = 0.00236 m^3.

[79] Values for the years 1799 - 1801 are given by Bulmer-Thomas and Bulmer-Thomas (2012), and 1802 - 1805 are found in MMS_Annual Report_1871.

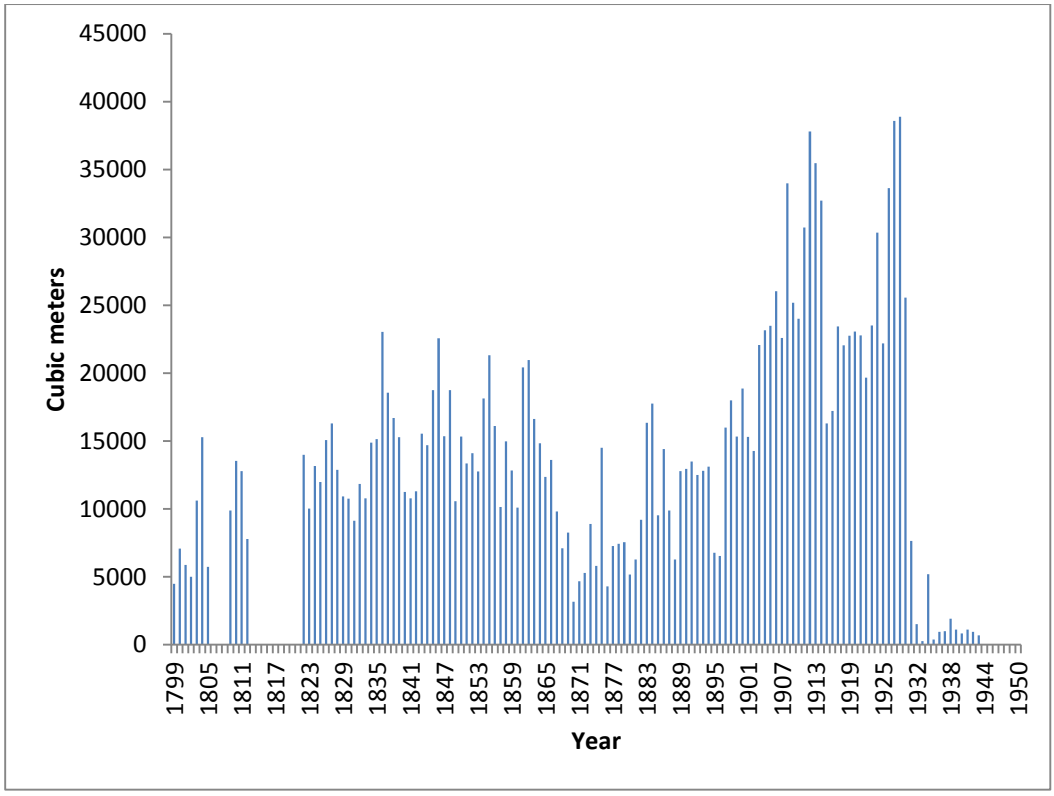

Figure 6.2 Annual exports of Belizean mahogany to Great Britain, 1799 – 1950

i) 1780 - 1865

The vast majority of all mahogany cut in Belize during the 18th, 19th and 20th centuries was exported to Britain. This was in contrast with the first eighty years of logwood cutting, where most of the exports reached the American and European markets. Figure 6.2 therefore gives a more complete account of the total amount of mahogany exported from Belize during the 19th and 20th centuries. Mahogany cutting for export did occur prior to 1799, even though it was only made legal in 1786 as part of the London Convention (Bulmer-Thomas and Bulmer-Thomas, 2012). Bulmer-Thomas and Bulmer-Thomas (2012) suggest that 950 m^3 was exported in 1765, and this rose to 4,500 m^3 by 1799 (Fig.6.2). Mahogany exports averaged 13,600 m^3 during 1780 - 1865, increasing from an annual average of 9,000 m^3 in the first decade of the 19th century, to 15,800 m^3 in the decade 1855 - 1864 (Fig.6.2). This reflects the growing domestic and industrial demand for mahogany including, fine household furniture, ecclesiastical furniture (altars, pews and pulpits), pianos, scientific instruments and dock gates.

After the 1830s, mahogany was used in the construction of railway carriages and coaches, although it was not until 1846 that mahogany was widely used in ship building; until then, its use was restricted by the Register of British and Foreign Shipping as poorly cut mahogany was highly susceptible to dry-rot

(Bulmer-Thomas and Bulmer-Thomas, 2012). Annual average mahogany export figures during the period 1820 - 1865 were 14,700 m^3. This period of increased demand for high quality mahogany was supported by economic policies of the British Governments of the day. During the 1820s and 1830s Belizean imports had lower tariffs than those from Jamaica, at a time when Belize was not yet recognised as a Colony and therefore should not have qualified for reduced tariffs (Dobson, 1973). In 1844 – 1845, all duties on imported mahogany were abolished, which further raised demand. This also meant that exports from Belize had to compete with other sources of mahogany, as now all countries were free of tariffs (Dobson, 1973). By the mid-19th century, mahogany supplies from Jamaica and the Bahamas had been exhausted, but Cuba remained a significant competitor (Bulmer-Thomas and Bulmer-Thomas, 2012). The impact of reducing tariffs actually reduced Belize's market share of mahogany exports during the mid-1840s, with Belizean mahogany accounting for 80% of global exports in 1845 (Bristowe, 1894) and 70% in 1846.

Within a trend of increasing mahogany exports during 1780 - 1865 there is some significant annual variation. Annual exports fell from 23,000 m^3 in 1836 to 11,250 m^3 in 1840, then rose to 22,500 m^3 in 1846, before falling to 10,600 m^3 in 1849 (Fig.6.2). These sharp trends reflect a complex picture of shifting economic legislation, changes to the labour market and the variable place of Belize as a global mahogany exporter. Falling exports in the early 1840s probably reflect the increased costs of production in Belize. Labour costs increased after the abolition of slavery in 1834;[80] in addition, by 1840 almost all of the easily accessible mahogany had been cut, requiring owners to spend more on labour and livestock to locate, fell and extract mahogany. These increased costs were in the context of falling prices elsewhere as new sources of mahogany emerged (Bulmer-Thomas and Bulmer-Thomas, 2012). In the mid 1840s Belizean mahogany exports were given a boost with increased demand from shipping; however, the abolition of tariffs led to a rapid expansion of global mahogany extraction and export that began to run ahead of demand, resulting in falling prices (Bulmer-Thomas and Bulmer-Thomas, 2012). Gibbs (1883) suggests that the 'depression' of the mahogany trade began in 1850 when the inaccessibility of mahogany greatly increased the cost of extraction, the trade in mahogany 'had always been a fluctuating one, but one good season went against a couple of bad or indifferent ones; by 1850 however, the margin for bad years had become less extended' (p.114). A poem 'Tears of Belize', written in 1843 at Belize by the Garrison Chaplain Edward Clark, documented the decline of the mahogany economy and the abolition of slavery. The poem was published in the *Honduras Observer* in March 1843, and was reprinted in the same paper in June 1866, with the sub-heading, 'the following line…appeared in our *Honduras Observer* of March 2nd

[80] Slavery in Belize continued for at least thirty years after 1834 in the form of 'apprentice ships' and indentured labour however, the cost of labour and labour shortages increased significantly after 1834.

1843; the year beginning the downfall of the great staple Mahogany'[81]. This suggest that both during the early 1840s and more than twenty years later, the decline in the mahogany economy was viewed as beginning in the mid-19th century.

ii) 1865 - 1950

The last half of the 19th century saw a sustained decline in Belizean mahogany exports, with an average 10,400 m^3 exported per year during this period, the lowest in this 150 year record of exports (Fig.6.2). The decline in exports was due to falling prices, rising costs and the increasing inaccessibility of trees (Gibbs, 1883; Bristowe, 1894; Bulmer-Thomas and Bulmer-Thomas, 2012). As iron rather than wood became the preferred material to hull ships, the demand and price for mahogany reduced further. A newspaper report in 1861 predicted the downward turn of the mahogany market:

> 'A large number of vessels are here waiting for wood…What will be done with it then I cannot tell, as the bulk of it is ship building wood, and from what we hear, it seems more probable that iron, and not wood, is to be used hereafter in ships of war. This, if true, will be a sad blow to this colony, as our principal business for the last fifteen years has been cutting wood for ship building purposes.'[82]

At the turn of the 20th century there was a resurgence in the export market, with annual average exports 25,500 m^3, peaking at 39,000 m^3 in 1929. Increased prices and demand were driven by a renewed and substantial British appetite for mahogany, now considered an extremely fashionable luxury item. Huxley (1934)[83] describes the early 20th century British love affair with mahogany:

> 'When I was a boy there was hardly, in all my acquaintance, a single reputable family which did not eat off mahogany, sleep in mahogany. Mahogany was a symbol of economic solidity and moral worth…in Victorian England, mahogany proclaimed the respectable man of substance. So loudly and unequivocally did it proclaim him that those whose trade was in luxury could never by lavish enough with their mahogany. In Pullman cars, in liners – wherever, indeed, it was necessary to give clients the illusion that they were living like princes – mahogany fairly flowed like water.' (p. 19)

[81] The poem was included in a newspaper cutting incorporated as part of Colonial Office correspondence, TNA_CO_127_2

[82] GBNA_The New Orleans Daily Delta_8.08.1862_p.2

[83] The British writer Aldous Huxley (1894 - 1963), author of *A Brave New World* (1932) and *Ends and Means* (1937), travelled across Central America and the Caribbean in 1933 and visited Belize. His account of this journey was published the travelogue *Around the Mexique Bay* (1934).

This resurgence was short lived. After 1930, exports declined sharply, averaging only 1800 m^3 per year during 1931 - 1950 (Fig.6.2). Huxley (1934) suggests that it was the changing tastes of the British that caused this decline:

> 'Alas, how quickly such sacred symbols can lose their significance!..I cannot think of a single modern high-bourgeois home in which mahogany plays more than a casual and inconspicuous part. My friends all eat off glass and metal, sit on metal and leather, sleep on beds that are almost innocent of enclosing bedsteads…The dark rich wood, so much beloved by our fathers and grandfathers, has not only lost its symbolic meaning; it is also…regarded with aesthetic distaste. Mahogany, in a word, is now hopelessly out of fashion.' (p. 19)

In the 1930s, mahogany's desirability to the British and wider European markets certainly waned, but this decline in popularity was eclipsed by the impact of the world wide economic depression which began in 1930, and this global economic context must certainly have played a significant role in the rapid and permanent decline of the Belizean mahogany industry.

6.2.3 Climate and the mahogany economy

Weather conditions are mentioned frequently in some newspaper articles and missionary letters written about the mahogany industry in the 19th and 20th centuries. Weather is often given as a reason for the perceived success or failure of the exports for a particular year. During the 1850s and 1860s, four years have been identified as having multiple (at least two)[84] contemporary newspaper reports or missionary accounts which link the weather to mahogany exports, three to the failure (1853, 1857 and 1860) and one to the success (1861) of that year's production. In each of the years 1853, 1857 and 1860 there are newspaper accounts which report that the usually dry months of May and April (when felling and hauling mahogany takes place) have been wet and the normally wet months, beginning in June (when the logs are transported down the rivers) have been dry. In the *New York Herald* on 30th June 1857, it is reported that: 'the dry or trucking season is over, and what makes it interesting here is, the season has been very wet, so much so that it has not been possible to truck out one-quarter of the wood that was fallen and

[84] Although there are numerous other articles from the period 1850 - 1900 that suggest weather conditions were a causal factor in increasing or decreasing the amount of mahogany available for export, only years with at least two (and preferably more) reports from different newspapers or other sources have been selected. **1853** has three relevant newspaper accounts, two in *The Economist* dated 30.7.1853, 20.08.1853 and one in *The Morning Chronicle* dated 18.08.1853. **1857** has four accounts, three in *The New York Herald* dated 21.05.1857, 30.06.1857 and 6.11.1857 and one in *The Morning Chronicle* dated 18.08.1857. **1860** has three accounts, two in *The New York Herald* dated 16.07.1860 and 21.11.1860 and one in *The Boston Courier* dated 20.08.1860. **1861** has two accounts, one in *The* Morning Chronicle dated 28.09.1861 and one in *The New Orleans Daily Delta* dated 8.08.1861.

prepared…'.[85] A similar account from July 1860, again from the *New York Herald* reports that:

> 'We have had very bad weather, rain having fallen plentifully each month of the dry season, and, in June when we ought to have had heavy rains, we had fine, dry and very warm weather, with only occasional showers…this interferes with our mahogany cutting operations. It prevents the wood from being trucked out, and what is trucked out cannot come down for the want of the flood.[86]'

The same unusual weather conditions are reported in 1853, with heavy rainfall in April and May, and a late onset of lower rainfall in June. In each of the three years, 1853, 1857 and 1860, mahogany exports were reduced, with values of 12,750 m^3, 10,150 m^3 and 10,100 m^3 respectively. This is significantly below both the average annual total for the period 1799 - 1865 (13,600 m^3) and for the whole record 1799 - 1950 (14,200 m^3), and suggests that these accounts of poor weather did indeed have an impact on the amount of mahogany extracted for export in those years. Conversely, reports of a lengthy dry season followed by sufficient rainfall in the wet season are linked to increased mahogany exports. Reports from Belize in July 1861 state that there has been 'an excellent dry season, and immense quantities of mahogany have been got out, and, as the rainy season has now set in, this season's wood will be good'[87]. A later report from September 1861 suggests that the extremely high rainfall had brought more than usual amounts of mahogany to market, 'the swollen state of the river had liberated immense quantities of mahogany which had been laid back high and dry for years, had come to market'.[88] 21,000 m^3 of mahogany was exported from Belize in 1861, which is 48% higher than average annual exports during 1799-1950, and 54% higher than those during 1799-1865, which suggests that in 1861 weather conditions were unusually favourable for mahogany production and transport to market.

The economic record (Fig.6.2) shows that mahogany exports were in decline during 1865 - 1899 and peaked during 1900 – 1930; some of the economic factors at work during these periods have been outlined. However, the account of the production of mahogany, and the examination of the possible role of weather conditions in the success or otherwise of mahogany extraction and transport, have demonstrated that the precipitation levels of certain months of the year were critical. The optimum conditions in April/May and September/October for felling and hauling were low precipitation, whereas high precipitation was required in June to transport large quantities of mahogany logs. Chapter 5 presented a meteorological record from Belize City dating from 1865, and this record enables mahogany export figures to be considered alongside monthly precipitation values for the mid-19th to mid-20th centuries. Table 6.1 presents average precipitation for the periods 1865 - 1899 (when mahogany was in decline), 1900 - 1930 (the peak period of mahogany

[85] GBNA_The New York Herald_23.07.1857
[86] GBNA_The New York Herald_18.08.1860_p.1
[87] GBNA_The New Orleans Daily Delta_8.08.1861_p.2
[88] BLNOL_The Morning Chronicle_28.09.1861

production) and 1865 - 2010 (an average value for the extent of the meteorological record), during April/May, June and September/October.

Table 6.1 Average precipitation values for key months of mahogany production and transport during 1865 - 1899, 1900 - 1930 and 1865 - 2010.

	Average precipitation (inches) in 1865 - 1899 (low output)	**Average precipitation (inches) in 1900 - 1930 (high output)**	**Average precipitation (inches) in 1865 - 2010 (overall average)**
April + May	8.7	7.7	6.7
June	7.5	9.5	8.8
September + October	10.1	8.7	9.8

During April/May 1865 - 1899 and 1900 - 1930 average precipitation was 30% and 15% higher, respectively, than in 1865 - 2010. Average precipitation in June 1865 - 1899 was 15% lower than average precipitation across 1865 - 2010, and 21% lower than that observed in 1900 - 1930. In September/October 1900 - 1930 precipitation was 11% lower than average precipitation during 1865 - 2010 and 14% lower than 1865 - 1899. Precipitation averages in June and September/October 1900 - 30 were more favourable for mahogany production than those in 1865 - 1899, and although average values for April/May in both 1865 - 1899 and 1900 - 1930 were higher than the average for the entire record, precipitation is higher in the earlier period. This suggests that weather conditions in the key months for mahogany production during the early twentieth century were more favourable than those for 1865 - 1899.

During the period 1865 - 1899 there were 26 years with both monthly precipitation data and annual mahogany export totals; there were 31 years with both sets of data available during 1900-1930. Correlation coefficients were calculated to assess the relationship between monthly precipitation totals and annual mahogany exports for each of the key monthly groups. The results (April/May R^2= +0.02, June R^2= +0.03 and September/October R^2 = -0.01) demonstrate that there is no individual correlation between precipitation in these key months and annual mahogany output. However, as mentioned in the report of September 1861[89], the cumulative effect of multiple years of favourable or unfavourable precipitation conditions may well have been a

[89] BLNOL_The Morning Chronicle_28.09.1861

factor in the overall rate of mahogany production during the late 19th and early twentieth century.

i) Hurricanes and the mahogany economy

Eight hurricanes occurred during the period of mahogany export records, in 1827, 1864, 1892, 1893, 1906, 1931, 1933 and 1942. Two hurricanes occurred in the first economic period 1799 - 1865, where average annual mahogany exports were 13,600 m^3. Two hurricanes occurred in the second economic period 1866 - 1899, with average annual mahogany exports of 10 400 m^3. One hurricane occurred in the period 1900 - 1930, when mahogany exports were at their highest and average at 25,500 $m^{3.}$ After 1930 there were three hurricanes and average mahogany exports were 1,800 m^3. Table 6.2 demonstrates that in six of the eight years in which hurricanes occur, mahogany exports were higher than average for that economic period of mahogany export.

Table 6.2 Hurricane events recorded during the economic record of mahogany extraction compared with annual export figures.

Hurricane Event (category)	**Annual mahogany exports (m^3) (average for the economic period is given in brackets)**
1st August 1827 (unknown)	16,300 (1799 - 1865 = 13,600)
7th September 1864 (1)	14,800 (1799 - 1865 = 13,600)
12th October 1892 (1)	12,500 (1866 - 1899 = 10,400)
7th July 1893 (1)	12,800 (1866 - 1899 = 10,400)
12th October 1906 (1)	26,000 (1900 - 1930 = 25,500)
9th September 1931 (4)	7,650 (post 1930 = 1,800)
13th September 1933 (1)	260 (post 1930 = 1,800)
9th September 1942 (1)	950 (post 1930 = 1,800)

Across all four economic periods (1799-1865, 1866-1899, 1900-1930, post 1930) hurricanes are associated with years of increased mahogany production. The two exceptions (1933, 1942) occur in the post 1930 period when global demand for mahogany was very low. Low category hurricanes (category 1 and 2) may have assisted mahogany production as they could clear areas of forest that may have otherwise taken considerable human effort. In addition, low category hurricanes would have caused less disruption to communications and financial cost to the export industry generally. Bridgewater (2012) suggests that low category hurricanes can provide ‘ideal conditions for mahogany regeneration, with mature trees withstanding damage

better than many other species.' (p.166) However, it is also clear that during the peak period of mahogany production (1900 - 1930) only one hurricane is recorded occurring, minimising the amount of disruption during this period of high demand for mahogany. Conversely, during the decline of the mahogany industry, three hurricanes occurred (1931, 1933, 1942), which may have contributed to the sharp decline in mahogany exports, especially post 1931, as the industry would not have made sufficient profit to mitigate losses incurred by the category 4 hurricane in 1931. Clearly, the relationship between hurricane events and annual mahogany exports is not simple; however, low category events may have assisted forest clearance, whilst an extended period without any events may have reduced the disruption and financial cost associated with high category hurricane events. In the final section of this record of mahogany production and export, the impact of the mahogany industry on the landscape of Belize will now be considered.

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6.2.4 The impacts of the mahogany industry

Bridgewater (2012) suggests that timber extraction is the most significant factor in the permanent demise of tropical forests across the Central American region, and that although today 50% of Belize is covered by forest, these modern forests are 'greatly altered by human hand' (p.161). In general, mahogany extraction since the 18th century has had a greater impact on the landscape of Belize than the logwood industry. Mahogany is a low incidence tree species, with trees of a harvestable height (>50 cm diameter) rarely exceeding two per hectare of seasonally dry tropical forest (Pennington, 2002). A larger amount of forest clearance was therefore needed to fell and extract one tree, compared with the high density species of logwood. The first phase of mahogany extraction in the mid-late 18th century occurred in the accessible areas close to the Belize and New Rivers of northern Belize (Fig. 1.5). Arguably this early extraction had the least impact upon the forests, with trees felled adjacent to the river banks, by small populations who did not yet have the additional assistance of slaves, cattle or wagons. The first mahogany works were in the same style as logwood cutting camps, a small collection of canvas or wooden palm-thatched living quarters, agricultural plots and timber processing areas on the river banks. Indeed, the first mahogany works of the 18th century probably existed alongside the logwood camps, as logwood cutters made the transition to the more profitable tropical hardwood. By the turn of the 19th century, the increase in the slave population and the number of cattle and wagons substantially extended the amount of mahogany that could be felled, transported and processed. The increase in the slave population meant the expansion of the mahogany works, with more housing and agricultural plots needed to accommodate >4,000 slaves working in Belize by 1823.[90] Cattle and wagons were in widespread use for hauling mahogany from 1800 (Morris, 1883; Gibbs, 1883; Bridgewater, 2012); they extended the distance mahogany could be transported to upwards of 16 km, and therefore

[90] Population data comes from Colonial Office Blue Books: TNA_CO_128_10

the reach of the mahogany cutter within the forests of the interior of Belize. The use of cattle also meant areas of forest needed to be cleared for pasture and grazing. Morris' (1883) description of wooden poles used as 'slides' or 'skids' across softer, damper tracks involved the felling and processing of smaller trees to use in this 'road making' and necessitated a substantial clearance of forest.

