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PATTERNS OF PALEOMOBILITY IN THE ANCIENT ANTILLES

AN ISOTOPIC APPROACH

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For Sam

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CHAPTER 1 INTRODUCTION

1.1 Introduction

Migration and mobility are core concepts in the social sciences and are important foci for attempts to understand multiple aspects of past human behavior from an archaeological perspective. Owing in part to its island setting and to decades of research on the topic of migration by the eminent Caribbean archaeologist Irving Rouse (Rouse 1952, 1964, 1986, 1989a, b, 1992), an interest in migrations and colonizations has characterized Caribbean archaeology since its beginnings. The Caribbean region has also been a fertile ground for the development of many migration methods and theories (Curet 2005; Keegan 1985; Keegan and Diamond 1987; Rouse 1986; Siegel 1991). Migrations and migration-related processes have also been invoked as explanations for various patterns of cultural change and variation in the pre-Columbian Caribbean (Berman and Gnivecki 1993, 1995; Booden et al. 2008; Coppa et al. 2008; Curet and Hauser 2011a; Fitzpatrick and Ross 2010; Hofman et al. 2007a; Hoogland and Hofman 1993a, 1999a; Keegan and Diamond 1987a; Keegan 1995; Rodríguez Ramos 2007; Rouse 1986, 1989b, 1992a; Siegel 1991). More recently the topic of migration has itself become a subject of investigation within this context [for extensive reviews of the topic of migration in the Caribbean, see (Curet 2005, 2011)]. However, in general, the vast majority of archaeological approaches to migration and mobility, in the Caribbean and beyond, can be characterized as macro-scalar. In this context, macro-scalar is polythemic referring both to the long-term, cumulative effects of migration(s) and also to the behavior of larger scale units, such as cultures or 'peoples'. From an archaeological perspective these are most evident through observations of spatial-temporal patterning in the material record.

Less common are micro-scalar approaches to understanding human migrations and mobility, examples of these approaches would include biogeochemical methods such as trace element and especially isotopic analyses. These approaches differ from macro-scalar ones in part due to their focus on processes occurring at much smaller temporal scales and by smaller scale social groups such as households, families, or individuals. The analysis and associated identification of a particular behavioral process, in this case migration, can be conducted at the scale of individual persons and this process can be repeated for multiple individuals and groups permitting a bottom-up approach (Hakenbeck 2008) to elucidating patterns of human mobility and migration. From this perspective, micro- and macro-scalar approaches can be seen as complementary approaches applied to similar phenomena.

The study presented herein is the outcome of one component of a large scale, international and inter-disciplinary research project focusing on mobility and exchange in the ancient circum-Caribbean. This research programme, 'Communicating Communities in the Circum-Caribbean' is funded by the NWO (The Netherlands Organization for Scientific Research) and directed by Prof. Corinne Hofman of the Faculty of Archaeology, Leiden University, The Netherlands. In the present study, I apply multiple isotope analyses to human skeletal materials from across the Caribbean islandscape to investigate patterns of migration and mobility from a micro-scalar perspective. The analyzed skeletal populations derive from a broad range of cultural, chronological, and geographic contexts within the Caribbean region. The primary analytical tool employed is strontium isotope analysis, complemented by carbon and oxygen isotope analyses. Additionally, a large component of the current project involved the mapping of biosphere strontium isotope variation in order to interpret the strontium isotope data obtained from the human sample populations. The resulting datasets concerning human migrations and origins are then applied to assess existing various hypotheses concerning past human migrations and mobility in the region and to develop new hypotheses in this regard. Particular emphasis is placed on elucidating: the size and composition of nonlocal or migrant groups, the possible types of migration that occurred in the past, and the consequences and implications of these migration patterns on the social relationships and interactions amongst and between ancient societies and communities of the Caribbean region.

1.2 Research Problem Statement

The identification of migration, versus other related but distinct processes, based on the examination of material culture patterning alone is problematic for several reasons. Traditional archaeological approaches to migration often rely solely on the appearance and supposed movement of material culture as a proxy for the actual movement of people. Problems arise in distinguishing migration from other related processes which may result in similar patterns in the distribution of cultural material remains, such as diffusion (the movement of ideas), trade and exchange (the movement of objects and materials), independent evolution and invention (the autochthonous development of similar ideas or cultural 'traits'), or emulation (the copying of behaviors). Furthermore, the processes of transculturation, acculturation, and assimilation often occur within multiple forms of symmetric and asymmetric relationships between migrant and local groups, in which the behaviors of one or both are modified rapidly enough that the presence of distinct groups is masked or made archaeologically invisible (Carr 1995; Clark 2001) [but see (Cusick 1998; Spielman 1991) for discussions of the variety of culture contact situations and their consequences].

Owing in part to the preceding difficulties in distinguishing these similar but distinct phenomena, archaeologists have attempted to develop rigorous methods to identify prehistoric and historic migrations [e.g., (Rouse 1958, 1986)]. While initial colonization and ultimate abandonment may be relatively easier to identify archaeologically, other types and forms of migration require quite stringent criteria to distinguish migration from the other aforementioned processes, making the confident identification of past migration(s) quite difficult and relatively rare [see (Haury 1958) for an exception]. However, there has been a widespread tendency to assume that migration did not take place in most cases where the evidence was not definitive (Rouse 1958, 1986) rather than the more accurate conclusion that we just do not know (Snow 1995). This tendency may have resulted in a gross underestimation of the existence, frequency, roles, consequences, and importance of migrations in prehistory. Migration was likely much more common than most previously employed criteria account for and much migration may elicit little or no (archaeologically observable) cultural change. However, this does not mean that migration is irrelevant because the comprehension of migration is still important if not essential for understanding many aspects of social behavior and other related processes (Anthony 1990, 1997; Burmeister 2000; Cameron 1995; Clark 2001; Curet 2005; Duff 1998). For example, a basic component of demography consists of calculating changes in population size over time. Population change equals population size, plus births, minus deaths, plus or minus migration (Anthony 1990). To ignore migration is to ignore an essential component of basic demography and requires one to either pretend that demography can be done with mortality and fertility rates alone, or to discount the role of demography for understanding long-term social processes (Lee 1966). Therefore, considerations of migration processes are vital to paleodemographic methods and theory (Curet 2005).

The recent renewal of interest in migration studies is characterized by the utilization of anthropological insights to shed light on ancient and modern migrations and migration-related processes and behaviors. These include approaches focusing on the observation and analysis of certain aspects of settlement (Cameron 1995; Duff 1998) and material culture patterns (Carr 1995; Clark 2001), mortuary and osteological patterns (Konigsberg 1988), and various combinations thereof (Burmeister 2000; Curet 2005). Advances in biogeochemical analyses in the last few decades, particularly isotope provenance studies, have prompted a flurry of research into ancient migrations based on a set of material evidence previously neglected or underutilized in archaeological studies of migration, namely skeletal remains. Despite the overall successes of such approaches to a broad array of research questions from different geographic and cultural settings throughout the world, isotope studies of human provenance have been under-utilized to date in the Caribbean.

Approaches to migration studies utilizing bioarchaeological and biochemical perspectives overcome some limitations of previous approaches by not relying on the movement and distribution of material culture as a proxy for the movement or migration of people. In fact, human remains can be perceived as a subset of material remains possessing data uniquely suited to investigating certain aspects of social behavior (Sofaer 2006). By shifting the focus from macro- to micro-level scales, one can identify and study actual migrants and not the long-term, cumulative effects of multiple behavioral processes, of which only some may be migration. Furthermore, such a perspective helps to overcome the traditional normative bias of earlier studies by providing more nuanced and finer-scaled explorations of intra-societal differences in human behavior. In other words, such approaches can then be utilized to make inferences at more appropriate scales of analysis through observation and analysis of the appropriate corresponding units. After all, it is people, as individuals, households, families, lineages, and other small groups that migrate, not cultures or material culture repertoires [paraphrasing (Anthony 1990)].

For too long, archaeological discourses on human movement, migration, and mobility have been dominated by macro-scalar perspectives. This has been especially true for the Caribbean region, where until quite recently most research on this topic has concentrated on colonizations and the migrations of large scale units, such as cultures or even supra-cultural units such as ceramic series, and movements occurring over very long periods of time (Berman and Gnivecki 1995; Carlson 1999; Hofman et al. 2007a; Keegan 1995; Rouse 1986, 1992; Siegel 1991; Sullivan 1981). Only in recent years has there been an explicit focus on the movements of individuals or smaller scale groups (Curet 2005; Hofman and Hoogland 2011; Keegan 2009; Siegel 2010). This emphasis on smaller scale processes and units not only provides a much needed counter-balance to existing approaches but is warranted in its own right if the archaeological community is truly interested in examining the migration patterns of individuals. I do not propose that micro-scalar approaches in general, or isotope studies more specifically, should replace more traditional, macro-scalar, material-based approaches, only that they are highly complementary and can potentially provide new insights and perspectives on a wide range of questions concerning human migration(s).