By the mid 19th century there are contrasting assessments of the availability of mahogany in Belize. An article in the *Caledonian Mercury*, 1857 reports, 'mahogany and logwood have had their day, and the axe and the saw must now give way to the spade and the plough'.[91] Another newspaper report suggests that there is still plentiful mahogany to cut:

> 'An impression has latterly existed that almost all the mahogany in British Honduras has been cut. This, however, is a mistake. There is sufficient wood in the country…to supply the European as well as the American market for many years to come…The best mahogany is found to the north of the river Belize.'[92]

Gibbs (1883) suggests that by 1850, all easily accessible mahogany had been felled, and the rising labour costs after the emancipation of slaves, the increased need for expensive trucking paths to be cut as mahogany became more inaccessible and the variable price meant that mahogany became less profitable. Gibbs (1883) suggests that in the late 19th century there was still mahogany to be cut in the forests, and even describes some form of forest management:

> While acting to some extent on the principle of killing the goose that laid the golden egg, mahogany firms have not been utterly reckless. The system has been to open a work in one direction, fell the largest trees…leaving the smaller trees to acquire the requisite dimensions. The work would then be closed for a time, from ten to twenty years, let us say.' (p.119)

Morris (1883) also suggests that mahogany could be cut in the same area every thirty years, with mahogany works re-opened after a period of abandonment. Pennington (2002) suggests that mahogany trees of a harvestable size can, in suitable conditions, grow in thirty years, which suggests that the 19th century forest management strategy described could prolong the occurrence of mahogany in the forests of Belize. The reduced period of extraction during 1865-1899 may have enabled the recovery of mahogany stocks in some areas, prior to peak demand in the early 20th century. However, by 1900 mahogany extraction had expanded to the south of the country, even though wood cut south of the Sibun River (Fig.1.5) was considered of poorer quality than that from the northern forests surrounding the New River and the Belize River (Morris, 1883; Bridgewater, 2012). This expansion in the south may suggest that mahogany stocks in the north and central regions had been exhausted, but may also reflect the high demand

[91] BLNOL_The Caledonian Mercury_221_15.09.1857
[92] BLNOL_The Daily News_3328_15.01.1857

and high price of, mahogany during 1900 - 1930; this may have made previously marginal mahogany profitable. The mahogany tree species is vulnerable to over harvesting as this removes 'the mature seed trees necessary for regeneration, and mahogany seeds do not retain viability in the soil for longer than one year' (Bridgewater, 2012, p.166). By the middle of the 20th century mahogany from the southern interior forests had been exhausted (Bridgewater, 2012).

The impact of the mahogany industry upon the forests of Belize is visible in the composition of the forest today. In 1774 a mahogany tree measuring 3.65 m in diameter was reported as being felled in the forests adjacent to the New River, northern Belize (Fig.1.5) (Weaver and Sabido, 1997). In modern times it is rare to find one with a diameter >50 cm, and *S. macrophylla* remains on a list of protected species (Bridgewater, 2012). Pennington (2002) suggests that 3.5 million m^3 of mahogany were felled from the forests of Belize during the 19th and 20th centuries. Mahogany exports during 1799-1950 totalled 1.9 million m^3, comprising more than 50% of all mahogany extracted. Grogan (2011) suggests that a single harvestable mahogany tree (>50 cm diameter) produces on average 2 m^3 of timber, therefore approximately 950,000 trees were felled in the period 1799-1950 and 1.75 million trees in total. As two mature mahogany trees occur on average per hectare (Pennington, 2002), this suggests that during the export period 475,000 hectares of forest saw the impact of the mahogany industry, and in excess of 875,000 up to the end of the 20th century. As Belize's total land area is 2,280,000 hectares (22,800 km^2) (Thompson, 2004), mahogany extraction has affected over 38% of the land of Belize, with up to 21% during 1799 - 1800 alone. Such an impact upon a substantial area, especially in northern Belize, for a period of over three hundred years may be visible in the pollen record, and so the archival records of mahogany and logwood extraction are now considered in the context of the pollen record presented in Chapter 4.

6.3 The documentary history of the timber industry of Belize and the palaeoecological record from Lamanai, NRL

The documentary records of timber export have shown that logwood and mahogany were clearly the dominant economic forestry products from Belize from the mid-17th until the mid-20th century. Although logwood was extracted and exported from as early as 1660, British economic records suggest that logwood was sent in significant amounts to the UK during 1750 - 1910. Mahogany cutting began in the mid-18th century, initially alongside the harvesting of logwood. Economic and narrative documentary records suggest that the peak period of mahogany exports occurred during 1800 - 1945. From 1800 cattle and wagons, as well as a substantial slave population, greatly increased the forest area available to cutters and therefore the volume of mahogany. Mahogany (*S. macrophylla*) and logwood (*H. campechianum*) are identifiable in the pollen record, and occur throughout the Lamanai 2010 short core; however, they are present in low amounts (<2.5%) which limits the

usefulness of their signal when exploring changes over decades. Mahogany and logwood are ecologically restricted, and occur in distinct vegetation types, with mahogany occurring in seasonally dry tropical forest and logwood in coastal and riverine regions, and inundated pine savannas. As such, a mahogany signal can be inferred from a broader signal of SDTF, whereas logwood can be inferred from changes in inundated pine savanna. The coring site at Lamanai, New River Lagoon, is surrounded to the east with pine savanna, and to the west by SDTF (Fig.1.6); such a site presents a significant opportunity to explore the changes in these two important vegetation types. As has been outlined in Chapter 4, the Lamanai 2010 short core has an uncertain chronology; however radiocarbon dates have established that the core represents the period c. AD 700 – 2010 (Table 4.2). This gives a sedimentary palaeoecological record of the logwood, mahogany and post timber extraction eras that can be examined in conjunction with the documentary accounts of such periods of economic exports. Table 6.3 presents the percentage pollen data for SDTF, pine savanna and herb taxa along with palynological richness and microscopic charcoal for the logwood, mahogany and post 1975 periods. In Fig. 6.4, the three periods of timber extraction are zoned onto the summary percentage pollen diagram from the NRL, Lamanai.

Table 6.3 Palaeoecological variables for the logwood, mahogany and post 1975 periods of timber extraction

Palaeoecological variables (averages)	**Logwood period (1660 – 1910)**	**Mahogany period (1800 – 1945)**	**Post 1975**
SDT forest (%)	26	20	31
Pine savanna (%)	26	32	35
Herbs (%)	26	26	18
Palynological richness ($E(T_{300})$)	33	31	35
Microscopic charcoal particles per cm^3	314	324	195

Table 6.3 and Fig. 6.3 demonstrate that logwood extraction from inundated savannas is visible in the pollen record. The pine savanna signal is reduced during the logwood period, with values 6% lower in the mahogany period and 9% lower in the post 1975 period (Table 6.3 and Fig.6.3). SDTF is 5% lower in the logwood period compared to the post-1975 period, but is 6% higher than the mahogany period, suggesting that although there is a visible impact upon the SDTF during the logwood period, this is not as extensive as the mahogany period. During the mahogany period SDTF is substantially reduced, averaging 20% compared to 26% in the logwood period and 31% in the post-1975 period. This reflects the general clearance of SDTF during the mahogany period as shown in the earlier accounts of mahogany production. Herb taxa is 8% higher during both the logwood and mahogany periods compared with the post-1975 period, reflecting a high disturbance signal during the peak periods

of timber extraction. Palynological richness is highest post-1975 and lowest in the mahogany period, suggesting that ecological diversity was most reduced by the extensive clearance of the forest during the production of mahogany. Microscopic charcoal is higher during the logwood and mahogany periods than in the post-1975 period, peaking during the 19th century. This peak in microscopic charcoal may reflect the combined impact of both strong mahogany and logwood industries during the late 19th century (Figs.6.1 and 6.2).

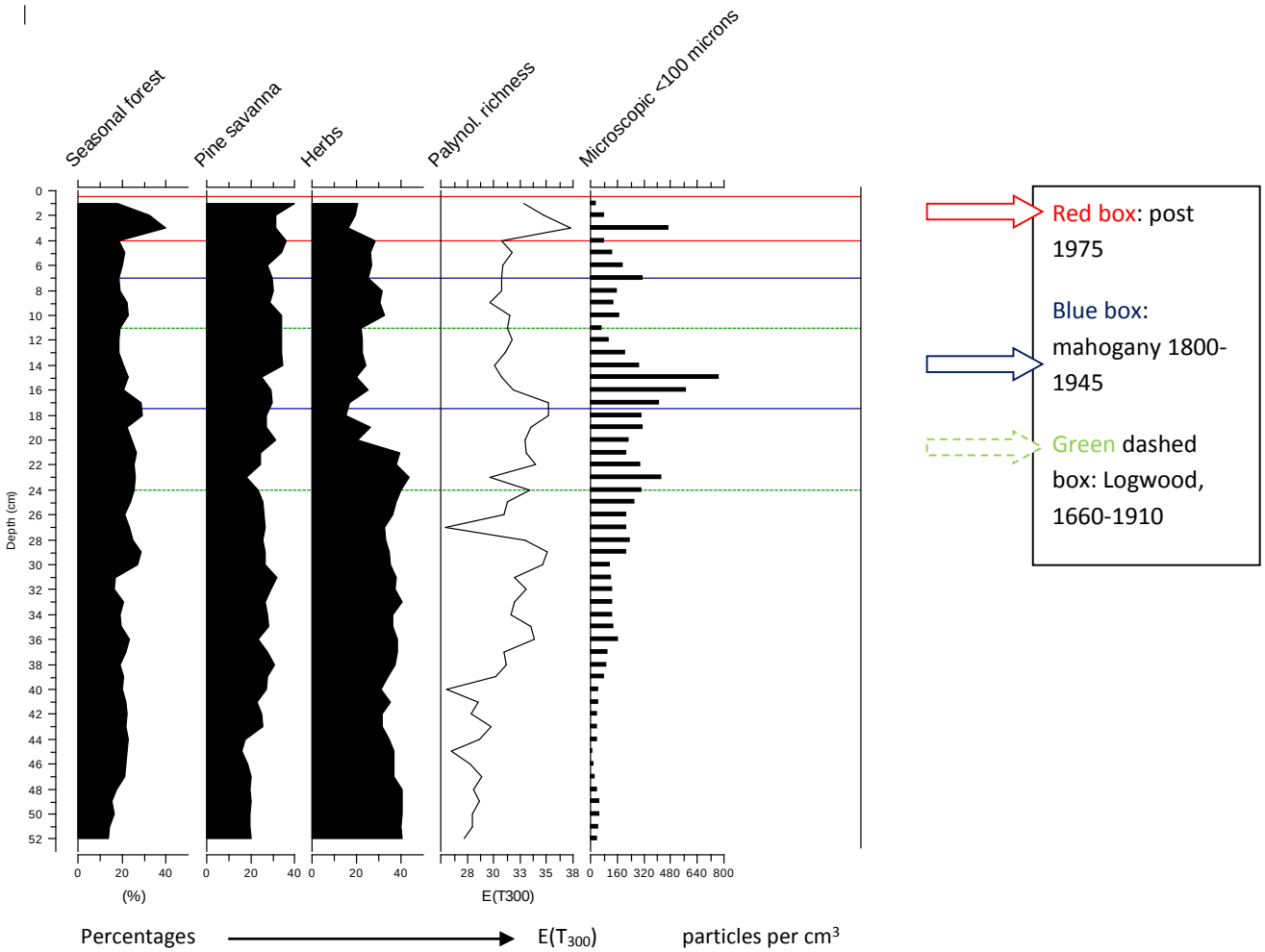

Fig. 6.3 Summary pollen percentage and palynological richness diagram from the Lamanai 2010 core, New River Lagoon, northern Belize, indicating periods of logwood and mahogany extraction.

Table 6.3 and Fig. 6.3 demonstrate that the impacts of two different types of timber extraction are visible in the palaeoecological record, both in terms of percentage pollen taxa of key ecosystems, palynological richness and the microscopic charcoal signal.

6.4 Summary

The distinctive methods of logwood and mahogany production have been reconstructed using contemporary documentary accounts. These demonstrate that post-1800 mahogany production involved substantial clearance of SDTF. Significant logwood production occurred during four centuries; however, this included periods of extremely low production during the early 19th century. Individual export records of logwood and mahogany have enabled the reconstruction of periods of low and high demand for both products; however, the mahogany record gives the more accurate summary of exports as during the 17th and early 18th century, the majority of logwood was not exported to Britain. The records of production and export enable an assessment of the different impacts of extracting logwood and mahogany on the landscape of Belize. The economic record of mahogany exports, and the partial coverage of meteorological data during the 19th and 20th century, enable an exploration of the possible role of changing precipitation particularly during the sensitive months of the mahogany production season. Higher than average rainfall during June and lower than average rainfall in September/October may have been conducive to increased mahogany production during the early 20th century. Conversely, lower than average rainfall in June and higher than average rainfall in September/October, possibly contributed to a reduction in mahogany production during the late 19th century. The economic records of mahogany and logwood export enable the identification of distinct, intensive periods of extraction of two specific natural resources, extracted from two separate vegetation types, SDTF and pine savanna. Changes in these two vegetation types during the mahogany and logwood periods are visible in the palaeoecological record, which indicates the large scale nature of mahogany and logwood extraction across northern Belize.

As has been demonstrated in Chapters 2 and 6, the British interest in 19th century Belize centred on the timber resources of the country. Chapter 7 examines the attitudes and perceptions of the (predominantly) British 19th century population, with a particular focus on climate and health in a tropical context. This expands the reconstruction of Belize's meteorological record presented in Chapter 5, building and environmental history that reconstructs the 'material' environment history (Fig.1.2) (temperature and precipitation) but also integrates a 'cultural/intellectual' history (Fig.1.2) which examines the perceptions of and the impacts upon the British population.

Chapter Seven

Climate, health and place: 19th century British encounters with the Belizean neo-tropics

7.0 Introduction

Chapter 2 demonstrated that much geographical scholarship since the beginning of the 20th century has been devoted to the discovery of how European understandings of tropical climates have evolved (see section 2.2.2). This chapter builds on that scholarship, analysing how the climate of the tropics becomes an object of concern – indeed, becomes visible – in a number of different themes. This object emerges through discussions of colonialism, health, race and religion. The first part of this chapter considers discourses surrounding health and climate emerging from the European population of 19th century Belize City and forms part of an intellectual or cultural environmental history (Fig.1.2). The vast majority of the documentary sources dating from the first sixty years of the 19th century comprise British Missionary letters and published travel accounts, published reports and Missionary Society minutes and regulations (see section 3.2.3). As has been outlined in Chapter Two (p.65) there are other potential voices from the 16th century Spanish encounter with the Belize and the accounts of the British loggers from the 17th, 18th and 19th centuries that have yet to be utilised in this research. Official British government documents, reports and published travel accounts are the predominant source for documentary material in the later part of the 19th century. This is probably due to both the decline in missionaries stationed in Belize post 1860, and to the strengthening of British political rule over Belize from the mid-19th century onwards (see section 3.2.4). These documents demonstrate a developed medical topography of the region, and the relative healthiness of Belize City and its environs was understood through a number of factors including vegetation, meteorology and topography. The second part of this chapter explores the Belizean experience of yellow fever in the 19th century through a case study of an outbreak in Belize City during the summer of 1860 (see section 2.2.3). The meteorological record presented in Chapter 5 has shown a possible link between increased precipitation and outbreaks of epidemic yellow fever. These incidences of increased precipitation may have been driven by extreme El Niño events (see section 5.3.2). The meteorological record does not extend to include 1860 and as such, the narrative, cultural environmental history presented in this chapter is the only opportunity to reconstruct the events of 1860 and the impacts of epidemic yellow fever on the colonial population. Through this case study it is also possible to chart ideas about climate through shifting understandings of the causes of yellow fever, and the preventative measures recommended by the British Government to limit yellow fever's impact upon the mainly British colonial population.

7.1 Missionaries, health and climate

7.1.1 'An inhospitable clime': missionary accounts 1820 - 1840

In the earliest surviving letter written by a missionary working in Belize, the perceived danger of the tropical climate to the health of Europeans was highlighted; with missionaries from different societies it is made clear that not only was the climate the source of their ill health, but also that a period of acclimatising or 'seasoning' had not been sufficient to ameliorate their condition. In his resignation letter written from Belize, in 1820, CMS missionary Joseph Ditcher wrote:

> 'This climate I have found, from the time of my first arrival, to be very ill suited to my constitution; but, hoping that after a short residence I should feel reduced inconvenience from its alarming influence, I resolved not hastily to remove; not withstanding I have been repeatedly urged to it by some of my Christian friends here…convincing that my constitution was suffering more than I was aware of, mentioned my case, particularly, to one of the medical officers of the garrison, who gave it as his opinion that my continuance in this climate another hot season might be attendant with very serious consequences.'[93]

Concern about the inhospitable nature of the tropical climate persisted as WMMS missionary John Greenwood wrote from Belize, nearly twenty years later in 1838:

> 'We are thankful to God that we are permitted to address you once more from this inhospitable clime. In the last few weeks…sickness and death have formed sickening dread here around us…Our Missionaries have not been exempt from the power of the disease which in so many instances had proved fatal… Honduras Bay is decidedly one of the most unhealthy stations upon the list of missionary operations.'[94]

Fellow WMMS missionary, Samuel Stanton, wrote repeatedly during 1839 and 1840 that the climate was causing both himself and his wife severe ill health. Despite restorative periods of 'change of air' and 'seasoning' away from Belize City at a Caye in the Bay of Honduras, on his return to Belize City, he again fell ill. In 1839 Stanton wrote:

> 'I have been the subject of much affliction. For a season I was entirely laid aside and was necessitated to remove from Belize and take up my abode on a small key in the Bay, for a change of air. There my health improved much and I returned to town to resume my labours, in the hope that, by the grace of God, after such a seasoning I should be better able to endure the climate. But

[93] CMS_Series B010_1

[94] MMS_West Indies Correspondence_Fiche Box 44_11.09.1838_Belize

> I had no sooner returned that I was seized again with the same disorder from which I had previously suffered and which is by no means uncommon here especially among Europeans.'[95]

Stanton here identifies that 'a change of air'[96] is a positive aspect and this could reflect the emerging climate topography where some areas were unhealthy and others restorative. This idea also has links with acclimatisation theories which suggested that Europeans needed to 'acclimatise' or be 'seasoned' initially when living in tropical climates, and that this and regular restorative periods in areas considered to have more temperate climes would prevent poor health (Harrison, 1996; 2002).

In May 1840, Stanton again wrote from Belize, 'amidst the indisposition and anxiety of which I am at present the subject I cannot do more than write you a few lines. Myself and Mrs S have been spending a few days at English Key for a change of air…'[97] In one of Stanton's final letters written from Belize to the WMMS Secretary in September 1840, he was clear that the climate has induced such severe ill health in him and his family, he has little choice but to follow the advice of the resident medical clinicians and return home to England at least for an extended period of recovery:

> 'The repeated and severe attacks of fever with which I have been visited have so debilitated my system in connection with the natural tendency of the climate…I am unable to attend to the duties of a missionary here…It is the opinion of my medical attendant that a change of climate is at once necessary and should it please the Committee to allow me to visit my native land I doubt it not but it would be attended with great advantages to myself and to my family. Mrs Stanton and our babe are now both laid up with fever and I am so weak myself that I can scarcely help them.'[98]

An unusual public acknowledgement by a missionary society of the perceived link between climate and ill health reported by missionaries working in Belize was published in a brief note in *The Baptist Magazine*, September 1840, and stated:

> 'Mr and Mrs Hosken, who arrived at Belize on the 20th March 1840 have removed thence to New York. They had both been ill, and Mr Hosken considered it to be their duty to remove to a climate more congenial with their constitutions.'[99]

During the first twenty years of British missionary work in Belize (1820 - 1840) missionaries reported back the extent of their illness to those who had commissioned them. The nature and type of ill health was defined in ambiguous terms such as 'sickness' and 'fever'. However, there was a clear consensus as to the cause; the climate was 'inhospitable' and 'incompatible' with European constitutions. The restorative effects of 'a change of air' were

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[95] MMS_West Indies Correspondence_Fiche Box 44_23.10.1839_Belize
[96] This term is in common usage in a whole suite of tropical scenarios related to ill-heath.
[97] MMS_West Indies Correspondence_Fiche Box 44_8.05.1840_Belize
[98] MMS_West Indies Correspondence_Fiche Box 44_28.09.1840_Belize
[99] 19CPOL_The Baptist Magazine_28_September.1840

found at the island Keys (Cayes) located off shore from the east coast of Belize City in The Bay of Honduras (Fig.1.5), but were not a long-lasting solution to climate-induced ill health; symptoms recurred when the missionary left the Key and returned to Belize City. Accounts of good health were often seen as fortunate, even Divinely enabled, as CMS missionary Henry Moore wrote in 1821, 'I am happy to tell you by the blessing of God I continue to enjoy good health in this sickly climate'.[100] This conclusion reflected the prevailing European understanding of how European constitutions fared in tropical regions, with ill-health induced initially by the different climate, but that it was expected that this could be overcome with seasoning. In the examples cited from the letters of Mr Stanton (WMMS), Stanton suggested that he expected to overcome initial bouts of ill health after a period of 'seasoning'; however this had not been possible in the case of himself and his wife. In the accounts of Mr and Mrs Stanton (WWMS), Mr and Mrs Hosken (BMS) and Mr Greenwood (WWMS), ideas and theories of European acclimatisation after a period in the tropics does not seem to be a reality, and leaving the tropics after a period of less than two years in the case of Mr and Mrs Stanton (only a few months in the case of Mr and Mrs Hosken) was the only permanent cure.

7.1.2 Pathological swamps and clean coastal air: an emerging medical topography, 1835 - 1860

During the mid-19th century, missionary accounts of climate induced sickness became more nuanced, and the nature and cause of disease began to be defined more clearly. Missionary experience of tropical climates was shaped by prevailing western ideas surrounding the healthiness of place and concerns about tropical acclimatisation, rooted in local geographical features. On the one hand, the lowland marshes and swamps that surrounded Belize City to the north, south and west, were perceived to be the source of disease, emanations from which were thought to be responsible for epidemic fevers, and were particularly dangerous to human health when accompanied by strong heat and sunlight. On the other, the coastal winds (the ameliorating aspect) were thought to drive clean, healthy air into the city. As shall be demonstrated, even as the overall assessment of the healthinesss of Belize shifts from broadly negative to positive during the 19th century, the binary opposition of swamps and winds remained remarkably constant.

Early 19th century assessments of the healthiness of Belize were predominantly negative. WMMS missionary Pilley wrote to the Secretary of the Society from Belize in 1835, and included a description of a proposed site for the mission house and chapel at 'Bluefields', Belize City:

> 'This climate is destructive to the health of an European as there being miles of marsh over which the sea breeze must pass before it could reach the

[100] CMS_SeriesCW059_2

> settlement, so that all the air, which could be healthier, would be impregnated with the effluence of pernicious and noxious swamps.'[101]

This account shows how both the 'sea-breeze' and the 'noxious swamp' are quite explicitly juxtaposed in Pilley's climate discourse. Here the swamps are seen as the dominant geographical feature, with its exhalations impregnating the air and reducing its quality. John Greenwood, a fellow WMMS missionary wrote in 1838:

> 'To remain on this station much longer would I fear be attended with considerable hazard; the climate being in every sense unfriendly to health. The country is very low and covered with marshes when the wind is from the land the atmosphere is necessarily impregnated with noxious exhalations. We have the sea breezes pretty regularly from March to August during the prevalence of which the place is comparatively healthy…'[102]

BMS missionary John Butterfield reported in 1845 that his health is poor due to repeated bouts of fever which he suggests is due to 'the unhealthy stagnant air',[103] and his colleague John Kingdom wrote in December 1845 that he has moved his residence because Butterfield's house was in an 'unhealthy situation'.[104] Richard Webster, a WMMS missionary wrote from Belize in August 1850 that his wife continues to suffer poor health and attributes her lack of improvement to the close proximity of swamps and suggests that the only remedy is to move to a highland location:

> 'In former letters to the Committee I have spoken of the state of Mrs Webster's health, I am sorry to inform you that no improvement has taken place, the country surrounding as is, as you are aware, very low and swampy, which appears to have seriously affected her condition…in consideration of Mrs Webster's health, if the committee could find a station for us in a District where the country is more mountainous, I should see it a great favour…our physician is of the opinion that my wife would greatly benefit from such a change…'[105]

Frederick Crowe travelled across Central America in the late 1840s and spent many months in Belize during 1849 publishing these experiences alongside his account of the work of the BMS in London in 1850. Crowe (1850) also noted the low lying position of Belize, and associates the 'insalubrity' of the settlement due to the miasmas emerging from the marshes which surround it:

> '[Belize City] is built of wood, upon a low flat shore, which is covered with mangrove bushes. This kind of coast extends many miles to the northward and to the southward…Inland are extensive swamps over-spread with thick jungle. The air, which would otherwise be insupportably hot…is daily tempered by vigorous sea-breezes; but the land-wind frequently comes down during the night charged with miasmas from the marshes. It is consequently

[101] MMS_West Indies Correspondence_Fiche Box 44_4.9.1835_Belize
[102] MMS_West Indies Correspondence_Fiche Box 44_15.1.1838_Belize
[103] BMS_West Indies Series_20.10.1845_Belize
[104] BMS_West Indies Series_9.12.1845_Belize
[105] MMS_West Indies Correspondence_Fiche Box 44_17.8.1850

> insalubrious. Intermittent fevers and agues being the prevailing disorders, the first more especially during the height of dry weather and the latter during the rainy season.' (p.30)

From these accounts the pathology of the swamp is clear, but so also is the potential ameliorating properties of the sea air, and in many cases these two features are clearly juxtaposed, creating two central elements of the climate discourse. In the periodical *The Great British Messenger*, the Headmistress of Belize High School reported in 1859:

> 'Although the climate and the natural disposition of the people are not favourable to hard work or deep thinking, still I think, slowly but surely the children are making progress…The school is in one of the healthiest positions in Belize, getting plenty of sea breeze…'[106]

Also, in the quarterly magazine published by the Free Church of Scotland a report published in 1853, gave details of the work of the Free Church in Belize. Here again the unhealthy nature of the lowland is contrasted with the beneficial coastal air:

> 'The coast, to which our observations are mainly restricted is low and marshy. A hot sun, combined with the dense and stagnant vapours renders the climate of the province somewhat unhealthy, but on the coast the inhabitants are refreshed by regular breezes, and there epidemic diseases are comparatively rare…'[107]

During an expedition to the northern region of Belize, in the forests that surrounded Indian Church (Lamanai) Rogers (1885) noted the relative healthiness of the 'fruitful interior' compared with Belize City:

> 'A fruitful interior hitherto unknown even to the inhabitants of Belize was scientifically surveyed and reported upon. The unhealthy, unimprovable low-lying sea coast was left behind, and a loft region reached which rivals the fertile mould of Barbados, or the rich uplands of Jamaica'. (p.212)

This account from Rogers (1885) again makes clear the binary opposition of pathological swamp and healthy coastal air. In many accounts the wind had been highlighted as beneficial for removing or mitigating fever inducing miasmas from the swamps surrounding Belize, but coastal air was also credited with providing relief from various biting insects, with accounts of pestilential insects emerging from the early 18th century and continuing into the early 20th century. Uring (1726) states 'there being such a multitude of biting and stinging flies, such as Muschetos, Sand Flies, Galley Nippers and Bottle Asses…In the Northerly winds, there are few flies to be seen' (p.20). In 1857 WMMS missionary John Greenwod wrote from Belize:

> 'We are also really tried by the great abundance of flies of different species. In addition to mosquitoes and sand flies there are swarms of what they call Botlaf (a small black fly) and Doctor flies, a large yellow fly, the same that is

[106] 19CPOL_The Great British Messenger_71_September_1859
[107] 19CPOL_The Magazine of the Free Church of Scotland_2_April_1853

> used by medical men, and is called the Spanish Blister fly. The pain caused by the bite of these flies is indescribable. They inject a poison which causes the places to swell and inflame, accompanied with great irritation…Only the coastal winds occasionally bring us relief.'[108]

Charles Swett (1868) also reported how during his stay in Belize in January 1867, he and his companions were only given relief from biting sand flies by a change in wind direction:

> 'The wind died entirely away at 8 o'clock this evening, and before ten changed to the north-west, causing an invasion of our premises by such a force of *sand flies* as to render opposition futile, and we were punished to a degree that it is impossible for us to make known…This morning the wind is blowing from the opposite direction, sand flies are gone, and we will attempt to forget the miseries of the past night, and more particularly, as we have determined not to be checked by any obstacle…' (p.23)

Late 18th and 19th century accounts of the Caribbean climate have identified the wind as the most common signal of a healthy climate, and this positive assessment continued throughout the Victorian era as the winds alleviated the tropical heat (Jankovic, 2007; Carey, 2011). In these accounts from Belize, the wind or 'breeze' is identified as both a positive and a negative aspect of the climate, sometimes dependent on its direction. In this context wind can be considered as healthy, both preventing illness and providing a restorative element in the climate economy. This is in contrast to the repeated identification of swamps as pathological. This is a complex climatic discourse, where multiple variables determine the healthiness of European settlers residing in Belize, however, during the first half of the 19th century the overriding assessment was that it was an 'unhealthy' colonial space.

Carey (2011, p.133) has highlighted the link made by medics of the late 18th and 19th century between health and swamps, which 'led physicians and other visitors to classify parts of the Caribbean as healthier than others according to local climatic conditions'. The medical differentiation between healthy and unhealthy topographies was not confined to British imperial expansion into the Caribbean, but is also reflected in British experience in 19th century India, where since the 1820s 'medical topographies' had 'loosely differentiated [India] into healthy and unhealthy zones – the former comprising coastal areas and temperate highlands' (Harrison 2002, p.115). A popular theory during the mid-19th century, polygenism suggested that if humankind has multiple origins, those who have not originated from the tropics may have a greater susceptibility to illness attributed to geographical features located within tropical regions. This shift in colonial discourse, from a state of European adaptability, to that of innate vulnerability in tropical climes, demonstrates that such imaginings of climate were shaped by individual's experiences of the tropics, including those articulated by those British missionaries and priests living and working in 19th century Belize. The development of medical topography in Belize during the mid-19th century may

[108] MMS_West Indies Correspondence_Fiche Box 44_1.9.1857_Belize

reflect the shift away from monogenist ideas. The innate human adaptability that monogenism presupposes was not reflected in the experience of the British missionaries who came to Belize in the early 19th century. Faced with the continued ill health and seeming lack of physical adaptability, or 'seasoning', British ideas about the tropical climate of Belize moved towards an understanding based on local geographical features. The importance of such features and their relative 'unhealthiness' increased when considering the causes of disease and sickness within polygenism.

This case study of 19th-century British missionary interaction with the tropical sphere adds to a growing body of work which demonstrates the important contribution of missionary insight to imperial discourses of (Grove, 1998; Livingstone, 2005; Sivasundaram, 2005). Missionary experience of the Belizean tropics led to the development of a medical topography, and this identification of healthy and unhealthy zones by missionaries may have contributed to the more nuanced understanding of the relative dangers of different tropical regions emerging by the latter half of the 19th century. This appreciation of the 'geographical distinctiveness of different missionary destinations within the tropical realm' (Endfield and Nash, 2005, p.381) evident in the accounts from Belize, has also been observed in South Africa (Bell, 1993), India (Endfield and Nash, 2005) and Uganda (Endfield, 2010) during the same period. In the following section, a case study of yellow fever epidemic in 19th century Belize will be considered in light of the medical topography previously established.

7.1.3 'A season of affliction': yellow fever in Belize, 1860

Missionaries working in Belize in the 19th century frequently mentioned and described accounts of fever, documenting their own ill health and the suffering of their families and congregations. Joseph Bourn, a BMS missionary wrote from Belize on 10th August 1824 that he had 'been laid aside from an attack of the fever and ague'[109] and a further letter dated 21st September 1825 from Mr Bourn stated that he was ill, and that one fellow Englishman had died due to the 'prevailing fever of the country'.[110] Richard Wedlock (a WMMS missionary), reported from Belize that although he and his family were currently well, 'the settlement is still very sickly, many have fallen and are continually falling around us'.[111] Fellow WMMS missionary Mr Greenwood wrote in a letter in 1838 that he and his family have suffered from fever, and that 'the town of Belize is very sickly just now. Fevers are very prevalent'.[112] In these accounts the missionaries associate their illness with a pervasive 'sickness' or 'fever' of the place in which they currently live, with the occurrence of disease linked to the settlement of Belize.

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[109] BMS_West Indies Series_8_8.10.1824_Belize
[110] BMS_West Indies Series_8_21.9.1825_Belize
[111] MMS_West Indies Correspondence_Fiche Box 44_12.10.1831_Belize
[112] MMS_West Indies Correspondence_Fiche Box 44_18.8.1838_Belize

From the middle of 1860, reports of a serious outbreak of yellow fever originating in Belize appeared in missionary letters and published accounts in missionary journals, newspaper articles and British Admiralty and Colonial Office documents. The first known report came from a letter written by WMMS missionary George Sykes, who wrote from Belize in July that 'during the last month our town has been visited by that dreadful disease, the yellow fever. Several Europeans have fallen victim to it, but the heaviest stroke has fallen upon our missionary family'.[113] The wife of a fellow missionary, Mrs Webb, fell ill on 23rd June 1860, and after only a few days illness Sykes reported that his wife had died from yellow fever.[114] A further letter written by Sykes' on 27th June 1860 reccounts how he and Mr and Mrs Webb along with WMMS school teachers Susannah Gooding Beal and Mr Sanders all received Communion at Mrs Webb's beside, but that Mr Sykes himself was taken ill at about one o'clock on the morning of 28th June1860. He describes his symptoms as a severe head-ache and pains in his limbs, followed quickly by a fever. He left the Mission House and stayed in the home of the Presbyterian minister Reverend Arthur, where he received medical treatment and ultimately recovered. Later during 28th June 1860, Mrs Webb died, with her husband at her bedside. Mrs Webb's death was quickly followed by the death of Miss Gooding Beal on 12th July 1860 (only six months after her arrival in Belize) and Mr Sanders on 14th July 1860. Mr Sykes reported that Mr Webb was a 'constant, supportive presence' at the bedside of both Miss Gooding Beal and Mr Sanders and that the loss of Miss Gooding Beal was:

> 'deeply felt by the children of the school and all those who knew her…She was of an amiable disposition, pious, devoted to the mission work, and anxious to do good. She laboured with great zeal…the sick frequently welcomed her visits, were encouraged by her prayers and gladdened by her gifts.'[115]

The account of this outbreak published in the WMMS Annual report (1861) states that Miss Gooding Beal 'was buried amidst the loud and bitter lamentations of those whom she had taught, which drowned the voice of the officiating Minister'.[116] The impact upon the WMMS work in Belize was acknowledged in the same Annual Report of 1861:

> 'These serious losses have necessarily interfered with the progress of the work. An additional Missionary was appointed by the last conference to assist Mr Fletcher, but during the prevalence of the sickness, it was considered inexpedient to send him.'[117]

Sykes wrote on 17th September 1860 that two Episcopal ministers had since died to yellow fever, as had the young child of fellow WMMS missionary

[113] MMS_West Indies Correspondence_Fiche Box 44_17.7.1860_Belize
[114] Ibid.
[115] Ibid.
[116] MMS_Annual Report_1861_p.60
[117] Ibid.

Richard Fletcher, stationed in the north of Belize at Corozal, on 3rd September 1860[118]. Fletcher writes from Corozal on 12th September 1860 that:

> 'During the last few weeks, out of the few Europeans living at Corosal five have been cut down by the yellow fever and among them my youngest daughter whose removal we deeply feel. She died on the 3rd of this month. Mrs Fletcher the week before was laid up of fever and since our other little girl, but God has been pleased to spare them and they are now nicely recovering, for which we cannot be too thankful to him.'[119]

In a further letter dated 4th October 1860 Fletcher reported that out of three hundred 'natives', forty have died of yellow fever.[120] By the beginning of November, Fletcher reported that Corozal had been free of yellow fever for the last month[121] and Sykes wrote that Belize was also free from the disease from about the beginning of October.[122] That the epidemic ended at the beginning of October 1860 is consistent with a report in the Colonial Office Blue Book of the same year, which appointed the 29th October 1860 as 'A day of General Thanksgiving for the deliverance of this settlement from the Epidemic of Yellow Fever'.[123] It is unclear exactly how many people died in the course of this outbreak. At least six European men, women and children associated with religious missions had died in the space of about six weeks, as well as the reported thirty natives in Corozal. The Belize City Public Hospital returns for the year compiled by the Medical Officer John Young for the 1860 Blue Book states that '288 patients admitted from 1st January to 31st December…From the prevalence of Yellow Fever in Belize during seven months of 1860, 18 patients died of that disease in hospital'.[124] Whatever the exact figure, the loss to the WMMS in particular was substantial.

The extent and virulence of this particular epidemic was such as to deter the Ladies Committee of the WMMS from sending a replacement for Miss Gooding Beal until early 1861, the Committee's Paper reported the safe arrival of Miss Smith in March 1861. The impact of the loss to yellow fever of the first Ladies Committee teacher to be sent abroad is clear in the letters of the second such agent.

Miss Smith wrote to the Secretary of the Ladies Committee, Miss Farmer on 15th May 1861:

> 'I am happy and thankful to say that my health continues as good as when I first arrived. I have not been sick a single day. Sometimes I feel the heat rather oppressive, but as it suits me better than cold, I cannot complain. This is the dry season, and it is very, very hot indeed.'[125]

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[118] MMS_West Indies Correspondence_Fiche Box 44_17.9.1860_Belize
[119] MMS_West Indies Correspondence_Fiche Box 44_12.9.1860_Corozal
[120] MMS_West Indies Correspondence_Fiche Box 44_4.10.1860_Corozal
[121] MMS_West Indies Correspondence_Fiche Box 44_9.11.1860_Corozal
[122] MMS_West Indies Correspondence_Fiche Box 44_16.10.1860_Belize; 16.11.1860_Belize
[123] TNA_CO_128_41
[124] Ibid.
[125] MMS_West Indies Correspondence_Fiche Box 47_15.5.1861_Belize

Here Miss Smith reports that she has not been 'sick a single day' since she arrived in Belize, which implicitly suggests that her health is continuing *despite* her arrival in an unhealthy place, and demonstrates the prevailing European understanding of medical topography which identified relatively healthy and unhealthy zones or regions. Miss Smith married the widowed Mr Webb in July of 1861, some four months after her arrival in Belize, and remained as the Headmistress of the Wesleyan Girls School until her replacement Miss Ward arrived in February 1862. Miss Smith, now Mrs Webb wrote to the Ladies Committee Secretary in January 1862 that she hopes Miss Ward will 'enjoy such health as I have done since I came to Belize'.[126] Miss Ward wrote an initially positive report to Miss Farmer in February 1862: 'My health has been pretty good since I came here, the heat is just pleasant generally, but it is winter now. I like it much better than our English winters'.[127] However, Miss Ward is less positive in the final known report from Belize by a Ladies Committee agent, dated 14th June 1862:

> 'The heat has been very oppressive for the last month [May], but I am getting accustomed to it and therefore do not feel it so much as I did. The Musquitoes (sic) and sandflies are very troublesome, constantly making us feel that, though small, they have power to torment. The bite of these insects causes a stinging sensation which is very unpleasant.'[128]

Miss Ward suggested that it is possible to become 'accustomed' or even acclimatised to the 'oppressive' temperatures in Belize during May and she also identified mosquitoes and sandflies as pests, which 'have the power to torment'. The mosquitoes are not linked to the spread of fever or promotion of poor health in Belize. However, they are part of discussions around health and climate in the same way that winds were identified by other writers as providing relief from both miasmas and biting insects. This 1862 report from the Ladies Committee marks the end of all surviving occasional papers, letters and reports for nearly twenty years, and when they resume in 1881, there is no record of what happened to Miss Ward or the work of the Ladies Committee in Belize.

The establishment of the Ladies Committee and their deployment of Susannah Gooding Beal to Belize in late 1859 (arriving in 1860) is an early example of the increasingly important role of women within British missionary societies, and this case study from Belize should be seen as part of a wider body of work concerning the place of women as missionaries in the Age of Empire (Haggis, 1998a&b; 2000; Semple, 2004; Endfield and Nash, 2005). Coupled with this comparatively early introduction of women into the 'mission family' is the tropical nature of the mission field they encountered. 19th century evaluations of European survival in the tropical environment were predominantly gendered (Livingstone, 2002; Endfield and Nash, 2005). In light of these widely held concerns about the particular health of women in the

[126] MMS_West Indies Correspondence_Fiche Box 47_16.1.1862_Belize
[127] MMS_West Indies Correspondence_Fiche Box 47_14.2.1862_Belize
[128] MMS_West Indies Correspondence_Fiche Box 47_14.6.1862

tropics, the deployment of Susannah Gooding Beal to Belize in 1859 by the WMMS is all the more remarkable. The 1860 epidemic of yellow fever occurred at during the first year of the WMMS Ladies Committee mission in Belize, and left a lasting, detrimental impact upon the work of that missionary society, which had been active in Belize for some forty years. The deaths of Susannah Gooding Beal, WMMS missionary Mr Saunders and missionary wife Mrs Webb in the context of a substantial loss of European population during the summer of 1860 must have decreased confidence of both the missionaries (and of their societies) in the ability of Europeans to survive the rigours of the tropical climate, and concerns surrounding health remain a key theme in missionary accounts from Belize in the 19th century.

The withdrawal of the Ladies Committee from Belize in 1862 came eleven years before the end of the work of the WMMS in Belize, with the regional mission to the West Indies ending in 1906. Although it is not explicitly stated in the reports from the WMMS, the heavy losses suffered during 1860 may have brought the mission to a premature end due to concerns about the healthiness of Belize, which were rooted in early 19th century explanations of meteorological and climate derived tropical disease. The impact of the 1860 yellow fever epidemic reached beyond the work of the missionary societies, with the wider European population also suffering significant losses. Fever in general, and yellow fever in particular, feature prominently in the British experience of 19th century Belize, and these experiences beyond those of the missionary accounts described are further explored. Through newspaper and British naval sources it is possible to chart the development of ideas surrounding the causes of yellow fever, and the preventative measures recommended to limit its impact upon the population. This research charts a shift in ideas around the causes of yellow fever, from a broadly miasmatic approach in the 19th century, to one that focused increasingly upon mosquitoes as disease vectors by the early 20th century.