1.3 Research Project Description

The approach advocated herein is derived from the perspective that: 1) migration may or may not be absent or present, rare or common, ubiquitous or universal; 2) that migration is amenable to archaeological investigation (utilizing theories, methods, tools, and classes of material that are appropriate to the questions that we seek to answer); and 3) that we should not assume *a priori* the existence, nature, rates, or patterns of migration but seek to examine them individually and empirically. An essential first step involves the articulation of bioarchaeological and anthropological theories of migration with refined methods and techniques for the identification and investigation of past migrations.

Accurate and reliable identification of migrants and migration in the archaeological record is a necessary pre-requisite for interpreting the full-range of past human behaviors as migration is inextricably intertwined with, influences, and is influenced by a great variety of socio-cultural processes. The development and advancement of isotope analyses of human remains have permitted the reliable identification and assessment of past migration patterns at the scale of individuals. When conducted within a multi-disciplinary and multi-scalar research program, in conjunction with requisite contextual data, and utilizing more nuanced and updated theories of migration these methods can permit reappraisals of the roles of mobility and migration(s) in Caribbean prehistory. The aim of this research project is to apply these approaches to ancient populations from the Caribbean to address or readdress hypotheses concerning the extent, nature, and dynamics of ancient migrations and related processes in the socio-cultural developments of this region.

The Caribbean region possesses several geographic and geological parameters that make it ideally suited to this type of approach: 1) the nature of islands necessitates the existence of some form of maritime transport and associated technology and knowledge of seafaring for inter-insular migrations to have taken place; 2) the Antilles in particular possess a particularly complex and varied geological history, providing the requisite degree of isotopic variation that is essential for strontium isotope studies of migration; 3) archaeological evidence indicates that people have been migrating to, within, and around the Caribbean for thousands of years; 4) ethnohistoric documentation indicates that migration and mobility were occurring at the time of European contact; 5) the presence of multi-island archaeological cultures or cultural realms and the widespread occurrence of imported or exotic trade goods suggest that both the means and motivations of inter-island movements were in existence throughout much of the region's prehistory.

Isotope analysis involves the characterization of isotopic compositions (signals or signatures) for a particular material. This type of analysis can be conducted on human remains to identify migrants and investigate migration. This approach is based on the following premises [for more thorough discussions see (Bentley 2006; Montgomery 2010; Price et al. 2002)]; that strontium exists naturally in several forms or isotopes, the ratios of which vary spatially in relation to the biogeochemical environment (primarily in relation to the age and lithology of the associated bedrock geology). Due to chemical similarities with calcium, strontium is often taken up by and incorporated into the skeletal tissues of animals (including humans) and is particularly concentrated in calcium-rich bioapatite. Strontium passes through the food chain without undergoing substantial isotopic fractionation and is incorporated into human skeletal tissues. Because dental enamel does not undergo significant remodeling once mineralization is complete, this particular tissue type preserves the biogenic strontium signal of the biogeochemical environment in which it developed. In other words, when an individual migrates they possess an identifiable indicator of their place of origin via the strontium isotope ratio of their dental enamel. If this signal is distinct enough from that of the region where the individual died and was buried, then it is possible to identify that individual as a nonlocal (and possibly as a migrant). For this reason, strontium (as well as a number of other isotope systems) isotope analysis represents a powerful tool for examining migrations and mobility from the archaeological record. Due in part to their density and structure, teeth are also highly resistant to diagenesis or postmortem contamination (Budd et al. 2000), and owing to their overall durability they are the most likely skeletal element to be preserved in archaeological deposits (Robinson et al. 1986).

It is important to stress that a wide range of archaeological, bioarchaeological, and biogeochemical data is necessary to address specific research questions and to test particular hypotheses for any given site assemblage or population with this approach. Furthermore, some of the most intriguing patterns produced by previous applications of this approach are that: 1) substantial proportions of certain archaeological burial populations are comprised of migrants or nonlocals (Price et al. 2001, 2008); and 2) individuals identified as migrants based on isotopic analysis often presented little or no indication that they were migrants based on the analysis of associated material remains

(Bentley et al. 2002; Bentley et al. 2003). These results indicate that further applications of these approaches to other cultural contexts and regions is justified and that these approaches need not be limited only to situations in which the associated material culture assemblages suggest the presence of migrants/migration.

The goals of the proposed research project are multi-faceted and include the following objectives:

1) To determine if nonlocals are present amongst several ancient Caribbean skeletal populations.

2) To assess the number and proportion of nonlocal migrants in these populations and assess the demographic composition of migrant groups relative to local groups.

3) To compare migrants verse locals in reference to mortuary, osteological (demographic), and paleodietary data.

4) To analyze spatial variations in migration patterns within and between different sites, settlements, islands, and areas within the circum-Caribbean region.

5) To analyze temporal variations in migration patterns within these ancient populations.

6) To contribute to the development of databases of isotope variation within the Caribbean region.

1.4 Organization of the Dissertation

In the following chapter, I provide an overview of archaeological approaches to migrations studies (Chapter 2). I begin with a brief history of the role of migration within the discipline of archaeology itself, including some of the general trends throughout the history of the discipline and some current themes and directions of migrations studies. Subsequently, I assess Irving Rouse’s seminal contributions to migration theories and methods, followed by a critical assessment of his approach to the identification and analysis of migrations in prehistory. This is followed by a detailed discussion of specific insights into various aspects and concepts of migrations and migration processes derived from a broad array of related disciplines including especially anthropological perspectives on human migrations. This chapter concludes with an overview of the role of migration in the archaeology of the Caribbean and an introduction to different approaches to the archaeological study of migrations in the region.

In Chapter 3, I present the basic principles of isotope archaeology with a specific focus on strontium isotopes in various environmental systems and research disciplines. A brief history of the use of strontium isotopes in archaeology is followed by a detailed discussion of the basic premises, assumptions, and limitations of strontium isotope approaches to human provenance and migration studies. I then present a general review of specific archaeological applications of strontium isotope analyses in different geographic and cultural contexts, and briefly note some related applications of this method in other fields. Lastly, I detail the basic principles of other isotope systems to provide a background for some of the stable isotope data that are incorporated into this study.

Chapter 4 presents the specific details of the methodology and techniques employed in this research project. The sample collection strategy and design are outlined for different sample types including human dental samples as well as animal and plant samples. The specific details of sample processing are then provided for the different types of sample materials (e.g., dental enamel, shell, plant tissues). The laboratory methods and protocols for sample dissolution and the separation and purification of strontium from sample matrixes are then provided. I then describe the mass spectrometric analysis and details of instrumentation for the measurement of strontium isotope composition via thermal ionization mass spectrometry (TIMS), including notes on error, precision, and reproducibility of results. Lastly, the principles of oxygen and carbon isotope analyses of enamel carbonate from human teeth are outlined, including descriptions of sample processing and measurement via isotope ratio mass spectrometry (IRMS).

The focus of Chapter 5 is the archaeological contexts of the analyzed skeletal materials. This chapter begins with a presentation of the geographic and chronological settings of the study area and some notes on terminology. This is followed by a brief description of the individual site settings and archaeological contexts of the skeletal populations from which the human skeletal materials were obtained. This section also includes any available information derived from analyses of the studied burial populations

Chapter 6 is a presentation of the results of this study divided into several parts. First, I present the strontium isotope results from the bioavailable samples as a whole, and then relative to associated geology, and per island/region. Next, I present the strontium isotope results from all of the human samples as a whole, and then for each of the different sample populations in this study. Lastly, I present the oxygen and carbon isotope results that were obtained from a subset of the total human sample population.

Chapter 7 is a discussion of the results. I begin with a discussion of the biosphere mapping component of this project and the implications of these results for strontium isotope provenance studies in the region. This is followed by a detailed discussion and interpretation of the human strontium isotope results, beginning with a discussion of the approach taken to the identification of nonlocals for each sample population. Next, I identify and assess the numbers, proportions, and possible origins of the individuals identified as nonlocals for each of the sites in this study. Next, I discuss general patterns of mobility at the scale of individual populations and for the entire dataset in reference to associations between residential origins various other relevant parameters, including age at death; biological sex; chronological age, grave goods; and dietary practices. Then, I discuss the carbon and oxygen isotope results in terms of assessing variations in dietary patterns at various scales and exploring the potential origins of specific nonlocal individuals. Lastly, I conclude this chapter with some final thoughts concerning the results discussed throughout this chapter.

In the final chapter (Chapter 8) I summarize the main findings of this study. I present the major conclusions in reference to advances in our understanding of spatial variation of bioavailable strontium isotopes in the Caribbean. I then summarize the main conclusions of the human provenance study, including some insights and proposals concerning specific aspects of patterns of human migration in the ancient Antilles. I provide some interpretive considerations, particularly in reference to the possible size and composition of migrating groups, and by inference, to the types of human migration and mobility that best match the patterns identified in this study. I then provide a few final thoughts on some of the most important archaeological implications of the present study, concerning various ongoing debates and dialogues in Caribbean archaeology with reference to specific hypotheses and models of migration, mobility, and interaction. Lastly, I present an assessment of the methodological approach taken in this research project and conclude with some general proposals for future research directions that could hopefully build upon, improve, and advance the work presented herein.

CHAPTER 2 MIGRATION STUDIES IN ARCHAEOLOGY

2.1 Introduction

In this chapter I provide a brief review of the history of migration studies in archaeology. This is followed by a summary of current trends in migration theories in archaeological studies and the general shift in focus from cultural to social archaeologies. I then discuss key insights and concepts drawn from anthropological perspectives on migration including the main aspects and issues pertaining to migration processes. This chapter concludes with a review of migration studies in Caribbean archaeology, past and present.

2.2 Archaeological Approaches to Migration

“One of the challenges facing archaeology today is to come to terms with the past movements of people and develop methodologies by which such movements can be identified, studied and understood” (Lightfoot 2008:1). Migration has a long and complex intellectual history within the discipline of archaeology and has played a key role in the development of cultural histories for many regions of the world (Adams et al. 1978; Anthony 1990; Hakenbeck 2008a) [for more extensive recent discussions of the history of approaches to migration studies see also (Anthony 1992, 1997; Brettell and Hollifield 2000; Burmeister 2000; Cameron 1995; Chapman and Dolukhanov 1992; Chapman and Hamerow 1997; Clark 2001; Curet 2005, 2011; Duff 1998; Greenwood et al. 1991; Härke et al. 1998; Härke 2004; Lucassen and Lucassen 2011; Manning 2005),]. In fact, during the first half of the nineteenth century when a normative and culture-historical approach dominated archaeological thought, there were very few attempts to address migration theory in any explicit or systematic way. As Hackenbeck has noted recently “The cultural-historical paradigm has been one of the most powerful and enduring frameworks of thought in archaeology worldwide, and it has so profoundly shaped our notions of migrations in the past that in may regions of the world it continues to dominate the archaeological discourse" (2008:13). During this era, migration was generally invoked, somewhat uncritically, as an explanatory mechanism for a wide range of cultural change. Meanwhile, theoretical and methodological approaches for identifying migration in the archaeological record were developed and proposed as early as the 1950's (Childe 1950; Haury 1958; Rouse 1958; Willey et al. 1956). These were, however, generally disregarded when processual or 'New Archaeology' was the dominant paradigm in American archaeology beginning in the 1960's (Adams et al. 1978; Anthony 1990). Although in other regions where prehistory was less directly and explicitly linked to a systems-oriented, empiricist approach, migration as an explanation did not diminish as much in importance during this time (Burmeister 2000; Chapman and Hamerow 1997; Härke et al. 1998; Härke 2004).

As noted, the "Retreat from Migrationism" (Adams et al. 1978) that occurred during the height of the processual era witnessed a general dismissal of the possible explanatory role of migration in archaeological research. This work (Adams et al. 1978) represents a (largely ignored) plea to the broader archaeological community concerning the importance of migration(s) in past and present human societies. Nevertheless, migration continued to be a topic of particular interest in the fields of demography, history, geography, sociology, and anthropology throughout the middle of the nineteenth century (Brown and Neuberger 1977; Clark 1986; Lee 1966; Lewis 1982; Sjaastad 1962; White and Woods 1980; Zelinsky 1971). Nevertheless, one of the only other major works on the topic of archaeological migration to come out of this era was Rouse's (1986) seminal contribution to the study of prehistoric migrations, which was partly based on decades of research on human migrations in the Caribbean. This contribution should be commended not only for continuing to highlight migration as an important and interesting topic of study but also because of the explicit effort to develop systematic and scientific theories and methods for the detection of migrations from the archaeological record. Nonetheless, there are some serious conceptual, theoretical, and epistemological problems with Rouse's perspectives that severely limit there utility for studying human migrations.

Interestingly, the year before the publication of Irving Rouse's (1986) treatise on migrations in prehistory, Jonathon Ericson (1985) had proposed a very different method and approach for identifying prehistoric human migrations. Ericson's approach drew on advances in isotope ecology and isotope geochemistry, and specifically proposed a number of significant archaeological research topics that could be addressed through the analysis of the strontium isotope composition of human skeletal remains. There is a certain irony to the timing and historical context of these two very important publications. Despite their vast differences in approaches both of these scholars recognized the importance of migration as a legitimate and important topic of archaeological study. Nonetheless, at the time of their publication neither had an immediate impact on migration studies in archaeology and it was only in the early to mid-1990's that migration began to emerge once again as a focus of serious and concerted research efforts in archaeology.

This reemergence was related to connected developments of both migration theories and methods as illustrated especially by: 1) Critical reappraisals of the theoretical and epistemological bases of migration studies initiated by the work of Anthony (1990, 1992) and 2) Early applications of Ericson's (1985) proposed Sr isotope method to archaeological migration and mobility studies by T. Douglas Price's research group at the University of Wisconsin, Madison (Ezzo et al. 1997; Grupe et al. 1997; Price et al. 1994a; Price et al. 1994b) and Nikolaas J. van der Merwe's research group at the University of Cape Town (Sealy et al. 1995; Sealy et al. 1991; Sillen et al. 1995). The second irony is that although Rouse (1986) does not cite Ericson's (1985) work in his book, he makes certain prescient statements that seem to predict this subsequent transition in migration studies. For example, Rouse states "In theory, archaeologists should also be able to obtain reliable hypotheses from the physical anthropologists to whom they entrust the study of the human teeth and bones they find in their sites, for these objects supply direct, empirical evidence about the local populations" (Rouse 1986:15). He goes on to note that "Some success has been achieved with teeth but, regrettably, bones do not preserve well and their range of variation is often too small to rule out the possibility of local development" (Rouse 1986:15).

Thus there has been renewed interest amongst archaeologists in exploring migration, from an explicitly anthropological perspective (Anthony 1997; Burmeister 2000; Cameron 1995; Clark 2001; Curet 2005; Duff 1998; Snow 1995; Spielman 1998), beginning in part with Anthony's seminal treatment of the topic (Anthony 1990), and coinciding with a greater appreciation of its theoretical complexity and a belated acknowledgement of its essential and important role inhuman history. More recent approaches to anthropological theories of migration stress that migration is best regarded as an informed, patterned, social behavior (Anthony 1990, 1997). Furthermore, it is apparent that migration is a complex, multi-faceted, and dynamic process, not an event (Curet 2005). Perhaps most importantly, archaeologists have generally tended to make the assumption that migration had not occurred in the absence of definitive evidence for its occurrence, instead of the more accurate assessment that we just do not know, or in other words "leaving presumed immobility (rather than simple uncertainty) as the default hypothesis" (Snow 1995:62).

These trends have also been paralleled by recent shifts in archaeological theory more generally, which have become increasingly focused on behaviors and processes at finer scales e.g., a broader shift away from larger units such as 'cultures' and culture areas with a corresponding greater emphasis on smaller scales and units of analysis, such as ethnic groups, minorities, communities, households, kin groups, and individuals. This shift is encompassed within a larger change in the dominant archaeological paradigm that increasingly highlights the complex, dynamic, contested, and negotiated practice of human groups at varying scales and with particular foci on intra-societal differentiation, corresponding with a move away from normative perspectives. The broadening of archaeological research avenues in the last few decades, to encompass a wider range of perspectives has included increased attention to issues and problems that are social, as opposed to purely cultural. Amongst these, the importance of individual persons and processes operating at the scale of individuals has been highlighted (Fowler 2004; Hodder 2000). A theoretical and analytical focus on individual persons permits more nuanced and contextualized interpretations of individual actors and agency (Clark and Wilkie 2006; Stodder and Palkovich 2007). Current research also increasingly focuses on disentangling the complex histories or life courses (Gilchrist 2000) of specific individuals that lived and died in the past, through explicitly integrated and inter-disciplinary approaches. Some of the most significant advances in this regard have been made within the broad field of bioarchaeology.