7.2 From miasmas to mosquitoes: changing understanding of the causes of yellow fever in Belize, 1820 - 1920

In addition to the missionary accounts of fever previously discussed, newspapers also reported early accounts of yellow fever among the British naval fleet. The *Hampshire Telegraph and Sussex Chronicle*, (HTSC) of 8th November 1830 reported the outbreak of yellow fever onboard *HMS Blossom* on 22nd August 1830, stationed at Belize which killed the First Lieutenant, a Midshipman, nine men and one boy within two weeks, with a further thirty sick on shore.[129] The HTSC also reported from Portsmouth in 1834:

> 'This morning his Majesty's ship *Tweed*, arrived from the West India and North America station…The Tweed has suffered very severely from yellow fever during the last two months of her servitude in the West Indies. The disease first made its appearance after she left Belize, and continued to prevail during

[129] BLNOL_The Hampshire Telegraph and Sussex Chronicle_117_8.11.1830

> her passage…scarcely an individual escaped: she had in all 160 cases, out of which number seventeen died on board and a great many were left dangerously ill…'[130]

These naval and missionary accounts of sickness in the 1820s and 1830s demonstrate that fever (and particular yellow fever) were common in Belize and that the British experience of Belize was of an unhealthy settlement. However in these accounts, the writers do not identify particular characteristics of the climate or geography of the settlement as promoting or inducing fever and sickness.

British and American newspapers contained reports of the 1860 yellow fever epidemic, with an article in *The Daily News*, London on 30th July 1860 reporting that 'the yellow fever is raging at Belize'.[131] *The Freeman's Journal and Daily Commercial Advertiser*, Ireland stated on 31st August 1860 that 'yellow fever was fatally prevalent at Belize on the 26th ultimo, and decimating the whole population'.[132] *The Bermudian* printed a report on 24th October 1860, which stated that a troop-ship containing the 2nd West Indian Regiment *The Perseverance*, visited 'a terrible hot-bed of yellow-fever at Honduras', where 'that foul disease was raging there in the most virulent manner, defying medical skill'.[133] This report states that the disease had 'swept off nearly the whole European population' and named the latest victims as two Episcopal clergymen, Reverends Craddock and Monghan.[134] *The Perseverance* was stationed briefly at Belize whilst additional troops from the 2nd West Indian Regiment joined the ship, and during this time Dr. Baggott of the regiment died of yellow fever. A further two officers died after the ship had left Belize, again of yellow fever. *The Birmingham Daily Post* also reported on 29th November 1860 that yellow fever was on board another naval vessel:

> 'Serious mortality on board a man-of-war – A letter from Belize, Honduras, dated September 27th, states that yellow fever had broken out on board the British man-of-war Icarus, eleven of her crew and two officers had died, and a great many were sick, including Captain Salmon. Subsequently, on her passage to Jamaica, she reported 33 dead, and still a heavy sick list'.[135]

A report from Belize written on 22nd August 1860 and published in *The New Orleans Times Picayune* on 12th September 1860 stated:

> Another cause of distress and anxiety here is the fatality of the yellow fever – for the first time in twenty years it is now raging in Belize and the suburbs – formerly it was brought here by the shipping from New Orleans, Havana or Chagres: it did not spread, and we thought this the healthiest part of all the tropics. But for two months now it has been very bad, and, with only a few exceptions, all who have had it have died. Thus, nearly all who are not

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[130] BLNOL_The Hampshire Telegraph and Sussex Chronicle_183_10.11.1834
[131] BLNOL_The Daily News, London_1871_30.7.1860
[132] BLNOL_Freeman's Journal and Daily Commercial Advertiser_112_31.8.1860
[133] BNA_*The Bermundian*_10_24.10.1860
[134] Ibid.
[135] BLNOL_The Birmingham Daily Post_3310_29.11.1860

> acclimatised, have been swept away. Truly, we have had sad times, and what is worse, none of the precautions which are in use in your city, Mobile and Havana, have been introduced here. We have a board of health, but I do not hear that they have taken any steps to prevent the spread of the malady, or to cleanse the few filthy parts of our town.'[136]

In this report the importance of an initial period of acclimatisation for Europeans in the tropics is explicitly stated, even in the 'healthiest part of all the tropics'. The lack of such a period is given as an explanation for the mortality rate in Belize during the 1860 outbreak, and this highlights how central the idea of European acclimatisation in the tropics remains in discourses surrounding climate and health in the tropics in the 19th century. The writer suggests that the Board of Health in Belize have not yet emulated the 'precautions' introduced in other cities such as Mobile and Havanna and suggests that it is the 'few filthy parts of our town' which may be the source of the disease; this suggests a sophisticated medical topography of fever areas within Belize City. Finally, this report also suggests that in the past, fevers had been brought out of Belize, and transmitted by ships travelling to and from the port of Belize City. British naval reports from 1860 provide further insights into the spread of yellow fever across the Greater Caribbean and northern American naval area.

In a British naval report of yellow fever in the North America and West Indies Station during 1860 - 62 authored by Sir Arthur Milne,[137] *HMS Icarus* is listed as having contracted yellow fever at Belize in September of 1860. Out of the 125 crew there were 100 cases, 37 of whom died. The outbreak ceased in October 1860 in Port Royal, Jamaica. Sir Milne suggests that some of the causes of yellow fever may include: 'bad weather and great heat; exposure to night air or sitting in a draught of air; sleeping on the ground when on leave or walking on bare feet on the ground or wet deck; wearing wet clothes or being stationed in harbours near swampy land'.[138] Present in each of Sir Arthur's stated causes is an element of meteorology or topography and the impact that each element has upon humans. These include extremes of temperature, damp conditions, droughts and swampy vegetation. For Sir Arthur, the model of disease transmission centred on local climate and topography.

In the Journal of *HMS Icarus* compiled by the Ship's Surgeon John D. MacDonald during 1st January 1859 and 31st December 1860,[139] it is recorded that *HMS Icarus* was at Belize between 12th and 14th September 1860 and it is listed as an 'unhealthy place' where 'yellow fever had swept off 32% of the white population' and was the source of the later outbreak of yellow fever on the ship after it left Belize.[140] The Ship's Surgeon acknowledges that 'the discovery of the real causes or the nature of the poison giving rise to the symptoms which in their sum constitute yellow fever 'is of great concern to the

[136] TNA_CO_128_41 – a clipping of the article was included in the Blue Book for 1860.
[137] NMM_MilneSeries_126_1
[138] NMM_MilneSeries_126_1
[139] TNA_ADM_101_218
[140] TNA_ADM_101_218

medical profession, and that there appear to differences in the intensity, manifestation and locality of the disease.[141] Surgeon MacDonald clearly draws upon a distinct model of disease transmission, linking the outbreak of yellow fever in Belize to low lying land, decaying vegetation in stagnant water and heavy rains:

> 'The presence of offal and filth, or stagnant water with infused animal and vegetable matter, may be regarded as affording something more than predisposing conditions, and such an unwholesome state of things is always present at Belize, but more particularly in sultry weather after heavy rains. The whole western, or coast district of British Honduras is a vast expanse of low land, which lies some 70 miles to the North of Belize and is conterminous with the Yucatan…A permanent superficial lodgement of water is therefore easily to be accounted for; and with this must be associated the development of the unicellular and other microscopic plants and animals in great abundance, whose influence as a source of disease is quite as much to be looked in their death and disintegration, as in their rapid multiplication in the living state.'[142]

Surgeon MacDonald identifies four key topographical features that form the unwholesome 'predisposing conditions' at Belize, namely 'offal and filth', a 'limestone base', a 'superficial lodgement of water' and 'unicellular and other microscopic plants'.[143] These underlying concerns were exacerbated by local weather conditions such as heavy rains and 'sultry weather'[144]. These local topographical and climate conditions found at Belize are linked by MacDonald to the healthiness of the settlement.

In the Medical Journal of another British navy ship, *HMS Imaum*, stationed at Port Royal in Jamaica during 1860, Surgeon Thomas Seccombe notes that the aetiology of yellow fever is an explicit and difficult problem for European medical officers working in and around Belize: 'my endeavour to obtain reliable information relative to the introduction and commencement of the late epidemic of Yellow Fever at Belize have proved abortive.'[145] Surgeon Seccombe states that there was a deadly outbreak of yellow fever at Belize City when *HMS Icarus* arrived in the port and suggests that the transmission of the disease to the sailors was due to their interaction with the local population:

> 'That the disease was raging in that Colony with terrible virulence, carrying off large numbers of the white population at that time the 'Icarus' anchored before the town is certain, it also appears certain that no very stringent measures were adopted to prevent the ship's company communicating freely with the inhabitants during her short stay. The disease made its appearance on board after she left Belize and was on her way down the coast of Spanish Honduras where she was most unfortunately but unavoidably detained, until great

[141] TNA_ADM_101_218
[142] TNA_ADM_101_218
[143] Ibid.
[144] Ibid.
[145] TNA_ADM_101_229

> ravages had been made among her crew, thirty two of whom had fallen victim to the disease, at the time of her arrival at Port Royal at noon on the 9th of October.'[146]

This suggests a shift in understanding of the transmission of disease, with a different model suggested. This model suggests that the disease is spread from human to human when there is contact with populations infected with yellow fever. Here mosquitoes are not mentioned, but neither are miasmas, nor local climate or topographical conditions. This particular model appears to built upon 18th and 19th century 'contagion theories', where disease was understood to transmit between people by means of direct contact and were often linked to a negative assessment of the physical and moral health of indigenous populations (Anderson, 1997; Worboys, 2000).

The spread of yellow fever from a land population, for example those in Belize City in 1860 to a naval population e.g. *HMS Icarus* and then on to other naval vessels, became the subject of some interest to the British medical profession, including Dr Bryson of the Epidemiological Society. Bryson's account of the epidemic and its spread across multiple ship's crews was reported under the title 'An Epidemic Tracked' in *The Hampshire Advertiser*, England on 16th March 1861:

> It has been an old and is with some a favourite belief that yellow fever is a disease not infectious, but solely due to a peculiar constitution of the atmosphere – strictly limited indeed in locality, and arbitrarily bounded in the duration. There is the gravest reason to doubt and even to deny this view…Dr Bryson's valuable paper at the Epidemiological Society, relating the successive outbreaks of yellow fever in a consecutive series of her Majesty's ships, supplies a strong chain of facts.'[147]

This opening paragraph of the account of the 1860 epidemic states that it is the orthodox view that outbreaks of yellow fever occur in certain areas and are caused by a particular climate. This view is challenged as being inaccurate and the report suggests there is an alternative model of disease transmission that has been observed between naval populations of *HMS Icarus* and *Imaum* and the settled populations at Belize City:

> 'The ship the *Icarus* had touched at Belize in August. There the yellow fever raged. Soon after leaving, her crew were attacked with the disease. Out of 120 persons 37 died…one of the *Imaum's* crew, who had only come in contact with the officers of the *Icarus* and their baggage on shore, was taken with the disease, which spread indiscriminately through the ship, attacking 38 persons, old and young, of whom 17 died...Finally, when the *Imaum* became the seat of yellow fever, as above stated, after communication with the ill-fated *Icarus*, a number of supernumeraries were removed from her to the *Barracouta*, but as much as possible segregated from its crew. Nevertheless, it was soon evident that these men had brought the seeds of the fever with them. Cases of yellow fever occurred among the supernumeraries, and then

[146] TNA_ADN_101_229
[147] BLNOL_The Hampshire Advertiser_109_16.3.1861

> it spread to the crew of the *Barracouta*, its fatal ravages being only checked by the ship running into more temperate latitudes.'[148]

Based on this detailed account of the spread of yellow fever, originating in the population of Belize City and spreading through the crew of four naval vessels, the report suggests that the disease is transmitted though infected humans having contact with others. There is still a link with climate and transmission, as the suggested cause of action for a ship's crew infected with yellow fever is to move to a colder, temperate climate. However, if this cannot be achieved the crew should be strictly 'segregated' to avoid the further spread of disease. Here there is a clear demonstration of human transmission of yellow fever: 'Nevertheless, it was soon evident that these men had brought the seeds of the fever with them', however there is also a clear link made with the older ideas of yellow fever linked to climate as the cure is to move from a tropical to a temperate climate:

> 'The case seems terribly clear. The experiment was more awfully complete than any human hand could have devised. From one centre the disease radiated in three directions, and at each spot, a fresh centre of death and infection was established. Infection by yellow fever being once fully settled to be a hard truth – and we do not see how henceforth it can be doubted - it follows that the landing of the sick crew or their dispersion can only tend to multiply circles of epidemic disease. In this case and in all others it was seen that nothing extinguished the disease like running into a cold climate, which is a speedy and safe remedy…If from the paramount considerations the sick must be landed within warm latitudes where yellow fever can continue to exist, their strict segregation becomes a matter of first importance.'[149]

In the aftermath of the 1860 outbreak of yellow fever, which had lasted some seven months, the medical profession were clearly trying to establish how the disease spread, and what preventative measures could be enforced to limit the loss of life, with a particular focus on naval crews. Local conditions such as 'sultry weather', low lying land and decaying vegetation in stagnant water appear to be some of the causes ascribed by the Surgeon on board *HMS Icarus* for the outbreak of disease in Belize. However the spread of yellow fever amongst four British naval crews on board *HMS Icarus*, *Imaum*, *Barracouta* and *Hydra* in 1860 led to the article in the Hampshire Advertiser dated 16th March 1861 to conclude that the disease was not restricted to a locality caused by the 'peculiar constitution of the atmosphere', but was an infectious disease that spread among humans, and that therefore segregation was crucial to prevent the spread of yellow fever.

As with the missionary explanations of tropical disease, local geographical features and meteorological conditions were important contributory factors in some naval accounts. However, after the 1860 yellow fever outbreak, theories surrounding the spread of epidemics began to be articulated to explain the spread of yellow fever across multiple naval vessels. After the middle decades

[148] BLNOL_The Hampshire Advertiser_109_16.3.1861
[149] BLNOL_The Hampshire Advertiser_109_16.3.1861

of the nineteenth century British missionary attention moved away from Belize, with societies seemingly unable to recruit and retain missionaries to work there. This may in part be due to a significant loss of confidence in the ability to establish a thriving British Christian mission, especially in the aftermath of the yellow fever outbreak of 1860. One consequence of this shift in missionary focus is a significant reduction in missionary sources available from Belize after the mid nineteenth century. As missionary engagement declined, British colonial governance increased. As such, much of the documentary history of Belize from the mid to late nineteenth century can be found in the official government documents reports and published travel accounts from Belize. This variety in source material enables the reconstruction of multiple, often contrasting narratives which can create a more complex retelling of British understandings of climate and health in nineteenth century Belize, and it is these government sources that are now considered.

7.2.1 Rehabilitation and rejuvenation: Restoring the reputation of Belize in the British consciousness post 1870

Official government documents written after 1870 have a different narrative of Belize from missionary sources written in the early to mid nineteenth century. The late 19th century government accounts demonstrate a view of Belize as a country of significant economic opportunity that had been much maligned and overlooked and, in fact, had a healthy climate. Thomas Browne, Staff Surgeon of the British Naval South and Coastal America and West Indian Station wrote of Belize in December 1878, 'In spite of the dreary, melancholy and fever like look of Belize and its immediate neighbourhood, the health of the community is fairly good'.[150] The government Medical Officer of Belize, Dr. Alexander Hunter wrote to the Colonial Office, in June 1887:

> 'I have endeavoured to point out the necessity for sanitary reform in the town of Belize, and in doing so I have used expressive words as I could command in describing the blots in its hygienic economy. I, however, do not wish to have it understood that the climate or place is unhealthy or undesirable as a residence. On the contrary…the general health of the town will bear comparison with that of any place of the tropics, and perhaps with some parts of Her Majesty's dominion more highly favoured by temperature and position.'[151]

These two official reports were written as a routine part of private correspondence and record-keeping which were not available for public consumption. However, three further optimistic accounts of Belize and its climate were published in the late nineteenth century and were all widely available. The first is *British Honduras: An Historical and Descriptive Account*

[150] TNA_ADM_101_235
[151] TNA_CO_123_188

of the Colony from its settlement, 1670 written by Archibald Gibbs (1883) and published in London. Gibbs (1883) suggests that:

> 'British Honduras has suffered the prolonged and unmerited injustice of having been given a very bad name for unhealthiness. 'Fever-pot', 'mud-bank' are specimens of the milder class of epithets applied to it…with a great deal more absence of truth than generally attaches to such inconsiderately-chosen epigrammatic distinctions.' (p.179)

Gibbs (1883) states that the potential for unhealthy, fever-laden miasmas affecting Belize are mitigated by both the coastal winds and possibly the mountain ranges:

> Although lying within the tropics, the climate of British Honduras is sub-tropical rather than tropical. This is principally owing to the prevalence of easterly trade-winds during four-fifths of the year… On the other hand some natural barrier or shield, such as high or mountain ranges to the rear, would seem to protect the strip of coast from the hot, miasma-laden breeze crossing the western interior.' (p.178)

Gibbs (1883) also cites the 1879 report of Dr Hunter as evidence of the healthy nature of Belize, 'contrary to what might be expected from the swampy nature, slight elevation, and luxuriant vegetation of the country in the immediate vicinity of Belize the climate is, on the whole, healthy' (p.180). It is interesting to note that miasmas are identified as responsible for the unhealthy climate, rather than the 'human transmission/climatic cure' hybrid model found in the naval accounts from HMS Icarus in 1860. This demonstrates that discourses surrounding health and climate are not simple, and do not shift seamlessly from one model to another.

A second positive assessment of the Belizean climate was also published in 1883, as part of a volume commissioned by the then Director of the Royal Botanical Gardens Kew (RBGK), William Thistleton-Dyer. This rich document, which has so much information about the climate, was first prompted by a significant economic, rather than climatic or public health problem. Thistleton-Dyer asked Sir Daniel Morris (Director of the Public Gardens and Plantations in Jamaica from 1879) to travel to Belize and report on any botanical 'economic prospects'. The need for even basic information was clear as in a letter dated 22nd March 1880 to the Colonial Office, Thistleton-Dyer acknowledged that 'the botany of British Honduras is almost entirely unknown' (cited in Bulmer-Thomas and Bulmer-Thomas, 2012). Morris travelled to Belize in 1882, accompanied by Alfred Hyde, a plant collector from the Jamaica Botanical Gardens, who made a collection of around sixty herbarium specimens that were incorporated into the collections at RBGK, and were arguably the first collection of Belizean plants housed in Europe (Bulmer-Thomas and Bulmer-Thomas, 2012). His account '*The colony of British Honduras: Its resources and prospects with particular reference to its indigenous plants and economic productions'* was published in London in 1883.

In the introduction to the volume Morris (1883) stated that, 'In England, little is known of British Honduras, and that little is not of a very flattering character. Its climate has been maligned, its resources only partially acknowledged…' (p. v). Morris (1883) further develops the nature and cause of the poor impression that the English have of Belize, linking this negative assessment to the assumption that swamps dominate the country and also highlighting the positive impact of the 'trade-winds':

> 'The general impressions of Europeans respecting British Honduras being derived from the town of Belize, they are apt to conclude that the whole country is nothing but a swamp and that the climate 'is only second to that of the pestilential coast of Western Africa'. This estimate is as fair to British Honduras as if the Plaistow Marshes were taken as typical of England, or the Gulf Coast as typical of the United States…The trade-winds sweeping uninterruptedly over it, clear away all miasmic influences, and keep the air pure and comparatively cool.' (p.9)

Again, this juxtaposition of 'trade-winds' which 'clear away' the swamp derived miasmic influences adds to the complex climate/health economy, which identifies swamps as the source of ill health but which can be mitigated by winds.

The third and final late nineteenth-century account of the Belizean climate to be considered here originates from *The Handbook of Belize 1892-3*. This publication was written in Belize and published in London for the years 1889 - 1893, with each volume covering 1st July – 30th June , enabling the most up to date economic data to be included. They contained historical, geographical, meteorological and other general information 'that cannot fail to be of material advantage to intending settlers who are interested in the progress and development of the country' (Bristowe, 1894). The handbook was financed both by advertisements placed at the end of the volume, and by British Government grants. It was clearly a document that was aimed at encouraging British settlers to travel to Belize and become part of developing and extending agriculture for their own profit and the profit of both nations. A section titled 'Information for intending immigrants' the Handbook (Bristowe, 1894) declared:

> 'The best time to arrive in British Honduras is in November, when the rainy season is generally past, the rivers easily navigable, and the temperature cool. The immigrant will thus have plenty of time to look about him, to select his land, to have the bush cut down and burnt off, during the dry months of February, March and April….There is a fine field for fruit planters, and a capital of $500 or $1000 will enable a man to start a plantation which he can enlarge according to his means.' (p.251)

This brief series of annual publications succeeded the equally short-lived *Honduras Almanack* which was supported by funds from the public assembly in Belize, with annual editions published between 1826 - 1830 and also in 1839 (Bulmer-Thomas and Bulmer-Thomas, 2012). In the 1892 - 1893 Handbook, Bristowe (1894) included a report on the healthiness of Belize first published in the Belize based newspaper *The Colonial Guardian*:

> 'Indeed to a stranger, Belize – surrounded as it is on three sides by swamps – must naturally appear far less sanitary than it really is…The malarial emanations which arise from these temporarily denuded surfaces are, however, to a great extent counteracted by the strong sea-breezes which prevail all through the dry summer season, and which blow back such emanations from the town…Considering the conditions by which the people are surrounded it is remarkable that there is such an immunity from this and other malarious affections which are understood to be the effect of exposure to the influence of these poisons, and the only explanations I can arrive at are;
>
> 1st The swamps are undergoing constant change, both mechanically and chemically.
>
> 2nd The sea-breeze is frequent and strong.
>
> 3rd The general healthiness and good physique of the people renders them capable of resisting the effects of the poison, which most frequently tells on the ill-conditioned and ill-fed. (p.42)

Here, as with the accounts of Gibbs (1883) and Morris (1883), Bristowe (1894) reported that it is the 'strong sea-breezes' as well as the constantly changing nature of the swamps and the good physical condition of the population that enable the colony to be considered free from 'malarious affections', and that the settlement at Belize is much healthier than either its reputation or its position suggest.