As a discipline, bioarchaeology has greatly matured and developed both methodologically and theoretically (Buikstra and Beck 2006; Knudson and Stojanowski 2008; Larsen 1997) since the basic tenets of the discipline were first systematically put forward over 35 years ago (Buikstra 1977). The enormous growth of the field of bioarchaeology (Buikstra and Beck 2006; Knudson and Stojanowski 2008) in part reflects its unique capacity "As a materials-based empirical methodology… united with a social science inherently committed to understanding the human social world…, we move effectively between the social and biological sciences to address both models of social process and issues of a historical nature" (Knudson and Stojanowski 2009a:2). The growth of the discipline has been paralleled by a broadening of emphases on contextual analysis (Buikstra and Beck 2006; Gowland and Knüsel 2006; Rakita et al. 2005) and an increasing focus on issues of identity at the level of both communities and individuals (Knudson and Stojanowski 2009b; Stodder and Palkovich 2007).

Bioarchaeology perceives of the human body as material culture, occupying a position at the interface of socio-cultural and biological processes (Buikstra and Beck 2006; Sofaer 2006). The human body is conceived not simply as a reflection of one or other process but as a creation of the embedded character of these interrelated phenomena (Sofaer 2006). From this perspective, the human body is the appropriate class of material for which to examine the articulation of a wide variety of biological and socio-cultural patterns and processes, including especially migration. These premises lie at the heart of bioarchaeological including biogeochemical approaches to studies of ancient migrations. Human provenance studies involving bioarchaeological approaches provide a unique means for addressing various issues of identity, as natal origins are clearly an important aspect of individual and community identity (Fowler 2004). Much recent research on intra-societal differences in migration behavior and differential origins at the level of individuals have derived from the explicit integration of social archaeological and bioarchaeological theories and perspectives. Amongst these, one of the dominant trends is the development of contextualized interpretations of human behavior based on chemical and isotope studies of individual human remains [see chapter three].

The last few decades have witnessed fundamental shifts and changes in archaeological epistemologies, theories, methods, and approaches. The convergence of several recent developments have contributed to a renewed interest in migration studies in archaeology, especially: 1) a shift in focus from normative cultural-historical perspectives to more socially oriented ones with increased attention to finer scales of social differentiation, smaller scale units of analysis, and multi-dimensional aspects of the lives of specific people and individual agency; 2) the application of more anthropologically informed theories of migration with a recognition that migration is a multi-faceted, dynamic, patterned process that is worthy of study in its own right; 3) the maturation of the field of bioarchaeology, a greater appreciation of human remains as an important source of information about social and biological aspects of human behavior; 4) scientific advancements in biogeochemical analyses in general, and isotope methods in particular, that permit more precise and direct identification of the movement of individuals in the past. In summary, there are several significant differences between these approaches that are relevant for the present study, and which highlight the main distinctions between the approach advocated herein and most previous archaeological studies of human migrations in the Caribbean. The main distinctions between approaches center on the: 1) materials analyzed: cultural remains versus human remains; 2) units of analysis: assemblages versus individuals; and 3) scales of analysis: populations versus individuals.

2.2.1 Critical Assessment of Irving Rouse's Contributions to Migrations Studies

Rouse's approaches, perspectives and contributions to migration studies in archaeology have recently been thoroughly and critically evaluated by Antonio Curet (2005, 2011). I summarize the main points of these critiques herein with a specific focus on the limitations of Rouse's approach to migration studies in the Caribbean. This critical assessment of Rouse's work and contributions is not presented merely for the sake of being critical and in fact more extensive assessments and critiques of his approaches to both migration studies and Caribbean culture-history have been recently summarized by a number of other scholars working in the region [e.g., (Curet 2003, 2004, 2005, 2011; Pestle 2010; Rodríguez Ramos 2010; Rodríguez Ramos et al. 2010)]. Some discussion of his work is necessary, however, not only because his body of work has been hugely influential to the archaeology of the Caribbean but also to migration studies in archaeology more generally.

Curet has recently provided the most extensive reviews and critiques of Rouse's approach and methods to the study of ancient migrations (Curet 2005, 2011). Curet notes three main problems with Rouse's approach: 1) "the idea that regions have to be culturally homogenous & occupied by a single tradition. In his view, in cases where heterogeneity occurs, the 'dominant' culture either absorbs, pushes away, or eradicates the less-developed group; coexistence is not an option."; 2) "his normative perspective, particularly, his assumption that cultures, not people, migrate. This brings out several problems since, sheltered on the idea that everyone in a culture follows the same norms, it eliminates from the analysis the role of human agency and any social, economic, political, or even religious factors involved in migrations."; and 3) the empiricist approach and the classificatory basis of Rouse's model. It is clear from Rouse's discussion that he believed that once data is spatially and chronologically organized in charts, the identification of migrations will be obvious." (Curet 2011:19). Thus, in summary, Rouse's approach is only a descriptive method for identifying the large-scale migrations of cultures or peoples (actually supra-cultural units) based primarily on inferences drawn from the spatial-temporal distributions of cultural remains.

Of these criticisms, Rouse's approach is particularly problematic for developing a more nuanced understanding of past human migrations that are more reflective of how people generally behave in the 'real world'. His normative perspective is well illustrated by the following statement "A people carries its culture with it when it migrates. We may therefore trace its movement by plotting the distribution of the norms that characterize its culture" (Rouse 1986:4). However, recent research into migrations clearly demonstrates the limitations and problems associated both with conflating migrations with population movements and secondly with the normative conceptualization of human cultures more generally (Anthony 1990, 1997). A reconsideration of migrations from a wide range of fields including cross-cultural ethnographic studies led Anthony (1990:908) to conclude that "'Cultures' do not migrate. It is often only a narrowly defined, goal oriented subgroup that migrates". Thus the decision to migrate (and perhaps more importantly the act itself) "is made at a lower level than culture, such as the individual, household, community, or descent-group level" (Curet 2005:33). This contradiction was already noted by Rouse himself who stated that "migrants may be atypical of their parent population, in which case they will not carry their entire cultural complex with them" (Rouse 1986:10). As noted by Curet (2005), this statement represents a clear contradiction, as Rouse acknowledges that smaller scale social units are the ones that likely migrate but also insisted that higher level units such as culture (actually *series*, which is a supra-cultural unit) are the more appropriate units of analysis.

2.3 Anthropological Insights into Migration Processes and Patterns

In this section, I discuss various facets and complexities of multi-dimensional migration processes beginning with a discussion of the problem of defining migration. This is followed by a review of many of the more important factors and variables concerning migrations and migration processes, especially as they pertain to archaeological studies. This review is not exhaustive and is a synopsis of several recent works and reviews concerning the development of more anthropologically oriented theories of migration (Anthony 1990; Clark 2001; Curet 2005; Duff 1998; Manning 2005).

2.3.1 Defining Migration (What is Migration?)

A persistent problem in dealing with the concept of migration is that it is difficult to define and to differentiate from similar concepts, such as mobility (Kelly 1983; Kelly and Todd 1988; Lightfoot 2008; Sellet et al. 2006). All migrations consist of the movement of people from one location to another. However, this broad conception alone also encompasses much behavior that is not considered migration, for example the movement of traders, foragers, hunters, warriors, visitors, and others. Migration may be perceived as a long-term, permanent, or semi-permanent relocation of residence, as opposed to other similar behaviors, which generally lack permanence. However, the stress on permanence is itself problematic when dealing with groups that are habitually relocating, as is often the case with prehistoric (and modern) foragers, nomadic herders or pastoralists, or others whose subsistence strategy includes seasonal or regular relocations of residence. In other words, there is generally, but not always, an implied degree of sedentism or permanence of residence that must be present for a movement to be considered migration.

Migration is also interconnected, implicitly and explicitly, with a wide variety of other phenomena, particularly invasions (Chapman and Hamerow 1997; Rouse 1986) and colonizations (Rockman and Steele 2003). A need to distinguish migration from other similar processes has prompted a concern with definitions (Otte and Keeley 1990). For example, Gamble defines five interrelated, migration-related processes; migration, dispersal colonization, adaptive radiation, and exaptive radiation (Gamble 1994). While Rouse distinguishes between two distinct but related types of movement; population movement and immigration, that are subsumed under the term migration (Rouse 1986). Concerning terminology, Rouse provides the following definitions "*Population movement*, in which the people of one area expands into another area replacing the latter's population. This process should not be confused with immigration, in which individuals or social groups from one population penetrate the territory of another population without overwhelming it. We shall use *migration* as a cover term for both processes" (Rouse 1986:13) [emphasis in original].