These positive assessments, arising from official Government reports and published travel accounts, use the same geographical features in their climate discourse as those of the missionaries – swamps are pathological and clean costal air is healthy. However, these two sources present divergent assessments of the healthiness of the Belizean climate. This might be expected from their differing motivations. Missionaries were anxious to present their direct experiences (some of which were redacted prior to publication), whereas governmental reports, perhaps mindful of the need to encourage settlement and enhance the poor reputation of Belize in Britain, were more favourable about the climate. Indeed the timing of the rehabilitation of Belize's reputation is significant; the flood of positive accounts occur in the late 1870s and early 1880s, only a few years after Belize is officially recognised as a colony in 1862 and Crown colony in 1871, giving the British government for the first time since the early settlements of the 17th century, unfettered rights and responsibilities for Belize and its population. *The Pall Mall Gazette* declared to its British readers in October 1890 that Belize 'under wise government, ought to develop into an excellent place for European settlers. The climate is damp, but nowhere unhealthy, and might be described as that of South Devonshire 'heated up'.[152] However, perhaps the key point about these contrasting assessments of the Belizean climate is that *the terms of the debate remain uncontested,* even while the interpretations differ: swamps were seen as pathological and clean coastal air was healthy. Given the

[152] BLNOL_The Pall Mall Gazette_7993_3.10.1890

contrasting final assessments of the Belizean climate, no doubt driven by differing motivations, this underlying agreement is all the more striking.

7.2.2 'Extra climate pay': financial reparation and the unhealthiness of 19th century Belize

In his account of British Honduras, Gibbs (1883) attributes the poor reputation of the Belizean climate to the 'military medical men' who have 'not forgotten to dwell exhaustively on the swampy nature of the soil, and the climatic influences they supposed were exercised on the health of the troops by residence in the colony' (p.179). Gibbs (1883) claims that army surgeons exaggerated the possible negative impact of the climate on the army troops stationed at Belize because they had little knowledge of the country beyond 'the marshes behind Newton Barracks' and because they wanted to 'make out a case for extra climate pay'. This latter explanation is particularly interesting and complicates the otherwise overwhelmingly positive government assessment of the Belizean climate on the health of European settlers. Despite extensive archival investigation, few other references to 'climate pay' have emerged, with the only usage linked to British Admiralty correspondence within the Colonial Office from the early- to mid- 20th century. The orders for 'extra climate pay' or 'climate allowances' mainly concerned officers stationed in China, the Persian Gulf, the Red Sea and the Gulf of Aden during the months April – September, but also covered the Nile, the Rivers of the Cameroon, Lake Victoria Nyanza and Lake Tanganyika. Climate pay was given to compensate for the difficult conditions caused mainly by temperatures in excess of 95˚F (35˚C), where 'officers and men experience great difficulty in obtaining sleep or even rest at night owing to the heat'.[153]

There is no mention in the official government records search in TNA, BL or BNA of climate allowances being paid in Belize, and as the examples cited above all date from at least thirty years after the publication of Gibbs' account, it is hard to assess the accuracy of his claims. The idea of 'climate pay' or a 'climate allowance' as presented by Gibbs (1883) perhaps legitimises the attitude that there can be an 'unhealthy' climate and shows that the government were aware that they needed to establish the rehabilitation of Belize's image. However, when providing financial compensation to mitigate the effects of climate as demonstrated by the British Naval records from the early 20th century, it is not clear whether this was to compensate for the acknowledged discomfort that an inhospitable climate caused or whether this was to mitigate an unhealthy climate. As there are no direct, first-hand accounts of 'climate pay' or a 'climate allowance' being paid to any member of the armed forces or government official resident in Belize, it is not possible to ascertain whether Gibbs' (1883) account is accurate. Climate was clearly a

[153] TNA_ADM_1_8439_331_24.7.1915

concern for the British government when deploying European or 'white' troops to Belize. In October 1920, the Acting Governor of British Honduras wrote in a confidential letter to the Colonial Office that he did not think the detachment of West Indian troops stationed in Belize should be substituted by 'a body of white regular troops', because he was 'convinced that it would not be advisable from a health point of view to station white troops in Belize'[154]. The Acting Governor identified the health risk to 'white' troops as one of contracting malaria from infected mosquitoes which bred in the swamps surrounding the Newton Barracks in Belize City:

> 'The Principal Medical Officer is of the opinion that thoroughly efficient screening of the Barracks, combined with proper precaution taken by the men themselves would speedily eliminate malaria to a great extent amongst the troops quartered in the Belize barracks'.[155]

This positive assessment from the Principal Medical Officer contrasts with that of the Director of Public Works, who suggested that due to the nature of the original construction of the Barrack buildings it was impossible to screen them effectively, and, that the brass netting used for screening was quickly corroded in the 'strong salt breeze'.[156] Due to this lack of screening the Acting Governor reported:

> 'Under the circumstances I very much regret not to be able to advise the stationing of white troops here until such time as the Colony can afford to drain the surrounding swamps and erect new barracks…I personally consider that it would be wise Imperial policy to have.'[157]

The Acting Governor suggested to the Colonial Officer that it would be 'wise Imperial policy'[158] to station white troops in Belize as, when 'white' troops were previously deployed to the Colony, the soldiers were 'greatly respected by the people and did a great deal towards fostering the love and respect for the English race in this the only British possession in Central America'.[159] In spite of numerous accounts published in Britain in the late 19th century which gave positive accounts of the Belizean climate (Gibbs, 1883; Morris; 1883 Bristowe, 1894), communication between the Government in Belize and the Colonial Office reveals significant concerns with the deployment of 'white' troops in a tropical region. Even in the post-WWI era, race was viewed as an important factor when determining an individual's vulnerability to disease, even when the disease vector was correctly identified as mosquitoes infected with malaria. This discussion of 'climate pay' has demonstrated an economic aspect to climate and health discourses which has the potential to be developed in other 19th century British imperial contexts; however, it has not been possible to identify any further reference pertinent to Belize.

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[154] TNA_CO_123_302
[155] TNA_CO_123_302
[156] TNA_CO_123_302
[157] TNA_CO_123_302
[158] TNA_CO_123_302
[159] TNA_CO_123_302

The shift identified in the understanding of the causes of disease is now examined in the context of yellow fever. This continued search for the causal factors of both the outbreak of yellow fever in 1860, and yellow fever in the tropics in general, produced multiple reports either commissioned by the British Government, or written by Government employees. Two of these reports, written by different Colonial Surgeons of Belize, Hunter (1887) and Eyles (1898), will be examined. A third report written by Boyce (1906) concerning the causes of yellow fever will also be considered and using these, the emergence (in British understanding) of a new model of disease transmission in the Belizean context will be explored.

7.2.3 *Drs. Hunter (1887) and Eyles (1898): Colonial medical assessments of the causes of yellow fever in late 19th century Belize*

Approximately 30% of the European or white population resident in Belize City died during the 1860 yellow fever epidemic, and the vast majority were British. This outbreak was followed by further episodes in 1869, 1878 and 1886 (Table 5.3) this succession of yellow fever epidemics at Belize City led the British Government to commission a report from the Medical Officer, Dr Alexander Hunter, stationed in the Public Hospital in Belize City. As discussed in section 5.3.1, this report (1887) investigated the causes of yellow fever and outlined preventative measures that should be taken by the local Government to limit the number and extent of further outbreaks. In his preface, Dr Hunter clearly outlined the need for a detailed investigation of the conditions under which yellow fever epidemics occurred and determining 'the most potent factors in the causation of much of the preventable disease'.[160] Past epidemics of yellow fever are described as being 'extremely rare in the history of the Colony' and Dr. Hunter stated that the records of these outbreaks are 'unanimous in ascribing the outbreaks to a peculiar epidemic of the atmosphere which, under certain topographical conditions, manifests itself in affections of this character'.[161] Dr Hunter identified three features which have a significant role in promoting favourable conditions for the spread of yellow fever, namely, 'Topography', 'Vegetation' and 'Meteorology'. Hunter suggested that the area of the City to the north of the Belize River was particularly unsanitary and unhealthy, due in part to 'a comparative absence of natural ridges on the north side…which from these natural causes enables more swampy ground to develop on this side than the south'.[162] He suggested that due to their reduced economic means the population living on the north side were less able to 'artificially fill up these swampy lots of land, so as to improve their hygienic condition'.[163] This is a clear medical topography of Belize City, with the natural topographical features of ridges and swamps delineating the healthy and less healthy spaces. Hunter described the vegetation at Belize City as 'large areas

[160] TNAUK_CO_123_188
[161] Ibid.
[162] Ibid.
[163] Ibid.

of swamp that can often form seething pestiferous pools or ponds, covered with green scum and exposed to the rays of the sun…Dense forests of luxuriating mangrove act as an obstruction to the forces of the sea-breezes'.[164] Here vegetation is seen both as the source of disease, producing miasmas as well as a barrier to sea-breezes which would clear away such misasmatic gases. These ideas clearly root healthiness of place within an understanding of miasmas which have featured since the late 18th century. As has been shown in section 5.3.1, part of Dr. Hunter's role as Medical Officer in Belize included both recording and supervising the measurement of daily meteorological observations at the public hospital in Belize. The comparison of Hunter's narrative account of meteorological conditions surrounding the 1886 outbreak of yellow fever with the meteorological record has shown some inconsistencies (section 5.3.1). The daily record from Belize only surrives from 1878 so it is not possible in the case of narrative account from 1860 to compare Hunter's observations with meteorological data. As such, this chapter focuses on examining Hunter's assessments of the nature and causes of yellow fever, and examining his conclusions within the wider context of understandings of tropical climates and disease. Dr. Hunter identifies the year 1860 as:

'an exceptional one in many respects, both in regard to the great atmospheric changes, and the appearance of a malignant form of fever which may be attributed in a very great degree to these changes'.[165]

In particular, Hunter suggested that the temperature was 'intolerably hot and oppressive' and 'rose to a degree unprecedented in the records of the meteorology of this place'.[166] Hunter noted that temperatures peaked on 10th June 1860 at 93.5˚F (34˚C) in the shade, and, that temperatures in the range of 90 - 93.5˚F (32 - 34˚C) persisted for more than two weeks in June 1860:

> 'When a period of fifteen or sixteen days in succession of this exaggerated degree of heat occurs there can be no doubt of its efficacy in bringing about changes in the atmosphere, the ground, and the surroundings, as well as in the system of individuals; which must inevitably result in general derangement, conduce [sic] to disease.'[167]

Here Hunter sets out a clear chain of associations which moves through meteorological and atmospheric conditions to topographical conditions and then to individual human systems and a more widespread general susceptibility to disease in a population. This chain is embedded in ideas surrounding local geographical conditions influencing the causation and transmission of disease, and the emphasis on local geographical features enables the identification of healthy and unhealthy zones. The drawing together of these features implies a specific model of disease causation and transmission that is based upon European ideas of tropicality and

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[164] Ibid.
[165] Ibid.
[166] TNA_CO_123_188
[167] Ibid.

acclimatization that persisted in British colonial understanding of healthiness in Belize throughout the 19th century.

In 1898 Dr CH Eyles (Colonial Surgeon, Belize,1888 - 1905) published an article in *The Edinburgh Medical Journal* called 'The influence of Rainfall in yellow fever',[168] which was based on four years of daily ground water level observations. Eyles (1898) suggested that the outbreak of yellow fever was linked to the ground water level, which in Belize, were determined by local rainfall. Ground water levels are low from December until the end of May, but increase with the annual rainy season, which begins around the beginning of June, with ground water levels high until November:

> 'It is needless to say that any given amount of rainfall will produce widely different effects according to the season. In the early months, with low water level and a parched soil, the effect of even heavy rainfall is but transient; whilst late in the year, with high water level and a damp soil, a relatively trifling shower of rain suffices to saturate the soil.'[169]

Eyles (1898) suggested that the dry, warm conditions in the first six months of 1860 were favourable to the initial outbreak of yellow fever. The intensification of the 1860 outbreak in the first week of June occurred due to the increasing groundwater levels at the beginning of the rainy season, and continued until the end of October when the soil became saturated, and conditions for yellow fever became less favourable. For Eyles (1898) rainfall patterns drive ground water levels, and these levels determine whether conditions for yellow fever are favourable or not. Warm temperatures are important but, as Eyles (1898) stated, high minimum temperatures were ever present in the tropics. Eyles made the following conclusions based on his research in Belize City:

> '(1) A dry state of the soil furnishes conditions that are favourable as antecedent to yellow fever; (2) that when this dryness is terminated by rain, the explosion occurs, and continues with a moderate amount of moisture; (3) that soil wetness, well pronounced, favours the decline of fever; (4) habitual wetness or moisture of the soil is unfavourable to yellow fever. All this means that yellow fever is a disease of the summer season in the Tropics, because this is a season when marked alterations in the soil are produced by rainfall…'

These conclusions locate moisture levels in the tropics including rainfall, soil moisture and ground water levels as the central concern for those trying to explain the causes and mitigate the effects of tropical disease. Section 5.3.1 has highlighted that increased rainfall, TPD and PI are consistent with the occurrence of YFYs, as persistent, low intensity rainfall provides the optimal breeding conditions for the disease vector. Although Eyles (1898) does not make associations with increased rainfall in June 1860 promoting the breeding of mosquitoes, he identifies rainfall (as a driver of groundwater levels) as a

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[168] Eyles CH (1898) The influence of Rainfall in yellow fever. *The Edinburgh Medical Journal* **4**:514-522 Accessed on 10.7.2012 via www.googlebooks.com

[169] Eyles CH (1898) The influence of Rainfall in yellow fever. *The Edinburgh Medical Journal* **4**:515

critical component of the favourability of conditions for outbreaks of yellow fever in Belize City.

Hunter's report (1887) focuses on the meteorological and topographical conditions that surrounded the 1860 outbreak, and concluded that the outbreak was caused by a combination of excessive temperature that induced atmospheric change and the prevailing topography (including the vegetation) of Belize City.[170] Eyles' 1898 report also highlighted the importance of local conditions, specifically meteorological, as he identified rainfall patterns and ground water levels as a catalyst for yellow fever outbreaks. This 1898 report has a broader explanation of disease in the tropics which Eyles applies to all tropical regions; although the case study comes from Belize City, the data gathered and the conclusions drawn are applicable across the tropical region. In the post-epidemic analysis of the spread of the 1860 yellow fever outbreak among British naval vessels, the idea that the disease was infectious and was spread between humans in contact with those infected with the disease was considered to be important. Bristowe (1894) notes in the Handbook of British Honduras that after an outbreak of yellow fever in 1886 there was much discussion among 'medical men in the colony' as to the causes of this and previous outbreaks of yellow fever in Belize (p.70).

Livingstone (1999) suggests that at the end of the 19th century, debates about the ability of Europeans to settle in the tropics remained framed by 'medical diagnosis, colonial imperative, Darwinian demography and moral evaluation' (p.93). This persistence occurred in the wider context of the dissemination of the germ theory since the mid-19th century by medical men including Luigi Westenra Sambon (1897, 1898) and Patrick Manson (1898). They began to publicly question the causal link between tropical climate and a number of diseases including malaria, yellow fever and tuberculosis (Bell, 1993; Livingstone, 2002; McNeill, 2010). With the emergence of this new disease aetiology, 'germs rather than sun, heat or tropical moisture gradually became to be considered as the primary constraints upon European colonialization' (Endfield and Nash, 2005 p.369). Furthermore, by the 1880s Carlos Juan Finaly (1833 - 1915) identified the mosquito *A. aegyptii* as the vector of yellow fever (McNeill, 2010). As well as being an early proponent of the germ theory, Sambon (1897, 1898) also called for a more nuanced understanding of the the space of the tropical climate (Livingstone, 1999; Endfield and Nash, 2005). Nevertheless, in the Belizean experience of fever and tropical climate, local geographical, topographical and meteorological features remained the predominant causes of disease throughout the 19th century, and this only began to change in the early 20th century, with the publication of a report written by Professor Boyce on the prevention of yellow fever in 1906.

[170] TNA_CO_123_188

7.2.4 Mosquitoes as the vector of disease: an emerging model of disease transmission in the early 20th century

In April 1906, the British Colonial Office sent out to every Colony and Protectorate a copy of a report titled 'The Prevention of Yellow Fever'.[171] This report was authored by Rubert Boyce, Professor of Pathology at the School of Tropical Medicine at the University of Liverpool. Sambon and Boyce worked within the same academic environment at the same time, as Sambon working at the London School of Tropical Medicine Boyce was commissioned to conduct research in the summer 1905 during an outbreak of yellow fever in New Orleans, USA. At the request of the then Governor of British Honduras, Boyce continued his travels to Belize to produce a report on its sanitary condition, with particular reference to the prevention of yellow fever. The resulting report was published at the expense of the Government of British Honduras and the Colonial Office.

Boyce is explicit that yellow fever is not caused by 'filth, miasmas, opening-up the ground, dredging, canal making, nor contact with yellow fever patients, their clothes or bedding',[172] but that yellow fever is transmitted by the bite of the 'Tiger' or 'Brindled' mosquito – *Stegomyia fasciata* (Fig. 7.2). Boyce uses the contemporary name – *Stegomyia fasciata*, but this is the same mosquito as the *A. aegyptii*, with the later scientific name in common use from 1920 (McNeill, 2013, Pers.Comm.). Boyce (1906) unequivocally rejects aetiologies of disease based upon acclimatization and local geographical and topographical features.

[171] TNA_CO_123_254
[172] TNA_CO_123_254

Figure 7.1 'The yellow fever mosquito *Stegomyia fasciata*' included in the report of Boyce (1906, TNA_CO_123)

As part of this report, Boyce mapped the location of yellow fever cases in Belize City during the 1905 outbreak (Fig. 7.3) and then during the period 17th September – 31st October 1905; he and a team carried out surveys of the city to map the breeding locations of the mosquito (Fig. 7.4).

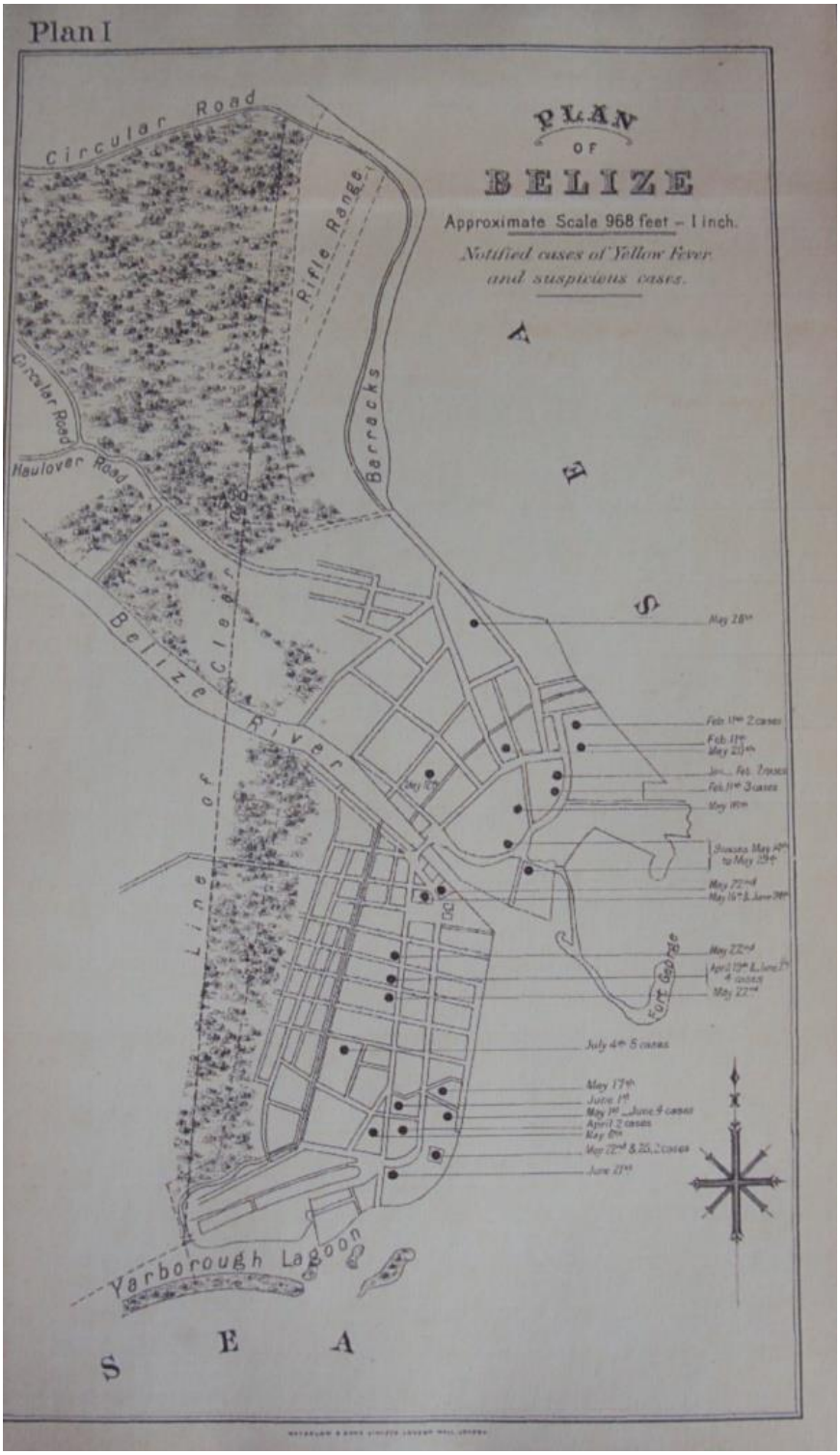

Figure 7.2 'Distribution and timing of yellow fever cases during the 1905 outbreak (Boyce, 1906)

Figure 7.3 'Distribution of *S. fasciata*, Belize, City' (Boyce, 1906)

The report includes an extensive list of the possible breeding sites of *S. fasciata*, which requires undisturbed water including water stored in cisterns, barrels, kerosene tins, flower pots, conch shells, old bottles and food tins. Boyce is at pains to make it clear to the reader that the mosquito is a domestic species and, as it frequently breeds in cisterns, will occur in wealthier and more sanitary districts, as well as poor, insanitary parts of the town of Belize City.[173] As water is vital to the breeding cycle of the mosquito (where eggs are laid and the larvae develop), Boyce stated that all water containers should be screened with brass wire gauze that is '18 meshes to the inch' and should be fixed rigidly using wood or nails, and that each householder or local authority should 'set the example by screening his own water cistern'.[174] 'The *Stegomyia* mosquito attacks its victim noiselessly and persistently during both the day and at night' and further measures that should be undertaken by individuals include sleeping under a mosquito net that should also have a gauge '18 meshes to the inch and must be securely tucked in'.[175] All preventative measures recommended by Boyce sought to limit the mosquito population and their contact with humans.