Although there is nothing wrong with these definitions per se, and I agree that "there is nothing sacred about definitions. We can define a word how we like for our own purposes, provided we do so *clearly* and *unambiguously*" (Dawkins 1976:12) [emphasis mine]. Regrettably, however, Rouse tends to use the terms population movement and migration interchangeably throughout this work (Rouse 1986) and later works (Rouse 1992) and tends to totally disregard, or at least ignore the potential importance of immigration or the movement of smaller scale social units. This is illustrated for example by the subtitle of the volume (Rouse 1986) to which I am referring '*Migrations in*

Prehistory: Inferring Population Movements from Cultural Remains' where Rouse's use of the term population movement is also problematic owing to his colonialist perspective on the outcomes of interactions between peoples of different social or technological complexity. For example, he states that "In population movement a people *invades* another's territory, traveling *only in one* direction, and establishes residence there. Its presence becomes so *overwhelming* that it is able to *replace* or to *assimilate* the local population" (Rouse 1986:12) [emphasis mine]. To me this definition would seem somewhat more appropriate for the term conquest than population movement.

In reference to migration studies in archaeology more generally, Curet has noted that "A fundamental problem with past migration studies is that they considered migration as an event rather than as a process" (2005:31). He goes on to summarize the four main problems with Rouse's definition of migration, and particularly of using the size of migrant groups to distinguish between different types of migration: 1) "it limits migration studies to a very narrow range of possible population movements; 2) "it is a post hoc definition, where the process is defined and studied based on the final conditions"; 3) "it does not consider that many major migrations are the result of multiple sequential smaller population movements"; 4) "it ignores situations in which the migrant group does not drive out or absorb the local population" (Curet 2005:33-34).

These criticisms of Rouse's model, methods, theory and the premises that they are based upon contributed to Curet's recent reappraisal of the concept of migration and how it has been used in archaeological migration studies in the Caribbean. Beginning with the issue of definitions, Curet asserts that "a more useful and analytically powerful definition for migration can be developed" (2005:33) and suggests the use of a definition initially proposed by Clark that a migration "is a long-term residential relocation beyond community boundaries by one or more discrete social units as the result of a perceived decrease in the benefits of remaining residentially stable or a perceived increase in the benefits of relocating to prospective destinations" (Clark 2001:2). Although this definition provides a needed and much improved version than the one used by Rouse (1986), I find it problematic to include the causes of migration in the definition of the term. My main concern is that the inclusion of causes ignores the possibility that decision making groups and migrant groups may not be coeval and thus many types of migration that fall under the general heading of ‘forced migration’ would not be considered migration according to this definition. This is of particular concern, regarding the profound roles that forced migrations have played in world history and especially in the history of the Caribbean region. As such, I prefer to use a much more simple and straightforward definition that does not include possible causes within the definition itself and propose the following modified version from the *Encyclopedia Britannica*: ‘Human migration is the permanent change of residence by an individual or group’. This definition is preferable not only in the sense that it removes considerations of causation and decision-making (which although very important may also be highly variable, unknown, and not in the hands of the people that actually migrate). More importantly, this definition focuses on the actual behavior and is not restricted to migrations of a certain size, occurring over a minimal distance, or only those with specific outcomes.

2.3.2 Types of Migration (Scale, Distance, and Boundaries)

There are two general approaches to migration, macro-level and micro-level. The former tends to focus on processes involving larger groups, aggregate social behavior and/or the structures causing them, the latter on smaller groups or individuals, and associated decision-making processes (Cadwaller 1992). Approaches emphasize one or the other, or both, depending on the questions each is seeking to address. Most traditional archaeological studies have emphasized macro-level approaches or the long-term effects of aggregate social behavior. Macro- and micro-levels are not mutually exclusive categories, and there may be utility in focusing on intermediate social units and time scales where the two may overlap (Hofman and Hoogland 2011) [see also (Rivera-Callazo 2011)].

Clark’s definition of migration emphasizes movement beyond community boundaries and points to a distinction made by some researchers between internal and external migration (Clark 2001). Internal migration refers to residential mobility or movement within a (cultural, social, environmental, or geographic) boundary, it is generally intra-regional and occurs amongst “habitually interacting” social groups

(Anthony 1990). Internal migration is generally characterized by shorter distance movements and may coincide with various life-events, such as reaching adolescence or adulthood, marriage (post-marital residence relocation), having children, or even changing occupations (career migration). These more frequent, short-distance movements are regarded as internal migration by some researchers (Anthony 1990, 1997; Brown and Neuberger 1977) and are not considered migration at all by others (Clark 2001).

Long-distance migration is expected to be less common, especially prehistorically, owing to the friction of distance or distance impedance (Burmeister 2000). The friction of distance refers to the relationship between spatial distance and the logistical and organizational difficulties associated with migration or transportation costs. There is an inverse correlation between distance and frequency, but it is mediated by other geographical, social, and transportation factors. It is necessary to acknowledge the possibility of a lack of direct correlation or correspondence between social and spatial distance in certain contexts. Short and long distance migrations are often conflated with internal and external migrations. A relationship exists between the two in that longer distance moves are more likely to cross boundaries, but the relationship is non-linear. Depending on a variety of factors, short-distance migrations may be external and long-distance migrations may be internal.

External migration is considered to occur less frequently but to be potentially more complex, more likely to result in major changes in material culture, and therefore potentially more archaeologically visible (Duff 1998) than internal migration. A similar tendency may be expected for the movement of larger versus smaller social units, necessitating the distinction between the terms population movement and migration (Rouse 1986), with the former being a subset of the latter. This denotes a difference in scale via the size of the migrating unit, and potentially the nature of the causes and consequences of migration, as long-distance and/or external migration may not only be more difficult and less common but also may have more profound consequences for migrants. While some researchers stress attention to scale and note the relationships between macro- and micro-level processes (Anthony 1990, 1997; Curet 2005), others doubt the possibility of examining micro-level processes archaeologically or focus specifically on macro-level processes (Adams et al. 1978; Burmeister 2000). The main distinction between internal and external migration is related to distance and scale but stresses boundaries which may be cultural, social, political, or physical (Clark 2001; Duff 1998). In reference to distance, Keegan has recently noted that "island archaeologists have tended to emphasize geographic distance…Yet there are other ways to measure distance" (2010:15). These include economic, demographic, ceremonial, political, and social distance. "All of those dimensions of distance are interrelated and codetermined" (Keegan 2010:15) [see also (Keegan 2004)].

Many other types of migration exist, some in specific social contexts. For example, local or internal migration is a circumscribed form of migration within a particular social milieu and is a relatively common form of movement (Brown and Neuberger 1977). Although potentially important for the creation and maintenance of regional cultures, internal migration may also leave little evidence because it does not necessarily involve the movement of people, goods, or ideas across discernible or detectable boundaries. Circular migrations are regular or semi-regular movements with the intention of future return, the movement of migrant laborers is a common form of this type (Anthony 1997).

Wave (or 'wave of advance') is a commonly employed migration model in which there is an incremental movement of people across a region usually as the result of population increase, or demic expansion (Ammerman and Cavalli-Sforza 1973), generally occurring over long periods of time, such as generations or centuries. This model was first applied to account for the Neolithic expansion of agriculture through Europe, whereby slow but continuous population increase resulted in the gradual expansion of farming populations, which are characterized as waves (Ammerman and Cavalli-Sforza 1973). Some have critiqued this model, claiming that waves are unfounded in migration theory, are the result of the coarseness of archaeological data, and that the available data can be better interpreted as representing a leapfrog model [e.g., (Anthony 1990, 1997)]. Leapfrogs are characterized by intentional migration or colonization to ideal regions or locations, and not necessarily to the nearest available area, leading to open expanses which may only later be filled in by further migrations. The importance of this distinction is that social aspects of migratory behavior (micro-level) such as directionality, intentionality, strategy, and decision-making processes, can be blurred and distorted over long time periods and may appear as the movement of peoples or cultures in waves across space and time (macro-level).

Chain, stream, flow, and current are similar types of migration patterns where later migrants follow earlier migrants, often to similar destinations and along similar routes. These types of migration may contribute to the formation of enclaves, usually characterized by the presence of spatially and socially clustered minority or immigrant groups and their descendants. The existence of enclaves provides evidence that immigrants are not always completely assimilated or acculturated into their new social milieus. An ancient example of an enclave may be represented by the Oaxaca Barrio, at Teotihuacán, Mexico (Spence 1976). Nevertheless, enclaves are often characterized as possessing 'hybrid' cultural traits or qualities intermediate between those of their parent and destination groups. Enclave migrants are often placed into a context where they are exposed to or interconnected with two or more somewhat distinct social networks and must be able to mediate and oscillate between them. Because the process of acculturation and 'hybridization' may happen quite rapidly (within the lifetime of an individual), migration into enclaves may lead to relatively rapid ethnogenesis, for example as amongst twentieth-century Puerto Rican migrants in New York or *Nuyoricans* (Bourgois 2003).

Another possible consequence of chain migration is that earlier migrants (pioneers, settlers, founders) may come to prominence owing to their roles as early migrants. Earlier arrival may give individuals or groups a 'head start' concerning the learning of physical, social, legal, economic, and political landscapes. Possession of such knowledge may allow for later differential access to power, prestige, status, or resources. The term 'apex family' refers to the situation whereby an immigrant group (and/or its descendants) possesses unequal access and special prominence within a migrant community owing to their experience or history of early migration relative to other later migrants [Alvarez 1987, cited in (Anthony 1990)]. A possible ancient example of which may be the supposed founder, and founding lineage of the ancient city of Copán, Honduras (Buikstra et al. 2004). Interpretations of the founding of Copan suggest that it may have been an intentional maneuver by an elite lineage seeking a place to manifest its political aspirations (Demarest 1988).

Involuntary, coerced, or forced migration may be caused by many factors and may result in the classification of certain migrants or migrant groups as refugees or displaced persons (Burmeister 2000). Interestingly, except under certain extreme conditions, even when the decision to migrate is not in the hands of the migrating group such as with some types of refugees, the routes and destination may still be partially or wholly determined by the migrating group (Anthony 1997). Coerced migration may also be an explicit manifestation of social control and political strategy. Various examples include the forced or coerced movement of various peoples (especially minority ethnic groups) by the Inkan, Roman, and Soviet empires.

Patrick Manning (2005) has developed a typology of different types of migration that are suitable to a wide variety of scenarios. Although originally developed in reference to language communities, I suggest that a more open and flexible definition of the concept of community would permit the application of his typology to a wider range of contexts and scales. Manning defines four primary types of migration as follows: 1) "*Home-community migration* involves movement of individuals from one place to another within the home community"; 2) "*Colonization* is the departure of individuals from one community to establish a new community that replicates the home community"; 3) "*Whole-community migration* is the displacement of all the members of a community"; 4) "*Cross-community migration* consists of selected individuals and groups leaving one community and moving to join another community" (2005:9). As a broad generalization, until recently, most archaeological studies of migration and mobility, especially in the Caribbean, have focused on colonization and whole-community migrations and have generally neglected home-community and cross-community migrations. This imbalance is particularly troubling considering that cross-cultural migrations studies indicate that the latter two types are much more common overall.

The concept of boundaries is potentially problematic especially in relation to that of community, which is often variably defined and perceived, contested and negotiated, or even imagined (Anderson 1991). Since there is an essential emic quality to both communities and their associated boundaries, there is a correspondent subjectivity in distinguishing movement within or between boundaries, and thus between internal and external migration. For example, Barth has noted that boundaries are often maintained despite the movement of people across them (Barth 1969). Meanwhile, the movement of peoples across and within boundaries may result in profound cultural and social changes of the sort that archaeologists are particularly interested in studying (Burmeister 2000; Duff 1998; Rouse 1958, 1986). Thus, in this study, I take the perspective that all migrations have potentially important implications and consequences, not only for the individuals or groups that move but also for groups from where they originate and to where they migrate. These consequences may differ substantially depending on a wide range of factors, including for example the size of the migrant group, the distance migrated, and the crossing of borders or boundaries but these are essentially differences of degree, not differences of kind.

2.3.3 Migrants and Migrant Groups (Who migrates?)

One of the main distinctions of modern approaches to migration, compared to traditional approaches, involves a greater emphasis on the nature and composition of migrant groups. Research in various social sciences indicates that migrating social units are neither random nor representative samples of the populations from which they are derived (Lee 1966; Lewis 1982). In other words, there is a strong degree of selectivity (and in some cases predictability) concerning the composition of migrant groups. Although quite variable, there appears to be biases related to age, gender, class, health, and possibly other variables as well (Anthony 1990; Curet 2005; Duff 1998). General patterns indicate that men, young adults, and unmarried people are highly migratory (Curet 2005; Manning 2005), although these are clearly very broad generalizations that are highly variable under different cultural, social, economic, political, and ideological conditions.

Various reasons for such patterning may exist and the causes for such patterns may themselves be quite variable depending on context. Gender bias may reflect a general cross-cultural tendency for males to be more oriented toward the public domain and thereby operating within larger and more complex networks of social interaction. This orientation may be interrelated with tendencies for males to travel further and more frequently, as hunters, fishers, traders, warriors, and scouts. Thus they may be expected to have greater direct experience, contact, and access to information concerning other peoples and places, including possible migration destinations and other migrants. Again though this is highly dependent on a number of other factors, not the least of which are the social, cultural, political, and economic context of the migration and there are of course numerous studies indicating the existence of the opposite pattern, e.g., where females are the more mobile or more migratory sex.

Similar reasons may be proposed for apparent age-related biases, concerning the seemingly high rates of young adults in modern times. This may denote social structures in which migration is a better and more feasible option for this subset of society relative to other members or groups within a society. For example, children would be expected to be less apt to migrate in the absence of parents, family, or adults except in particular circumstances, while older adults may have reduced motivations, in that they may have less to gain and more to lose by migrating, relative to younger adults. On the other hand, secondary or ancillary migration refers to the movement of individuals via the agency of another person, for example the migration of dependent children by parents or the head of the family (Manning 2005), and secondary migrants may represent a large proportion of migrant groups under certain condition.

Class and status patterns amongst migrants are more variable and more difficult to interpret. Within modern world-systems perspectives there are obvious structural forces and motivations behind the movement of peoples in response to fluctuations within global, regional, and local labor markets (Kearney 1986). However, it is less clear how to interpret relationships between socioeconomics and migration outside of these contexts. In any situation involving differential access, one may presume that those with less access to power, prestige, control, or other resources may derive greater benefits from migration, but may also possess reduced capacities to overcome the costs of migration. This may be especially true in contexts where the initial costs of migration are relatively high. Such interpretations are further exacerbated for prehistoric contexts in which the recognition of intra-societal differentiation is potentially problematic.

Other influences on the size and structure of migrant groups include the relationships between decision-making units and migratory units. Duff notes that these units need not be the same and yet their relationship may be patterned (Duff 1998). For example, in situations where decision-making is centralized there may be an increased likelihood of movement at the level of community or population, involving coordinated planning (Duff 1998). If decision-making is decentralized it may allow for greater flexibility of behavior allowing for smaller units such as households to both make the decision and to migrate (Duff 1998). Nevertheless, one should not expect a direct linkage between the two in that even in contexts of strongly centralized decision-making, migratory units may still consist of small, sub-groups. In other words, just because the decision-making is out of the hands of those migrating, this need not indicate that the entire group, community, or population migrates.

Who migrates appears to be highly influenced by who has migrated and research suggests that the best predictor of future migration is past migration, in that once someone or some group moves they seem to have an increased likelihood of moving again (Anthony 1990). This may be an effect of lowered thresholds for the initiation of migration as the result of past experiences. In addition, past migration not only influences migration-related behavior for the migrants themselves but also appears to have a corresponding effect on others. The persistence and maintenance of social interactions and contacts between migrants and parent communities has direct links not only with the likelihood of future migration between these locations but also the routes that they may take. Migration streams or currents refer to the movements of migrants from specific origins to specific destinations, following well-defined routes (Anthony 1990). Future migrants tend to be those that have access to information or prior knowledge concerning potential destinations, often obtained through social ties with previous migrants.

There is a definite relationship between selectivity and causality (Burmeister 2000) within migration. The nature and source of various causes for migration (including various push/pull factors) tends to structure the size and composition of migratory units. Forced, involuntary, or coerced migration as a direct or indirect result of war, famine, drought, plague, flood, abrupt or extreme environmental change, or other natural or human-induced circumstances may condition selectivity by inducing the movement of larger units than other types of migration (Burmeister 2000). The exact size and composition of the units will be relative to the nature of mediated pressures on groups or individuals, whereby selectivity is determined both by external factors and internal social structures influencing responses and abilities to respond to stimuli beyond just migration, not to mention the perceptions and agency of individual agents and actors. A classic example is refugees, who are generally less selective than most migratory units but also are often not mere random samples of the groups from which they originate (Burmeister 2000).