In his report Boyce (1906) cites the work of the American Reed in Cuba in 1900 who, with his team, 'succeeded by most exacting and convincing experiments to prove conclusively the role of *S. fasciata* in transmitting yellow fever' (p.13); Boyce's preventative screening measures and chemical fumigation treatments (Figs.7.5 and 7.6) replicated the measures undertaken by the US Army Yellow Fever Commission in Cuba (1900 - 1902) and Panama (1903 - 1906) (McNeill, 2010). The US Army Yellow Fever Commission was established in 1900, led by Sr. Walter Reed, and began its work in Cuba, which had been occupied by the US since 1898 (Pierce and Writer, 2005; Mc Neill, 2010). Reed and his colleagues undertook a series of experiments to establish that mosquitoes were spreading yellow fever and, having successfully made their case to the US Army Generals, began a mosquito eradication programme, with measures including the limiting of mosquito breeding sites by covering rain barrels and cisterns and putting up nets and screens (McNeill, 2010). By 1902, Havana was almost completely clear of yellow fever (Gillet, 1995; Oldstone, 1998; McNeill, 2010). Boyce's report of 1906 marked the beginning of a new British understanding of the causes of yellow fever and other mosquito-borne diseases prevalent in Belize, with ideas of disease prevention shifting from seasoning and swamp clearance to screening and fumigation. This reflects the decline of theories of acclimatisation, and the emergence from the early 20th century with medical theories about germs and disease vectors (Pols, 2012). It is interesting to find Belize, a rather insubstantial aspect of the British Empire at the frontier of research concerning disease aetiology. This is probably due to the rather fortuitous and timely visit of Boyce in 1905, who was an academic colleague and contemporary of Louis Sambon (Livingtone, 1999).

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[173] TNA_CO_123_254
[174] TNA_CO_123_254
[175] TNA_CO_123_254

Figure 7.4 'A screening gang about to screen a room containing a yellow fever patient' (Photo: Boyce, 1906, TNA_CO_123)

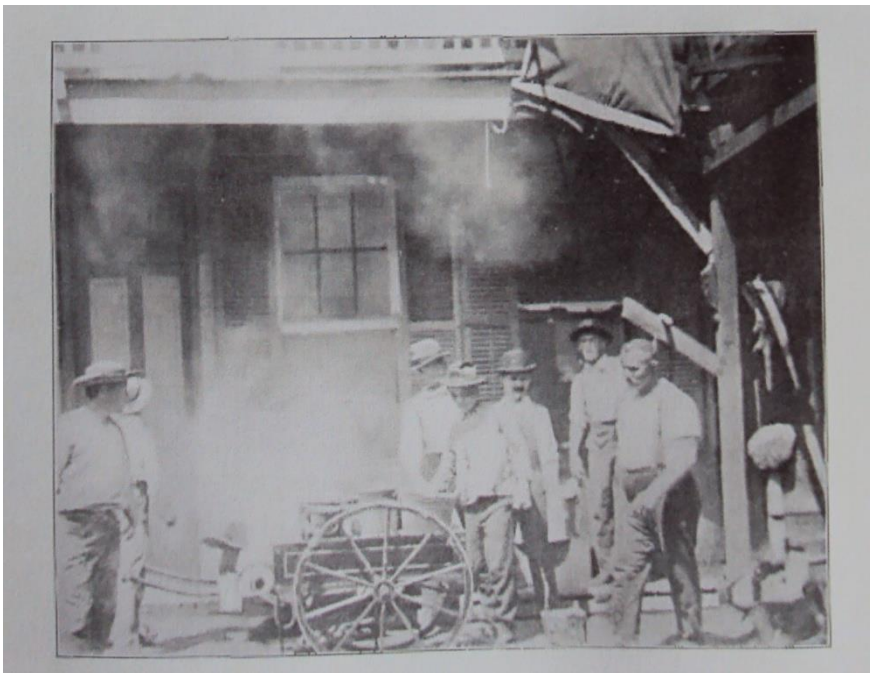

Figure 7.5 'A fumigation gang at work, Belize City, 1905' (Photo: Boyce, 1906, TNA_CO_123)

Even with the emergence of the 'Germ theory' at the turn of the 20th century, concerns about acclimatisation continued (Deacon, 2000). This was partly due to the clear and substantive differences of tropical temperature patterns and rainfall regimes, compared with the temperate regions (Stepan, 2001). It may also have been that some of the observations made by those ascribing moral and physical potency to tropical climates undertook action that was consistent

in reducing disease. Swamp drainage was widely recommended; if this were not possible, houses were situated away from swampy regions; both practices would have reduced human susceptibility (as currently understood) to mosquito borne disease even if the 20th century understanding of the causes was different. In Belize, swamps and marshes remained a tangible part of British understanding of disease well into the 20th century as some of the images and captions from Eyles' (1898) report demonstrate (Figs.7.7).

Figure 7.6 A Quarantine station, Belize City. This image is accompanied in the original with the caption 'note the extensive marshes' (Photo: Eyles 1898)

7.3 Summary

The 'cultural/ intellectual' component of an environmental history of Belize (Fig.1.6) can be used to explore how British colonial ideas and theories of climate, health and disease in the tropics changed during 1820-1920. In the early and mid-19th century, disease theories focused upon acclimatisation and medical topography, where tropical regions (and certain localities within those regions) were considered more or less unhealthy due to local meteorological and climatological features. The 1860 epidemic of yellow fever was a significant event in the history of Belize City and of the wider country, with contemporary estimates suggesting that over 30% of the European population died of the disease. All of the accounts considered demonstrate the nature

and impact of this yellow fever epidemic upon the European population resident in Belize. These sources suggest that in the aftermath of this epidemic, naval surgeons in particular began to articulate a different model of disease transmission, identifying human contact with infected populations as the central cause of the spread of yellow fever. These same writers suggested that segregation of infected crews was important to contain the disease, but also that removal to a colder climate would be the most expedient cure. The curative element of a colder temperate climate (and conversely the injurious aspect of a warmer tropical climate) highlights a remaining link between understandings of disease transmission and meteorological and topographical features. The reports of 1887 and 1898 identify meteorological conditions and underlying topographical conditions as the cause of such an extensive and deadly outbreak, and these conclusions are founded upon medical theories of acclimatisation, tropicality and medical topography that dominated the 18th and early 19th centuries. Although these medical theories did not identify the link between increased precipitation during the mosquito breeding season and the occurrence of yellow fever (that has been explored in sections 5.3.1 and 5.3.2), the theorists of the period did identify variable precipitation as a causal aspect of yellow fever. The report of Boyce, published in 1906 and distributed by the British Government across their Colonial territories, identifies the mosquito as the vector of yellow fever. This is the first known official account from Belize that articulates this model of disease transmission, and reflects both the experience and shift in understanding of other Colonial powers interacting with tropical zones in the late 19th and early 20th centuries; it is probably also a product of a close academic relationship between Boyce and Sambon. Alongside this emerging model, more traditional 19th century understandings of climate and health in tropical climates persisted in Belize, a pattern which was matched across the tropics (Deacon, 2000).

Using four different kinds of archival source, I have tracked various continuities and changes in European imaginings of the healthiness of Belize. These assessments are built upon the foundational idea of ‘acclimatisation’, which implies a dynamic interaction between body and climate to produce states of health and disease. Through missionary sources, naval medical records, governmental reports, and public health documents, I have shown how, during the nineteenth century, Belize shifts from being a place associated with pathology and ill-health to one that is significantly healthier than other tropical places for Europeans. Despite this shift – and the political agendas that may have driven it – the underlying terms of the debate – principally around swamps and costal air – remain unchanged. This medical topography is all the more striking for its survival of the shift unscathed. A break with this topographical system, with this logic of health and disease, emerges in the twentieth century. Disease and health are no longer thought to depend solely upon successful adaptation to climatic conditions. The focus shifts to mosquitoes as disease vectors, a fundamental break with previous ideas. Concerns over the healthiness of Belize endure, but have been transformed. Chapter 8 draws together the empirical research detailed in Chapters 4, 5, 6 and 7 and considers how each of these themes can be

considered alongside one another, to produce an integrated environmental history of northern Belize.

Chapter eight

Towards an integrated environmental history of northern Belize

8.0 Introduction

The guiding framework or methodology underpinning this thesis has been environmental history. The term 'environmental history' has been seen as both referring to an academic discipline (Worster, 1988; Green, 1993; Merchant, 2002) but also an interdisciplinary methodology (Powell, 1995). In writing an environmental history of northern Belize, Worster's (1988) three lines of inquiry and McNeill's (2003) three varieties have been a constant frame of reference (Fig.1.2), and each of the four empirical chapters (Chapters 4 – 7) have sought to meet one or more of these aims (Fig.8.1). Information derived from palaeoecology (Chapter 4) has documented how the SDTF and pine savanna ecosystems have changed over the last 3,500 years in response to Maya, British and Spanish interaction with the landscape (first thesis aim, section 1.2). An examination of the British colonial archival sources identified mahogany and logwood as key exports during 1650 and 1950 (Chapter 6). The extraction of each of these exports during distinct periods appears to be visible in the palynological records (Fig.6.3) and this meets the second thesis aim (section 1.2). Records of temperature and precipitation from Belize City for the period 1865 – 2010 have been reconstructed using documentary records (Chapter 5) (section 1.2, third thesis aim). These meteorological records have been drawn together with archival documentary records of yellow fever to explore whether increased precipitation coincides with outbreaks of epidemic yellow fever (Chapter 5). The documentary records have also enabled the exploration of British colonial interactions with the 'tropics', both actual and perceived, using narrative accounts and meteorological measurements (Chapter 5 and 7), meeting the fourth thesis aim (section 1.2). Information from palaeoecology (Chapter 4), historical climatology (Chapter 5), natural resource extraction and export history (Chapter 6) and histories of climate (Chapter 7) have been drawn together to provide an integrated, multidisciplinary reconstruction (Fig.8.1). This integration has involved uniting different streams of information to create a new understanding of human interaction in the tropics. Documentary records of British colonial timber exports (logwood and mahogany) (Chapter 6) have been used to inform a palaeoecological record of vegetation change (Chapter 4). The documentary record temporally constrains logwood extraction to AD 1660 – 1910 and the palaeoecological record identifies pine savanna as the ecological context extraction. Similarly the documentary record identifies AD 1750 – 1945 as the period of mahogany extraction, felled from the SDTF as demonstrated in the palaeoecological record. The pollen record (Fig.6.3) shows a period of suppressed pine savanna signal followed by a period of supressed SDTF signal. Due to poor chronological constraints of the Lamanai 2010 core it was not possible to date the changes in the pollen record observed at these points.

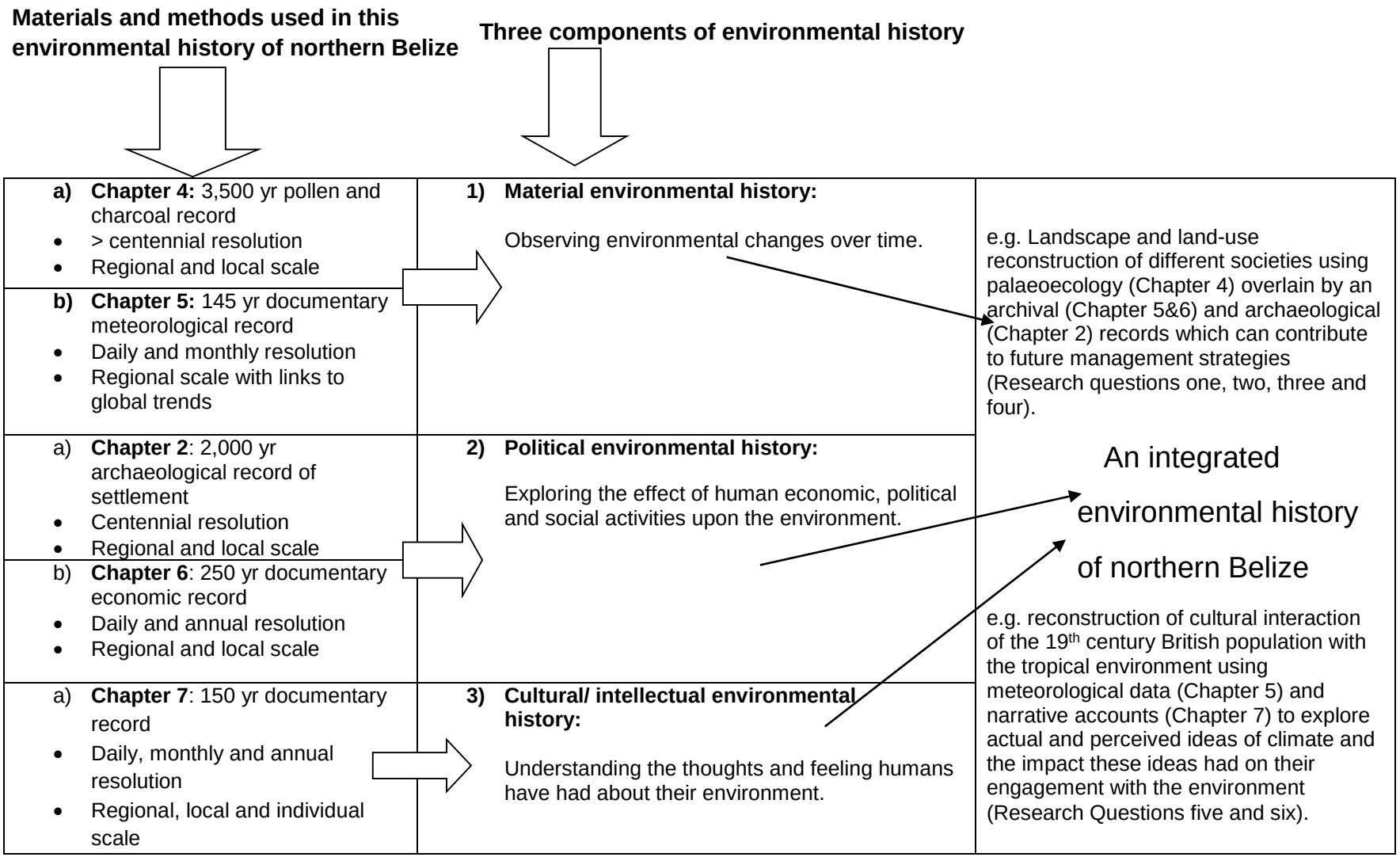

Figure 8.1 Summary diagram of the framework that informs this environmental history of northern Belize

However, when the palaeoecological record is compared to the documentary record of exports it is possible to broadly date the changes in the pollen record, and to attribute these changes to human extraction of specific resources.

Precipitation records derived from documentary meteorological data (Chapter 5) have been compared to a documentary derived chronology of 19th century yellow fever, reconstructed using narrative accounts (Chapter 5 and 7). This has shown that during six of the seven YFY with a corresponding meteorological record there were ideal precipitation conditions for *A. aegypti* to breed. However, there were ten further years during 1878 and 1947 where these ideal conditions were observed yet there were no recorded out breaks of yellow fever.

The precipitation record has also been compared to timber export records (Chapter 6). This comparison demonstrates that precipitation levels that are favourable to timber extraction occur in the mid-to-late 19th century, during a period of peak exports. Similarly, precipitation levels that are unfavourable occur during the early 20th century, when export levels decreased. Although the link between precipitation and timber exports is not simple, by drawing together these two records it is possible to demonstrate that during these two periods, precipitation patterns may have had a role to play in the success or failure of timber exports. Narrative accounts of specific outbreaks of yellow fever in the mid-19th century have been compared to meteorological records which reveal a disparity between instrumental meteorological records and an individual narrative account of the climatic conditions surrounding a specific outbreak (Chapter 7). This occurs even when the instrumental records and narrative accounts are compiled by the same individual and emphasises the importance of multiple, contrasting sources of information to reconstruct an accurate, nuanced account of human interaction with the environment. These examples illustrate how the different lines of inquiry and sources of information have been integrated, meeting the fifth thesis aim (section 1.2).

At the opening of this thesis (p.1-2) six research questions were raised as fundamental to this research. With the central focus on how humans interact with tropical lowland environments in the past, and how this could inform future management of ecosystems currently under threat. Chapter 8 returns to these questions, drawing on the empirical research presented in Chapters 4 – 7, and the wider literature discussed in Chapters 1 and 2. First to be considered are the questions that examine human interaction with the tropical forest (research questions one, two, three and four, p.1).

8.1 Human interaction with the tropical forest

Figure 8.2 outlines the eight major phases of human interaction at Lamanai, northern Belize since 1500 BC. Three broad categories of activity or change within the landscape are identified, namely: crop cultivation (orange triangle);

Phase	1. c. 1630 BC	2. c. 1240 BC	3. c. 1150 – 800 BC	4. c. 170 BC – AD 150	5. AD 500 – 1000	6. AD 1450 – 1700	7. AD 1750 – 1945		8. Post AD 1950
							1660-1910	1750-1945	
Symbolic summary of landscape development									
Sedimentry proxies (Pollen & Charcoal; Metcalfe et al., 2009)	Crop pollen present at c. 1630 BC.	c. 1240 BC synchronous increases in charcoal, herb taxa, crops coincident with decreases in forest and savanna taxa.	Peak in forest assemblage coincident with a decrease in palm and crop pollen.	Pine pollen abundance v low, increased charcoal concentration, presence of crop pollen. Metcalfe et al. (2009) reported elemental peaks c. 170 BC – AD 270.	Absent pine pollen, peak palm taxa, increases in economic trees. Crops also present and high charcoal concentration.	Increase in forest pollen assemblages, alongside presence of crops and palm cultivation and low pine pollen values.	Low pollen diversity, absence of crop and palm cultivation. Reduction in forest and pine savanna assemblages. Peak charcoal concentration.		High values of SDTF and pine savanna pollen, and peak biodiversity alongside decreased palms and herb taxa and low charcoal concentrations.
Archaeological proxies (Pendergast, 1981;1982a-c; 1996; Graham, 2004)	Settlement at Lamanai suggested at c. 1500 BC			Construction on High Temple began c. 100 BC.	Construction and development at Lamanai: Mask Temple (AD 500-600), Main Plaza (AD 600-700) and ball court (AD 800-1000).	Continued Maya presence at Lamanai until the end of 16th century and construction of 16th Spanish churches.	British sugar cane plantation at Lamanai, with construction of a mill and importation of foreign labour during mid 19th C.		Archaeological excavations begin in 1974.
Archival proxies (Export records, newspapers, travelogues)							British colonial extraction of logwood from pine savanna (AD 1660 – 1910) and mahogany from SDTF (AD 1750-1945).		End of extraction of timber for exports. 1985: creation of the Lamanai Archaeological Reserve (396 ha).

Figure 8.2 Phases of landscape development at Lamanai, northern Belize, 1500 – post AD 1950

= no known proxy available = crop cultivation = land clearance = vegetation re-growth

land clearance (purple square); and vegetation re-growth (green circle). Information has been gathered from sedimentary proxies, archaeological accounts and archival sources and this, where appropriate is summarised for each phase in chronological order, and at the conclusion of the discussion. Conclusions are drawn as to how far each of these research questions have been answered and what remains for further study.