2.3.4 Reasons, Causes, and Models (Why do people migrate?)

As Anthony has noted "If archaeological approaches to migration have been slowed by a failure to ask the right questions, then one of the greatest culprits must be the question of causes" (Anthony 1990). However, our ability (or lack thereof) to determine the causes of migrations does not mean that we can not still identify basic patterns and structures of migration. Furthermore, since migration is closely linked to various other phenomena, its study is worthwhile and important even in the absence of concerns with causality. Perhaps, more importantly most migrations are likely the result of multiple causes (Burmeister 2000).

Causation in migration studies can be divided into four basic categories or types: 1) Push/Pull theories- based primarily on neoclassical economics and the spatial/temporal imbalance of resources, such as land, capital, and labor. These theories are characteristic of most traditional anthropological studies which tended to focus on or assume economic, ecological, and especially demographic reasons and motivations behind migration. 2) Decision theory- based on rationale, agency, information flow, and subjectivity. This perspective makes the important distinction that decisions are based on perceptions of reality, which may or may not be accurate. To some extent decision theory helps to account for migrations that seem to conflict with expectations derived from simplistic cost/benefit analyses, whereby people do not always move when and where they would most benefit but often to destinations where they have preexisting social ties. 3)

Sociological theory- unequal distribution of power or prestige, existence of structural and anomic tensions. Perceives migration as a mechanism for resolving tensions or as a control mechanism, whereby migration is deemed a viable option or response. 4) Others- dependency theory, Wallerstein's world system, and Marxist concepts provide frameworks or systems of global dependency, inducing migration and reproducing the conditions for the continuance of migration [summarized from (Burmeister 2000)].

Many archaeological migration models tend to incorporate multiple factors that include both positive and negative push and pull factors (Anthony 1990; Burmeister 2000). Perceptions of these factors are based upon the flow of information between a home region and possible destinations, with access to information and the accuracy of perceptions determined by the nature, scope, and intensity of existing social networks, previous experience, and possibly influenced by the presence and role of previous migrants. Information flow is structured by the nature of preexisting social networks, which are often based on kinship and familial ties, but also consist of exchange networks and trade relationships.

Decisions to migrate are based on perceptions of push and pull factors mediated by concerns with transportation costs. Costs generally vary directly with distance (impedance or friction of distance), thus there is a general inverse correlation between distance and migration rates or frequencies. However, various other factors can affect this general tendency, especially transportation technologies, which can greatly reduce travel logistics and transportation costs. The feasibility of various routes may be determined by both the presence of and access to transportation technologies. The introduction or development of certain transportation technologies may be essential for certain types of migration to take place, for example insular voyaging or intercontinental transportation. Furthermore, certain transportation technologies may open new routes and initiate migrations by reducing costs and/or restructuring social relationships and networks. Transportation technology mediates relationships between social and spatial distances in different ways for different people in that access to transportation technologies may be highly variable. Lastly, like any other technological innovation, temporal change in transportation need not be progressive or unilineal.

Many models of migration have focused primarily on density dependence as a cause of migration [e.g., (Ammerman and Cavalli-Sforza 1973)]. Anthony has poignantly demonstrated the limitations of population pressure or density dependence models, by pointing out that density-dependence is culturally defined and mediated (Anthony 1997). The population density that can be supported by any territory varies depending on multiple factors, including; 1) basic subsistence strategies, 2) technological capacities, 3) resource management practices, 4) the social organization of labor, 5) food preferences and choices, 6) attitudes toward conflict and cooperation, 7) comfort thresholds for crowding. Furthermore, previously popular density dependent approaches fail to consider pull factors, information flow, transportation costs, and other types of push factors. Therefore, density dependence models are best considered as only a subset of possible push factors [summarized from (Anthony 1997); see also Curet 2005].

Push factors include not only demographic, economic, and ecological factors but also social, political, ideological ones or even various combinations of these factors (Curet 2005; Hofman and Hoogland 2009; Hofman et al. 2011; Hofman and Hoogland 2011; Keegan 2010). Examples of these may include; social- primogeniture or other social regulations that unequally distribute power or prestige, such as that implicated in the conquistador phenomenon (Sauer 1966); political- lineage or village fissioning resulting from political competition or expediency, in various contexts such as the Yanomami (Chagnon 1977) and classic Maya (Demarest 1988); ideological- climates permitting religious expression or escapes from persecution, for example early colonial America (Bunker 2010).

2.3.5 Destinations (Where do people migrate?)

In general people do not migrate to places for which they have no previous knowledge (Duff 1998). This conclusion, based on modern patterns of migratory behavior, has led some prehistorians to rethink previous notions of the history of human dispersal, settlement, and colonization. For example, Irwin has contested previously held notions that the Pacific was colonized directly by one-way exploratory colonizers (Irwin 1990;

Irwin 1992). After reanalyzing the available data in the context of known modern and historical processes, Irwin concluded that the idea that prehistoric peoples migrated into completely unknown regions was quite unlikely (Irwin 1992). Owing to the risks and high transportation costs of prehistoric open-ocean voyaging (with available transportation technologies), early Pacific colonists would have suffered from quite high rates of loss if they had attempted to colonize into the complete unknown. More convincing explanations are derived through considerations of multiple factors including the direction of winds, currents, and travel, the order of settlement, distance, island size, and other factors, including patterns of migration, and especially the possibility of return migration.

Irwin and others have focused on colonization processes, a distinct set of migration processes in which people migrate into regions that lack previous occupation (Graves and Addison 1995; Irwin 1990; Irwin 1992) [see also various readings in (Rockman and Steele 2003)]. Colonization processes can be divided into stages [summarized from (Graves and Addison 1995)] 1) discovery- through intentional exploration or through information obtained while involved in other activities; 2) colonization- the movement of people into an unoccupied region presumably with the intent to settle; 3) establishment- refers to when a colony has reached a stable size, whereby it is resilient to stochastic processes and can successfully reproduce itself, both socially and biologically. These distinctions point out an essential lesson of modern migration research, that migration is best understood as a complex and multi-dimensional process, and not a rare, random, or unpatterned event. From this perspective, it may be more parsimonious to conclude that in most cases people relocate to places for which they have previous knowledge (discovery) and that not all colonies are viable in the long-term (colonies), until they have reached a stable population density (establishment).

Moore (2001) has used computer simulation software to analyze various colonization models, including; 1) matrix, 2) beachhead, 3) string of pearls, 4) outpost, and 5) pulse. Input variables included initial population size, sex ratios at birth, polygamy, the likelihood of pregnancy, fertility and mortality rates, and marriage prohibitions. An important result of this analysis is that initial population size is an extremely important factor in determining long-term success. While nearly any size population has some chance of viability, the smaller the initial population the more susceptible it is to stochastic processes especially early on in the colonization process. However, stochastic processes can be greatly mediated by several factors, including the maintenance of interactions (biological and social) with one or more other communities, and/or further pulses of migrants. He interprets these results as indicating that certain models of migration are so unlikely as to be inappropriate and can probably be abandoned (Moore 2001). However, the continuation or maintenance of interaction, further migration(s), and even random factors can contribute to the long-term viability of colonies, regardless of the model employed.

In cases of initial colonization into previously unoccupied, unsettled or vacant regions, population interactions may need to be maintained with the parent community until viability is achieved. In other cases there is more flexibility and the development of interactions with other neighboring populations may supplement or even supplant interactions with parent communities. In cases where the parent and migrant communities are separated by long distances or where high transportation costs exist, the development of interactions and relationships between migrant groups and destination groups may be advantageous or even necessary for the long-term reproduction and survival of colonies or migrant groups.

The history of interactions, attitudes, and potential hostilities between migrants and destination groups and other groups along migratory routes can all be included as other potential mediating factors (Anthony 1997). As previously mentioned, the flow of information from previous migrants back to donor or parent communities may contradict the basic premise of distance as a cost in that better information about distant, potential destinations may be more important than little or no information about closer potential destinations (Rockman and Steele 2003). Chain migration is another term to refer to this channeling of information and migrants to specific destinations, routes and social settings or enclaves and may help explain many instances of long-distance migration, especially to and from specific places or localities (Anthony 1997).

The implications of the preceding insights are potentially substantial for archaeological and prehistoric studies of migration. Concerning Irwin’s conclusions regarding Pacific colonization, it may necessitate the incorporation of elements of several theories of migration, including sociological, decision, and push/pull (Irwin 1992). The recognition of intentionality and decision-making in migration and colonization strategies by prehistoric peoples marks an improvement over previous models where people were conceived as uncritically reacting to external conditions over which they have little or no control. This recognition at least grants the possibility of awareness of extant conditions and that migration may be better characterized as an informed, if not calculated, social strategy (Anthony 1997; Curet 2005). This may partially account for "migrations without any discernible, objective reason or the absence of migration despite such reasons" (Burmeister 2000) and acknowledges that migration is merely one of many possible responses to various internal and external factors and forces.