In *phase one*, crop cultivation is observed at Lamanai through the presence of *Z. mays* and cucurbita pollen grains at c. 1630 BC, and the archaeological record suggests that settlement at Lamanai occurred c. 1500 BC. *Phase two* is identified approximately four hundred years later (c. 1240 BC). Here the palaeoecological record suggests larger-scale field-based agriculture and palm cultivation to support a more substantial settlement, although there is no clear evidence from the archaeological record as to the extent of the settlement at this point. As with the second phase, *phase three* of human interaction at Lamanai (c. 1150 – 800 BC) is only indicated by the palaeoecological proxies. Here, peak SDTF pollen assemblages coincide with a decline in palm and crop pollen, which is suggestive of forest re-growth, however there is nothing in the archaeological record to suggest a substantial change in the format or size of the settlement. During *Phase four* there is palaeoecological evidence of anthropogenic land clearance from pine savannas for lumber and fuel, as pine pollen abundance is very low and this is accompanied by high charcoal concentration and the presence of field-based crop pollen and palm pollen. Metcalfe et al. (2009) also report elemental peaks during phase four which indicates increased erosion in the NRL catchment. The evidence from the sedimentary proxies of anthropogenic pine savanna clearance for construction is supported by the archaeological record: during this period, work on High Temple (Str. N10-43) began at Lamanai.

It is clear from these four phases of human interaction at Lamanai, that the pre-Columbian Maya societies had a discernable impact upon the environment. Substantial forest and savanna clearance is visible in the pollen record, possibly for construction of settlements and field-based agriculture (*phase 2*, c. 1240 BC). The extraction of pine at significant levels is also apparent perhaps for use in construction, as a fuel, to be traded as a ritual good or a combination of all factors (*phase 4*, c. 170 BC – AD 150). These two phases of significant human activity are separated by a c. 350 year period of increased forest and pine savanna, coincident with a decrease in crop and palm pollen. It is unclear from the archaeological record as to the possible cause(s) of change in vegetation composition, and the settlement of Lamanai was continuously occupied during this period. This record of pre-Columbian modification of the landscape is further evidence that refutes the ‘pristine myth’. According to this particular narrative, pre-Columbian societies lived in ‘ecological balance’, in contrast to the destructive, exploitative post-Columbian engagement with the natural resources (Denevan, 1992; Whitmore and Turner, 1992). Denevan (1992) described the ‘pristine myth’ as an ‘invention of 19th century romanticist and primitivist writers’ (p.369) and Blaut (1993), suggests that this identification of lands encountered by Europeans as ‘empty’

was used to explain and justify European colonial expansion. Iterations of the 'pristine myth' can often cast indigenous populations as Adam of the Genesis account, before the fall, placed in the Garden of Eden by God. In this role the indigenous population innately understood the workings of animals and plants, and cared for them as brothers and benefactors (Miller, 2007). However, this is another colonial construct that persists in a more dilute, acceptable form in the post-colonial era. As Miller (2007) suggests:

> 'Like Europeans, Indians perceived nature primarily as provisions to be extracted and consumed. Animals were meat, hide, fur, sinew, tooth and bone; trees were lumber, firewood, fruit and nuts.' (p.26)

The palaeoecological and archaeological records (Chapter 4) demonstrate that for the Maya, trees were sources of lumber, fuel, fruit, torches and incense, and palms provided materials for thatching and weaving, fruits and nuts. In all likelihood many other plants provided sources of food, medicine or had ritual significance. These four phases of human interaction with the landscape give valuable insight as to how human societies, in this case pre-Columbian Maya, have interacted with the forest (research question one, pg ref). The Maya built settlement within the SDTF, clearing areas on which to build ball courts and temples, dwellings and places for storage. The Maya also grew enough crops to feed substantial populations (far greater than the modern day settlements at Lamanai) and cultivated palms and felled pine. All this occurred one thousand years before the flourishing of the Late classic Maya societies (c. AD 800 – 1000) and two thousand years before European arrival, which suggests that in spite of these phases of human interaction, the SDTF and pine savannas were resilient ecosystems, able to persist through substantial periods of anthropogenic modification (research question two, p.1).

Phase five of human interaction with the landscape occurs between AD 500 and 1000. As observed in the fourth phase, there is continued clearance of pine savanna for lumber and fuel. Alongside this clearance, there is evidence of high palm concentration, an increase in economically useful trees in the pollen assemblage, and the presence of field-based crops. When this palaeoecological record is placed in the context of an archaeological record that demonstrates a period of construction and cultural development, the presence of multiple types of natural resource cultivation suggests multifaceted anthropogenic management of resources. The second narrative of human interaction with the tropical forests is the 'collapse morality tale' (where the disintegration of historical societies are examined for future lessons) has had an increasingly prominent role since the 20th century. Concerns surrounding population growth, environmental degradation and global climate change, have led some authors to search for 'alarming futuristic scenarios in historical digests' (Butzer and Endfield, 2010 p.3628). There is no palaeoecological or archaeological evidence from Lamanai of any period of 'collapse' indeed, the evidence points to the opposite – a flourishing of cultural diversity, population growth and ecological wealth. This suggests the Maya 'managed' their way through a period of population decline and cultural disintegration for other settlements across the region. That Lamanai continued

to flourish when other settlements did not (e.g. Altun Ha c. 30 km east of Lamanai) adds weight to the growing call for a greater understanding of the temporal and spatial variability of both societal change (Graham, 2001; 2004; Aimers, 2007; Luzzadder Beach and Beach, 2012) and variations in climate (Metcalfe et al., 2009; Aimers and Hodell, 2011) during the Late and Terminal classic periods. Dunning et al. (2012) suggest that these collapses were 'typically complex, multigenerational and asynchronous events' that occurred during a period of 'profound transition and transformation of Maya society' (p.3652). Butzer and Endfield (2012) suggest that 'longer-term diachronic experience offers insight into how societies dealt with stress, a more instructive perspective for the future than offered by apocalyptic scenarios' (p.3628). These phases of varied human interaction demonstrate that a variety of land-use practices and management strategies were employed by the Maya as the settlement of Lamanai evolved (research question three, pg. ref). This is an important reminder that we should not, from a 21st century perspective, view thousands of years of Maya culture as a homogenous entity. As different European nations delivered different modes of colonialism so too must Maya cultures, from different centuries and millennia, be viewed as distinct societies with different ways of viewing and using the landscape.

Maya societies were able to develop complex cultures and feed substantial populations to build temples and support the rituals and beliefs housed within them. Seemingly there is much to learn from these Maya phases of development in the forests of northern Belize and this idea has been subtly present in many ethnobiological studies of tropical forests. Here, in contrast to the passive role ascribed to the Maya within the pristine myth, the Maya are espoused as agents of constructive managed change (Fedick, 1996; Ford, 2008; Ford and Nigh, 2009), with an unrivalled source of 'traditional' knowledge or wisdom. Present in these narratives is an element of teaching, an aspect of the narrative seeking to use stories about the past to better inform the communities to which they are told. This is hardly surprising, as Cronon (1992) identifies the importance of this educational aspect as a key component of telling stories about nature. Hughes (2006) suggests that this approach demonstrates that:

> 'environmental historians have a responsibility to the wider audience of the human community, since their work helps to provide the awareness necessary for deliberations concerning the decisions that society must make in terms of the environmental crises it faces' (p.117)

This multifaceted Maya management of resources, particularly visible in *phase 5* of the Lamanai record has resonances with the 'managed mosaic' or 'forest garden' models of management described as being present in modern day Maya communities (Fedick, 1996; Ford, 2008; Ford and Nigh, 2009). Whether these models are the most effective method of conservation (research question four, p.1) will be considered in this Chapter.

During *phase six* (AD 1450 – 1700) the palaeoecological record suggests some re-growth of SDTF alongside the continued presence of field-based crop

pollen and high palm pollen concentrations. Pine pollen abundances are also very low. This suggests a complex picture of landscape development, with the continued presence of a perhaps reduced population of Maya (compared to *phase five*) cultivating palms and crops during this period of forest re-growth. The palaeoecological record indicates anthropogenic extraction of pine from the savannas at Lamanai during this period, which coincides with the construction of two 16th century churches at the site. *Phase six* occurs at a time during which Europeans made contact with much of the Americas. The palaeoecological records reflect the distinctive Spanish presence, with low pine values indicating the construction of a permanent physical presence that was not evident in the cultivation of different crops or a different composition of the available edible resources. In spite of their church buildings, the Spanish had only an ephemeral presence in the palaeoecology of Lamanai. This is a different story of Columbian encounter than found elsewhere in Central America, where the arrival of Europeans was hugely damaging to the indigenous populations who died from a combination of conquest, disease and famine (Butzer, 1992). Butzer (1992) comments that the tragedy of the conquest of the Americas, was the sheer scale of human loss to primarily 'old world' disease. This undoubted tragedy has lent moral weight to other aspects of the European encounter, predominantly European conquest of the landscape. Indeed, a unifying feature of the three cultural narratives previously outlined (the 'pristine myth', 'Maya managers' and 'collapse morality tale'), is the place that judgements of 'good' or 'bad' ecological behaviour held. The 'pristine myth' places moral weight behind the 'transparent', 'ecologically balanced' indigenous cultures, and against the 'destructive', 'arrogant' Europeans.

Melville (1990; 1994) has described the introduction of sheep to Hildalgo State Vallley, Mexico as a 'plague', whilst emphasising the indigenous population's ability to live within landscape in a state of ecological balance, reinforcing the dichotomy Denevan (1992) and others (Whitmore and Turner, 1992; Butzer, 1992; Butzer and Butzer, 1997; Sluyter, 1999) seek to challenge. Moral judgements are clearly visible in accounts of the 'collapse' or otherwise of the Maya at Cobá, Mexico, as Leyden (2002) suggests:

> 'The Maya became the dominant environmental engineers after they entered the Lowlands. The result of their actions, as seen in the pollen record clearly demonstrates the capacity of humans to change the world…Was it arrogance with respect to this power over nature that ultimately led to the collapse of Maya civilisation? Perhaps.' (p.98)

McNeil et al. (2012) cite the case of the Maya at Copán, Honduras as a culture which has been unfairly blamed for their own destruction:

> 'For more than twenty years, the ancient Copán Maya have been held up as an example of a population that failed to practice sustainability and thus suffered a complete collapse…The 'fact' that the Copán Maya destroyed their environment in the Late classic period has been accepted by many scholars in a range of disciplines, and theories of societal collapse have been rewritten to reflect this assumption.' (p.1021)

Whether one agrees with the conclusions of McNeil et al. (2012), it is clear that the Maya use (or misuse) of forest resources at Copán have been considered destructive and ultimately immoral, with the resulting sudden population decline a warning to similarly profligate 21st century populations.

A further related problem of language can be observed in relation to a key term in palaeoecological literature: 'disturbance'. 'Disturbance' can imply both general anthropogenic changes in the landscape, typically forest cover, as well as a specific term linked to a group of pollen taxa (disturbance taxa) associated with human presence in the landscape. As such, palaeoecologists have used the term 'disturbance' in their pollen diagrams (e.g. Islebe and Sánchez, 2002; Carrillo-Bastos et al., 2010), research titles (e.g. Binford and Leyden, 1987; Northrop and Horn, 1996; Leyden, 2002) and in broader discussions of forest 'disturbance' and 'recovery' (Abrams and Rue, 1988; Pohl, 1990; Jones, 1994; Curtis et al., 1998; Redman, 1999; Webster, 2002; Shaw, 2003; Rushton et al., 2013). The use of 'disturbance' in these palaeoecological reconstructions is to describe anthropogenic changes in the landscape, and is usually represented by synchronous changes in pollen taxa and charcoal concentrations. Used in this context, it does not reflect subjective concepts such as 'damaged' or 'denuded'. In the discussion of forest disturbance and recovery at Lamanai in Chapter 4, anthropogenic disturbance is only suggested as occurring when such synchronous palaeoecological changes occur. However, when the term 'disturbance' is linked to deforestation and, particularly within a 'collapse morality tale', previously ethically neutral terms (including 'recovery') become value-loaded and consequently misunderstood. Ford and Nigh (2009) suggest that accounts of deforestation in palaeoecological records have been interpreted as evidence of Maya destruction of the forest (Binford et al., 1987; Rice, 1996 Leyden, 2002; Webster, 2002). It is certainly true that studies have and continue to equate Maya deforestation as 'over exploitation' and 'misuse' of the forest and a causal factor of collapse (Binford et al., 1987; Rice, 1996; Islebe et al., 1996; Webster, 2002; Evans, 2008). However, this is not a consistent interpretation by palaeoecologists working in the Maya region (McNeil et al., 2010; McNeil, 2012; Rushton et al., 2013).

Although the various uses of the terms 'deforestation' and 'destruction' may appear merely semantic, the moral weight of the latter is lent to the former. This has led some to misinterpret palaeoecological records and thus reject their conclusions (Ford, 2008; Ford and Nigh, 2009). Many presentations of palaeoecological records from the Maya Lowlands frequently use ecological groupings such as 'herbs' in pollen diagrams to reflect the presence of such taxa in multiple formations including 'disturbed' or cleared forest, agricultural fields, grassland savannas and understory shrubs (Leyden et al., 1994; 1998; Leyden, 2002; Piperno, 2006; McNeil, 2012; Rushton, 2013). This enables those interpreting the record to draw their own conclusions as to why such taxa are present. The wider literature has moved away from 'disturbance'; terms such as 'impact', 'transformation' and 'settlement' have featured in reconstructions of past Maya environments (e.g. Beach et al., 2008;

Luzzadder-Beach and Beach, 2009; Metcalfe, 2009). This is, perhaps, a tacit acknowledgement of both the complexities of such research but also recognition of the importance of clarity and nuance in its communication. Terminology used to describe the phases of landscape development in Fig. 8.2 have been carefully selected to avoid any implicit value judgements and simply to reflect the change observed at a particular period of time.

These phases of human interaction at Lamanai emphasise the need for site specific understandings of landscape development in tropical lowland forests and in wider understandings of human-environment interactions (research question two and three, p.1). Lamanai was not a pristine landscape before European encounter, neither did the Maya 'collapse' but seem to have managed multiple types of natural resource visible in the pollen record. Management of animal, bird and unknown or palaeoecologically invisible plants is highly probable and further demonstrates the nuanced and complex way in which Maya societies utilised their environment for their own economic, cultural and religious purposes. It is clear that Maya 'forest gardens' (Ford, 2008; Ford and Nigh, 2009) did promote the conservation of economically important trees and palms, and that these species may otherwise not have flourished had the Maya focused solely on high clearance, field-based agriculture. In this sense they do provide a model for 21st century management of natural resources, both in the field and the forest, in the context of an urban settlement (research question four, p.1).

Phase seven and *phase eight* have the benefit of information derived from sedimentary, archaeological and documentary proxies. During *phase seven* (AD 1750 – 1945), there is evidence from all three proxies of land clearance in both SDTF and pine savanna ecosystems. The palaeoecological record demonstrates that cultivation of crops and palms is greatly reduced, together with a reduction in forest and pine savanna assemblages. Alongside an archaeological record of 19th century British colonial construction, there is a documentary record of colonial timber exports (Chapter 6). Furthermore, this documentary record enables the further elucidation of the palaeoeological record of land clearance. Using this annual record it is possible to identify two distinct periods of timber extraction, where logwood is selectively cut from pine savanna regions and mahogany is felled from SDTF. *Phase eight* occurs post AD 1950. All three proxies suggest re-growth of pine savanna and SDTF, a decline in palm and crop cultivation and an increase in biodiversity. Archaeological excavations began at Lamanai, and the Lamanai Archaeological Reserve was created in 1985, which suggests that the re-growth of vegetation is most likely due to a greatly reduced human presence at the site. This integrated record of pollen and archival sources demonstrates how an environmental history can bring clarity to changes observed in a palaeoecological record by identifying the type and nature of resource extraction in two sub-phases of British colonial interaction, logwood extraction from pine savannas (c. AD 1660 – 1910) and mahogany extraction from the SDTF (c. AD 1750 – 1945) (research question one and two, p.1). Due to the edaphic controls on the vegetation around Lamanai it is possible to ascribe

changes in the pine signal to changes in the pine savanna as opposed to the SDTF. However, in spite of the large-scale British export of logwood the pine savanna values are lowest during Maya phases of interaction at c. AD 350 – 1000 and c. AD 1000 – 1500 (see section 4.4.3). This suggests that Maya extraction of pine may have had a greater impact upon the pine savanna ecosystem both in terms of the volume of timber removed but also because unlike pine, logwood grows in thickets near watery areas (e.g. along the banks of the NRL) that would have been easily accessible for cutting (research question three, p.1). SDTF cover is reduced during the British colonial period, but this is at similar levels to those observed in the Maya *phases one, two, four* and *five*. This is on an industrial scale, hauling mahogany, using cattle and clearing forests for trucking roads and mahogany works. Today although mahogany grows in the forests of northern Belize, it is highly endangered (Meerman, 2004). Yet, the resilience of the tropical forest as a whole is clear, just a few decades after the trade in logwood and mahogany ceased in its colonial form (c. 1910 and 1930 respectively), SDTF and pine savanna values increase, with the highest levels of biodiversity found at any point in 3,500 years of human interaction at Lamanai. As with the regrowth observed in *phases three* and *six*, *phase eight* demonstrates that it in the absence of population the SDTF values increase rapidly. This suggests that the future management of these ecosystems should include protected areas (e.g. National Parks or Reserves) where human interaction is minimal to enable the species utilised by different societies indifferent millennia to continue to be available in the future (research questions two and three, p.1).

This interdisciplinary record of human interaction with tropical forests over a 3,500 year period provides new understandings of various uses of the forests of northern Belize. It also gives an insight to the resilience of the forest and pine savanna ecosystems. A similar interdisciplinary approach has offered new insights to 19th century British interactions with tropical climates, and these are now considered in light of research questions five and six (p.2).

8.2 Human interactions with tropical climates: a new history of climate and culture from Belize

As demonstrated in Chapter 7, perceptions of health and susceptibility to disease featured strongly in British colonial engagement with tropical environments, and this reflects the positioning of Belize as part of British Caribbean holdings as opposed to a Central American dimension of Empire (research question five, p.2.).

Combining reconstructions of meteorological records and narrative sources has extended the temporal reach of the climate history of Belize; it has also enabled the reconstruction of a cultural climate history which, thus far, has been limited in the Caribbean context (Carey, 2011). The transformation of ideas surrounding climate, health and place across the 19th century and at the beginning of the 20th century has revealed how understandings of

epidemiology shifted and developed. Throughout the 19th century, medical topographies dominated. The central feature of these discussions was a binary opposition of pathological swamps and clean coastal air the central feature of discussions, regardless of whether the writer considered Belize 'healthy' or 'unhealthy'. Fortuitously, the medical research network of the early 20th century that was based in the London and Liverpool Schools of Tropical Medicine extended to Belize, when Prof Boyce travelled to Belize City in 1905 to investigate an epidemic of yellow fever. Here, an outpost of the British Empire suddenly became part of relatively early research into the best preventative measures and treatments of yellow fever and included mapping yellow fever cases and undertaking surveys to monitor *S. fasciata* populations.

This cultural climate history highlights that although epidemics of yellow fever were limited in their mortality (especially when compared to outbreaks in the southern American States where tens of thousands died, Diaz and McCabe (1999)) and Belize was seen as a marginal unimportant nation, significant transformations in ideas of disease causation and transmission occurred. Even with these transformations specific features of the environment were still considered more 'unhealthy'. Marshes and swamps remained a prominent feature of concern as they were recognised as habitats for the insect vectors of disease, as opposed to previously imagined sources of 'noxious exhalations'. When examining the thoughts and understandings of the 19th century population it is clear that climate, health and place, and the triangulation of links within these three components developed a specific set of cultural and narrative terms. 'Fever' became the preferred explanation for many aspects of ill-health experienced and this is important to recognise if these types of sources are to be used in the construction of past episodes of particular disease. In the reconstruction of historical outbreaks of yellow fever, only years which contained multiple, contrasting sources which specifically described 'yellow fever' was ascribed as a 'yellow fever year'. This caution may have meant that some small outbreaks were not incorporated into the record. The comparison of narrative accounts of disease and climate and meteorological records (even when complied by the same individual or team of individuals) demonstrates the importance of wherever possible using multiple accounts to accurately outline a single event. It also hints at the importance of distinguishing between an 'event' and the resulting 'impact' or perception of impact, and this can often be more accurately viewed over a longer period of time.

The British colonial population at Belize City was primarily there to profit from the natural resources of the landscape, particularly the forests. The central narrative focus of the population on health and disease perhaps reflects rather reluctant colonialists who preferred the warmth of the Caribbean islands or the opportunities offered by Boston and New York. As such, human interaction, although at times involved in clearing extensive areas of forest was by its nature very different to the indigenous population. Unlike the Maya, the British built few stone buildings and had minimal trade networks save the export of wood and the import of essentials for living. For the British, Belize was a

useful source of inexpensive, fashionable dyes and hardwoods but this engagement was in the context of Maya interaction, ephemeral, lasting at most two hundred and fifty years. Belize never became a new site of British culture in the way it had in India, or how Spanish culture informed colonial Mexico and other Central American states. This transitory engagement is reflected in the insignificant place Belize has and some argue continues to have in the British consciousness (research question six, p.2).

8.3 Challenges and opportunities encountered when writing an environmental history of northern Belize

As noted in Chapter 1, the methodological and material scope of environmental history is vast, covering ever growing areas of academia. This thesis has drawn palaeoecologial proxies together with archival documentary sources and is informed by previously published archaeological and palaeoclimate records. This provides an account that as far as possible responds to three components or lines of inquiry identified in Chapter 1 as being central to an environmental history (Fig.1.2). Such an approach has brought its own challenges and opportunities and these will now be considered.

8.3.1 Integration

The key contribution that an environmental history can make is the integration of multiple lines of inquiry and how this is to be achieved has been considered in Figures 1.2 and 8.1. Two particular areas of concern regarding this integration include the different spatial and temporal resolutions and scales encountered during research of this nature and these will be considered in turn.

i) Spatial scales and resolutions

McNeill (2003) suggests, ‘one issue that environmental historians have not systematically confronted is that of scale…ecological processes unfold with no regard for borders, and cultural/intellectual trends do so nearly as blithely’ (p.35). A key opportunity afforded to this thesis has been the use and integration of diverse materials and methodologies across multiple scales. This has been necessary in order to incorporate information from both natural (Chapter 4) and human timescales (Chapter 5, 6 and 7) which together can provide a more complete understanding of the nature and causes of change in the environment over time. This long term palaeoecological record provides insight to both local and regional scale changes in the landscape. The large size of maize, squash and palm pollen grains restricts the interpretation of agricultural activity to the local scale, reflecting activity within the settlement at Lamanai which is adjacent to the coring site in the NRL. The smaller, more mobile, wind-pollinated grains such as *Brosimum* and pine provide a regional scale picture of changes in the forest and pine savanna ecosystems although, the immediate presence of both of these ecosystems at Lamanai suggests

that the record has the capacity to demonstrate local changes. The archaeological record of Maya settlement provides a local picture of the evolution and development of the indigenous culture and this becomes particularly important during the period after AD 800, as many other Maya sites experienced substantial change that is not reflected in the records from Lamanai (Graham, 2004). The archaeological record of Spanish and British interaction with Lamanai gives insight into the different experiences of the two distinct colonial periods both at Lamanai and in the wider region. The construction of Spanish churches in the 16th century alongside Maya cultivation of palms and field based agriculture points to Spanish socio-religious engagement, with the congregation system used to tax and socio-politically demarcate appropriated land and people. In contrast, the British focus on timber extraction alongside a short-lived 19th century sugar-cane plantation and mill, suggests a colonial period of natural resource extraction for profit and little social, political and cultural engagement with the landscape. The palaeoecological record further demonstrates these two periods of colonial interaction with the forests at local and regional scales. The Spanish colonial period occurs during phase six (Fig. 8.1), where continued crop cultivation happens alongside a re-growth of the SDTF – locally agriculture continues, but regionally forest cover increases post-European encounter. Phase seven (Fig.8.1) demonstrates little settled agriculture at Lamanai, and heavy resource extraction from the pine savanna and SDTF which reflects both local and regional trends during this period.

In Chapters 5 and 7, documentary sources are used to examine issues surrounding climate, health and place at both local and regional levels. In Chapter 5 the reconstruction of a local meteorological record is considered alongside place specific accounts of yellow fever and ENSO trends, which integrates local and regional records within a global context. Chapter 7 features individual descriptive accounts of perceptions of health and climate in the context of a specific place (Belize City). This enables the reconstruction of a geographically rooted medical topography that can also speak to wider experiences of 19th century British populations in the tropical region. Some parts of the documentary record are less spatially nuanced with different aspects providing regional or local information, but are not able to look across both. Travelogues and other documentary sources enable the reconstruction of forestry practices used across the region, and although these are probably consistent with those used at Lamanai, there is no specifically local insight. Similarly, the records of logwood and mahogany exports reflect national trends that can point to possible local trends in natural resource extraction and associated land clearance. The meteorological record is perhaps the least flexible in terms of spatial scale. Temperature and precipitation observations made at a fixed point (Belize City) whilst extremely valuable locally, can only be used as a general guide to regional or national changes. This is perhaps evident in discussions of precipitation and mahogany export trends explored in Chapter 6, if local meteorological data were available from the northern region might be possible to identify a link between precipitation regimes and variable rates of mahogany production.

i) Temporal resolutions and scales

Multiple temporal resolutions and scales feature in the proxies used in this thesis and these are summarised in Fig.8.1. The palaeoecological record provides the most extensive history of change, extending beyond even the archaeological record at Lamanai. The importance of a long-term record of environmental change is noted by Cronon (1983): who argues that 'the great strength of ecological analysis in writing history is its ability to uncover processes and long-term changes which might otherwise remain invisible' (p. xv). Miller (2007) emphasises the need for records which extend beyond the life time of an individual:

> 'One of the tasks of history is to expand human memory beyond a single generation…The work of environmental history is to recover, in a sense, what has been lost, and to make it clear to our historical consciousness. Only by putting nature in our official past can we potentially grasp its substantially altered place in our present and future.' (p.5)

The temporal resolution of the palaeoecological record (and indeed the archaeological record) is limited by the radiocarbon chronology available. The challenges of constructing a reliable and sensitive chronology have been discussed in section 4.1: however, in a general sense it is evident that the palaeoecological record presented in this environmental history is the proxy that is the least temporally constrained and with the lowest resolution. The chronology for the Lamanai II (2010) core is particularly imprecise, but it is possible to place events in a temporal sequence with some confidence. This partial clarity is further enhanced by integrating the documentary record of British colonial extraction of logwood and mahogany for export, as has been demonstrated in Chapter 6. The high resolution (annual) records of timber exports and more general accounts of production enable the identification of distinct periods of extraction from different ecosystems. The integration of these two records, with two very different temporal scales and resolutions, creates a new account of natural resource extraction. Furthermore, when this period of activity is placed in the context of a much longer-term record of vegetation change, it is possible to infer both the scale of such colonial activity and the probable resilience of the forest and pine savanna ecosystems. Although the export records reveal that logwood and mahogany were removed from Belize in substantial quantities (and that there were timber works on the banks of the New River Lagoon) the palaeoecological record from Lamanai suggests that post AD 1950 there is a substantial increase in forest and pine savanna values. Significantly, the modern endangered status of mahogany suggests that this increase in forest cover does not indicate re-growth of mahogany, but rather of secondary SDTF. Belize remains a densely forested nation, but the nature and composition of the forests have changed.

Chapters 5 and 7 contain short-term high resolution records. In particular, the 145 year meteorological record comprises monthly and predominantly daily precipitation and temperature data. These records have the added advantage

that they are reliably dated as each observation was made and recorded in chronological order. These high resolution records are limited in scale, as meteorological observations were only made in Belize since 1865 and of these records only a percentage have survived the passage of time. Similarly, the cultural climate history presented in Chapter 7 has the same temporal advantages and challenges. Letters, annual reports and newspaper articles are often reliably and consistently dated however they are only available for a comparatively short period of time and only when they have been preserved in the archival record. The importance of combining multiple types of record with differing temporal scales and resolutions is clear. Long-term, low resolution proxies underpin records of change that have periods within them of much higher spatial and temporal resolution. Both are necessary for a as complete an understanding as a partial reconstruction can ever be. It is not possible to assess the extent of the short-term high resolution record without the longer term low resolution context: similarly, general inferences cannot be made as to the nature and causes of change without the integration of precisely data high volume short term records.

If this integration of multiple lines of inquiry is achieved, this provides an opportunity to create an interdisciplinary account of the environmental history of northern Belize and the importance of this type of research is now considered.

8.3.2 'Interdisciplinary' vs. 'multidisciplinary' approaches

The growing prominence and importance of research projects that seek to address human society/environment questions has increased the opportunities for academics working in different disciplines to collaborate (Aimers and Hodell, 2011). This can be positive, and many have highlighted the importance of such projects if answers to key questions about human societal interaction with climate are sought (deMenocal, 2001; Constanza et al. 2007; Metcalfe et al., 2009). Caseldine and Turney (2010) have highlighted the importance of integrating environmental data with histories of societal change, particularly when researchers seek to provide 'valuable analogues of what may happen in the future' (p.88). Dunning et al. (2012) have suggested that 'the conjunctive use of palaeoecological and archaeological data to document past human-environment relationships has become a theoretical imperative in the study of ancient cultures' (p.267). Terms such as 'interdisciplinary', 'multidisciplinary' and 'multi-proxy' have become frequent adjectives in research approaches and methodologies (Leyden et al., 1993; Curtis et al., 1998; deMenocal, 2001; Beach et al., 2008; Kennett et al., 2012). The popularity of these terms notwithstanding, distinctions between them have become blurred and confused, blunting their analytical precision. Interdisciplinary research seeks to bring together two or more academic disciplines into a single research project and creates something new by crossing academic boundaries. In contrast, multidisciplinary projects can simply be making use of several different academic disciplines to inform a

particular research project. Opportunities for synthesis in some multidisciplinary projects can only extend to correlation or calibration of different proxies, whereas in an interdisciplinary project the integration of contrasting materials and methods can lead to a new framework of understanding.

Environmental history is an exemplar of interdisciplinary research and, as both a theoretical framework and research methodology, offers distinct opportunities. Two opportunities that are particularly pertinent to this research have been identified: 1) the observation of change in different proxies that, when brought together can imply causes of change and 2) the incorporation of data with multiple temporal and spatial resolutions and scales. When these two aspects are brought together, this enhances the robust nature of the reconstruction.

i) Terminology and issues of interpretation

Clarity of terminology is an essential part of communicating research effectively and this is increasingly important when speaking across multiple academic fields as a part of multidisciplinary research. Part of the problem can be the elision of stages when making an academic argument. This is best explored using an example from Chapter 4. In discussions of the palaeoecological record from a relatively recent temporal period, it is clear that anthropogenic activity or absence is responsible for much, if not all, of the change observed in the landscape of northern Belize. However, it is important to observe and identify the nature of the change itself before applying interpretation, e.g. vegetation re-growth is what is observed, whereas the recovery of forest cover in the absence of human activity is the interpretation. It is only when these two separate phases of an academic argument are delineated can those working in other related disciplines best infer their own conclusions. Such enforced clarity may avoid misunderstandings and misinterpretations that have featured in some ethnobiological explorations of palaeoecological records from the wider Maya region.

Research which uses human derived proxies to reconstruct human-environment interactions over time should recognise and understand the importance of different cultural contexts which surround such materials. As has been discussed in Chapter 3, ‘observer bias’ can significantly shape the reliability of information concerning climate and environment, particularly when the observer has recently arrived to an unfamiliar region. In the main, missionary and traveller accounts from 19th century Belize were shaped by prevailing Western attitudes surrounding healthiness of place and climate of tropical regions. As these cultural understandings shifted (in diffuse rather than linear transformation) across the 19th and early 20th centuries, so did the way in which health and climate was perceived. An appreciation of the perceptions of climate and environment and the impact of environmental events is best understood when documentary records are examined for both

the information which they may contain and the cultural context in which it was constructed. This is especially pertinent when using sources emanating from different regions during different time periods.

8.4 Further work and future challenges

Thus far, this chapter has explored the opportunities and challenges encountered when writing this thesis and in the wider field of environmental history. Information elucidated from three distinct academic disciplines has been brought together to create a new account of the environmental history of Belize. This has been a palimpsest approach, layering histories of different temporal and spatial resolutions and scales to reconstruct a history that encompasses a long-term record of vegetation change, a 145 year meteorological record, documentary reconstructions of hurricane events and incidents of epidemic disease and, finally, an account of the thoughts and perceptions surrounding climate, health and place from the 19th century British population in Belize. In keeping with the methodological framework of environmental history, the scope of this thesis has been broad and at times in the research process it has been extremely challenging to produce detailed precise accounts across such a varied academic portfolio; however, I would argue that this provides the most complete account of the nature and causes of landscape change in northern Belize over the past 3,500 years.

Further work could be undertaken to further improve the spatial scale and resolution of the palaeoecological record. Additional pollen records from water bodies of different sizes, at locations both some distance and adjacent to Maya sites in northern would enable greater analysis of both the spatial scale of landscape change and the ability of pollen records to detect this. The incorporation of vegetation surveys to better understand pollen records has become more regular practise in European contexts (Bunting et al., 2013) and such techniques may prove a useful addition in the neo-tropical context. A more constrained chronological framework for the Lamanai II (2010) core, in particular, would allow further analysis of the palaeoecological record from the Spanish period, and enable more distinct comparisons between the two periods of European colonial interaction at Lamanai. The Spanish colonial period at Lamanai in particular and across northern Belize and the impact upon the environment would be better understood if sources identified in the Spanish and British colonial records were available for this earlier period. The British colonial period has been the focus of post-Columbian land use in this thesis, although further work could identify and utilise additional documentary sources from Spanish Colonial archives to explore the relative impacts of this earlier period. Chapters 1 and 2 have demonstrated that, although environmental historians are perhaps best placed to consider questions regularly posed about human interactions with the environment past, present and future, these types of integrated studies are not commonly undertaken. Notable examples include the work of Butzer and Helgren (2005) in Australia, Butzer (2005) in the Mediterranean and Lawson (1974) in the United States,

although the later was not classified as a work of Environmental History at the time. The key challenges of chronology and terminology have been discussed, but a further challenge is the complexity and volume of research materials that need to be devoted in this type of study. Obtaining both chronologically coherent and suitable sedimentary records in difficult coring locations is a challenging undertaking. When combined with the desire to identify and analyse a spatially relevant documentary record, such opportunities are further reduced.

8.5 Summary

In this environmental history, an account of the relationship between humans and the environment (in particular the tropical forests) of northern Belize have been re-examined. Using palaeoecological records and archival sources, this environmental history rejects the binary opposition of the benign, passive Maya landcape and the violent, devastated European colonial landscape (Denevan, 1992). Furthermore, the polarised imaginings of the Maya as both destroyers and protectors of the tropical forests have been challenged. The opportunities and challenges presented by environmental history are complex and context specific. As with all research that has an historical dimension, accurate and precise chronological frameworks are essential. The somewhat limited application of the research approach undertaken in this thesis is perhaps due to the infrequent occurrence of all the necessary research components at the same time. However, this thesis demonstrates that when this research approach is possible, it should be embarked upon as an optimal way of reconstructing the most complete understanding of the relationship between humans and nature over time.

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Appendix I: Detailed laboratory preparation protocol for pollen preparation - items in yellow form part of the revised protocol established by Whitney et al. (2012)

Stage No.	**Detailed preparation protocol**
1.0	**Set up**
1.1	Unless new, soak the centrifuge tubes overnight in a strong bleach solution and rinse with distilled water.
1.2	Locate all chemicals and equipment that you require. If solutions stocks are low, inform a technician.
1.3	Ensure there are no sources of pollen contamination in the lab (e.g. open windows/doors, flowering plants).
1.4	Ensure all lab surfaces are clean.
1.5	Set up the fume cupboard with the hot water bath, centrifuge, whirly mixer, and waste bottle, leaving a clear working place for your test tube rack and solution bottle.
1.6	Tert-butyl-alcohol (TBA) is solid at room temperature. Nearer the final stages of preparation, loosen bottle cap, and place it in some warm water to heat.
1.7	Unless otherwise stated a lab coat, goggles, green gloves must be worn.
2.0	**Removal of Carbonates**
2.1	Place 1ml of sample into a centrifuge tube, using a cut-off syringe, add 5-8ml of distilled water.
2.2	Centrifuge sample at **3000 rpm for two minutes** and decant. Use this procedure for all centrifuge stages unless otherwise stated.
2.3	Test the sample for carbonate content by adding a few drops of HCl. If carbonates are present, add 10ml of cold 10% HCl, and stir it occasionally until fizzing stops.
2.4	Place tubes into hot water bath (ca. 60˚C for 4 mins).
2.5	Add a few additional drops of 10% HCl to test if there are any remaining carbonates. If clear, centrifuge and decant and repeat. Do not proceed with the next stage until all the carbonates are digested. Once carbonates are digested centrifuge, decant, and break up the pellet using a whirly mixer. Add 10ml of distilled water, rinsing around the sides of the centrifuge tube. Mix with a wooden stir rod, centrifuge and decant. **Use this method for all succeeding rinse stages.**
3.0	**Removal of abundant clays**
3.1	Add 10ml calgon (sodium pyrophosphate – to make one litre up use – 7g sodium carbonate anhydrous and 35g sodium hexametaphosphate).
3.2	Heat the centrifuge tubes in a water bath (60˚C) for 6 mins. Centrifuge, decant, whirly mix and top-up with distilled water.
3.3	Repeat the washing and centrifuging until the supernatant is clear. In very clayey samples, this may require 10-15 washes.
4.0	**Acetolysis Stage** During this stage this procedure must be performed in a fume cupboard. Marigold industrial heavy black gloves must be worn over green gloves. A full visor, PVC chemical apron and oversleeves must also be worn.
4.1	Wash the sample with 10ml glacial acetic acid, centrifuge and decant.
4.2	Prepare acetolysis solution: 1 part concentrated sulphuric acid, added 1ml at a time to 9 parts acetic anhydride). Wait for each 1ml to react before adding anymore. When stirring at this stage use glass rods, NOT wood.
4.3	Pour 8ml of the acetolysis solution into each of the centrifuge tubes and stir with a glass rod. Heat in 90°C water bath for a maximum of 3 mins and stir occasionally. Centrifuge and decant into a waste bottle/glass
4.4	beaker. NEVER decant into water.

	Wash with 10ml distilled water. Centrifuge and decant waste in to glass beaker. Do three complete rinses with water. If material is clumpy with sediment falling out, continue with as many rinses as needed as this is due to the chemical residue and not the sample. When the water is cloudy/brownish maybe that clays are in solution which is optimal. When the glass beaker containing waste is finished with, pour down the sink with the tap running continuously.
5.0	**Sieving stage**
5.1	Begin by suspending the pellet in 10ml of 10% NaOH (or KOH), and heat in boiling water bath for 6mins, stirring frequently to disaggregate the sample. You want a loose pellet – must be absolutely sure that material is suspended (except the organic bits). Unless you are sure, don't sieve –
5.2	maximum in hot bath is 8mins. Transfer pollen from tube to beaker using 30ml of distilled water making sure the sieve and glassware are cleaned after each stage – use brush
5.3	and detergent and final rinse of distilled water at the end of each sample. Pass the sample through a 53 micron brass sieve with a few short blasts of distilled water from a squeezy bottle, trying to keep the total volume of filtrate to <100ml. Save both the filtrate (for the main pollen count) and the
5.4	residue (to scan for large cultigen pollen). The residue should wash off the sieve and into a 15ml centrifuge tube. Concentrate the filtrate by centrifuging in 15ml tubes, decanting and topping up with additional filtrate until the entire fine fraction is contain in
5.5	the pellet. Centrifuge all the 15ml tubes (now double the amount) and decant. N.B. at this point the fine fraction goes back in the original tube, and the coarse fraction goes into a separate tube. At this stage, the analyst can check whether the sieving has been successful. Choose any tube containing the coarse fraction (>53µm) of a sample and whirly-mix the pellet. Using a clean pipette, transfer a small aliquot of the sample onto a slide and scan at 100x magnification. Check to see if the sample contains 'clumped' organic material which will bind small pollen and prevent it from being passed through the sieve. If this is the case, the coarse fraction should be re-suspended in 10% KOH (or NaOH) and re-sieved. The resulting filtrate is then concentrated as above and combined with the fine fraction from the first sieving attempt.
6.0	**Addition of lycopodium tablets**
6.1	Add 2 or 3 lycopodium tablets (usually 2 per fine fraction and 3 per coarse fraction) and note batch number. Add 1ml 95% ethanol and 6ml of 10% HCl. Stir vigorously until the reaction has ceased. Top up with distilled
6.2	water to 12ml aprox. Centrifuge and decant. Wash with distilled water, centrifuge and decant.
7.0	**Dehydration using TBA** This stage must be undertaken in a fume cupboard.
7.1	The mounting medium (silicone oil) is immiscible with water therefore, it is necessary to dehydrate the samples using TBA before adding the oil. TBA has a freezing point of 25°C – in order to have it in liquid form place the bottle of TBA into a beaker filled with warm tap water, until it melts.
7.2	Wash the samples with 8ml of TBA. Centrifuge and decant. REPEAT this stage. (N.B. Coarse fractions may need a third rinse as pellet is small and large amount of water to remove).
7.3	Transfer sample to labelled vial and insert lid. Centrifuge at 3000rpm for 2mins and decant. If there is sample left back in the centrifuge tube, add this to the vial (after it has been decanted), centrifuge and decant – again for 2mins at 3000rpm.
8.0	**Addition of the mounting medium**
8.1	Add silicone oil (12,500 cSt), approx 2x volume of sample. Stir well with a
8.2	wooden rod. Place open vials (with wooden rods) in the dry block at 60°C for at least 48hrs to evaporate the TBA (stir the samples at least once a day). The samples are ready for mounting when they no longer smell of TBA.

9.0	Slide preparation
9.1 9.2 9.3 9.4 9.5	Stir sample in vial with wooden rod until it is thoroughly mixed in silicone oil. Spread a drop of sample evenly over the slide using the wooden rod. Wait 2-3 mins until the air bubbles have disappeared. Place a cover slip over the slide and wait until the sample has spread over most of the cover slip area. Place the slide on a hot plate and add paraffin wax to the perimeter of the slide to seal the sample. The temperature should be around 60°C – just high enough to melt the wax.