The work of Moore points to a need for greater awareness between networks of interaction and exchange, migration as social behavior, and population density (Moore 2001). In contexts where people are living in small, dispersed groups (i.e., at low population densities,) there may be strong motivations for establishing and maintaining contacts and interactions with other groups for the purposes of reproduction and survival. In such contexts, one might expect there to be prevalent push and pull factors related to migration potentials and rates. These ideas have been more fully developed in Kirch's (Kirch 1988, 2000) 'lifeline' model, whereby colonies or new communities maintain intimate social ties with parent communities. In the Pacific, this may have entailed long-distance interactions (as much as several hundred kilometers or more) over long periods of time (multiple generations) at least until colonies had become more stable and enduring (Kirch 1990, 2000). This tendency may partially account for widespread similarities in material culture in certain contexts meeting these conditions, for example such disparate cultures as the Aurignacian in Paleolithic Europe; Clovis in North America; or Lapita in the Pacific (Gamble 1986, 1994). Over time, these once dispersed 'cultures' seemed to have been 'replaced' by more localized cultural traditions. These phenomena may be interpreted as related to changes in both population density and the associated need to maintain widespread social interactions as the requirements for biological and social reproduction no longer necessitate the maintenance of widespread social networks and long-distance movement [but see (Clark 1994)]. Reproductive needs can be met by the greater availability of local contacts made possible through increased population density. In other words, there may be a dialectical relationship between migration and wide-ranging social networks, in which cause and effect cannot be separated. However, the lack of cultural similarities does not necessarily imply the converse, as the presence of migrants or migration is not necessarily manifested in changes in material culture.

2.3.6 Impacts and Consequences of Migration

Many approaches to migration studies rely to some extent on patterns and structures derived from observations of modern and historical migration (Burmeister 2000; Duff 1998). In contrast, Zelinsky has observed a correlation between demographic or secular trends and mobility trends (Zelinsky 1971). He has hypothesized a historical mobility transition that corresponds with the global demographic transition, and argues that mobility (and migration) has increased throughout history as global populations have increased (Zelinsky 1971). More recent work concerning the study of historical migrations has focused on developing modes, definitions, and models that are cross-cultural applicable and permit the comparison of patterns of migration from a global perspective (Lucassen and Lucassen 2009; Lucassen et al. 2010; Lucassen and Lucassen 2011). Regardless of the validity of this argument, it is clear that substantial migration and mobility were present throughout human history (Gamble 1994). Some have used similar lines of reasoning to dispute the validity or utility of applying understandings of modern migration behavior into past social contexts (Clark 1994; Rouse 1986). Epistemological debates concerning sources of analogy notwithstanding, it is the recognition of a need to be cognizant of the complexities and dynamics of migration processes, structures, and patterns (not necessarily the contextually dependent details) that is the essential lesson to be learned from studying migrations in the present.

The consequences of migration are many and varied, and can impact all parties involved, including the parent group, the migrant group, and the destination group (Curet 2005). The size, structure, and demographic composition of each group and the scale and rate of migration can profoundly influence the outcomes of migrations. If sufficient in size or scale, or heavily biased in composition, emigration can have drastic consequences for donor communities or groups. In certain circumstances, migration may result in radical changes in donor group social composition and precipitate restructuring of intra- and inter- societal relationships.

In the extreme, emigration has been observed to lead to abandonment of settlements and regions, both historically and archaeologically [for discussions of abandonment see (Nelson and Schachner 2002; Spielman 1998)]. In fact, abandonment and collapse are two of the more archaeologically visible manifestations of migration (Cameron 1995). Although it is feasible that long-term, disproportionate fertility and mortality rates may result in the extinction of a local group, some degree of emigration is often implicated in demographic collapse, and site and regional abandonment. One might predict that extremely low population levels might influence survivors to leave or disperse and that local population 'extinctions' or collapse are thus unlikely to occur without some degree of emigration or dispersal.

Similar factors concerning the size, scale, composition, and rates of migration can be influential for both migrant groups and the communities and regions to which they migrate. In the case of migration into unoccupied territories, or initial colonization, the arrival of migrants brings evidence of their presence through the existence of their material culture. This represents another type of migration with potentially high archaeological visibility, via the introduction or appearance of cultural material remains. Other evidence for the arrival of humans to a previously unoccupied or unsettled area include; the introduction of foreign or exotic flora and fauna, the introduction of disease pathogens, landscape or habitat alterations, and the extinction and extirpation of certain local species which can be particularly prevalent and severe in insular or island settings (Keegan and Diamond 1987).

In cases where regions are previously occupied or settled, the consequences of (im)migration are complicated by a variety of factors. First, extant groups may be a source of information flow; prior to, during, and subsequent to migration. The presence of resident populations and communities is potentially beneficial for migrant groups by providing better conditions for rapid landscape learning and may mediate difficulties associating with adapting to local environmental and ecological conditions. However, the presence of other peoples also necessitates the movement through, and learning and negotiation of new physical and social landscapes by immigrants, and in some cases by local groups as well (Rockman and Steele 2003). Hence, the past histories of interactions between groups strongly influence future interactions and developments within and between them.

The presence and degree of differences in size, demographic composition, technologies, subsistence practices, social organization, histories, and culturally determined and mediated conceptions of foreigners or migrants, as well as cultural conceptions of cooperation and conflict all potentially condition future relationships and outcomes (Curet 2005). Under certain conditions, various disparities between groups may lead to differential power relations between them. However, because of the potential influences of so many different factors, the results of any given contact situation are highly complex and often unpredictable (Cusick 1998; Spielman 1991). These processes may include; displacement and dispersal, conflict and cooperation, diffusion and exchange, acculturation and assimilation, enculturation and emulation, and transculturation and ethnogenesis. In addition, the long-term effects of migration often induce processes of identity formation, negotiation, maintenance, and restructuring (Burmeister 2000; Duff 1998).

Return migration further complicates the potential outcomes of migration and can precipitate changes for all groups involved (Gmelch 1980; Kearney 1986). It may further alter the size, composition, and nature of multiple communities. It also provides relevant information and knowledge to potential future migrants concerning routes, destinations, and social landscapes and may induce or reduce future migration. In addition, return migration is a potential source of change through the exchange and introduction of new ideas, technologies, materials, and people (Anthony 1990; Burmeister 2000).

In modern contexts, the phenomenon of remittances, in which migrants return with, or send, money or resources back to their parent communities, is widespread. This may have taken place prehistorically as well and could account for the presence of foreign or exotic luxury goods in certain contexts, and therefore may be archaeologically visible (Anthony 1990; Burmeister 2000). Return migration has been implicated as a causal factor for social change in parent communities through these mechanisms (Gmelch

1980; Kearney 1986). Another consideration is the possible effect of changes in prestige or status obtained by migrants owing to knowledge obtained through distant social networks, and/or access to foreign/exotic materials, goods, ideas, and technologies. Helms has noted the role of migration and long-distance or foreign travel as a mechanism for increasing prestige and social status (Helms 1988; Helms 1979), whereby migration itself is a potential pull factor.

2.4 Migration Research in Caribbean Archaeology

An interest in migration(s) appears in some of the earliest works on the archaeology of the Caribbean region (de Hostos 1923, 1924; Lovén 1935; Rainey 1940; Rouse 1952). Early migration studies in the Caribbean were an inherent component of the construction of cultural chronologies for the regions. Most generally accepted models for Caribbean prehistory recognize five main, large-scale migrations as developed primarily by Rouse over several decades: 1) the initial Lithic/Archaic colonizations of the islands; 2) the Early Ceramic Age (Saladoid/Huecoid) migrations; 3) the Late Ceramic Age (Ostionoid) expansion; 4) the colonization of the Bahamas; and 5) and the Island Carib migration(s) (Chanlatte Baik 1981; Chanlatte Baik and Narganes Storde 1983, 1986; Curet 2005; Keegan 1992, 1994, 2000; Rouse and Allaire 1978; Rouse 1989a, b, 1992; Siegel 1989a; Siegel 2005; Wilson 1997, 2007). It should be noted, however, that this list does not include a number of other possibly distinct large-scale migrations or colonizations, for example the colonization of the southern Caribbean islands, e.g., Aruba, Bonaire, Curaçao, Los Roques (Hofman et al. in press) from northern South America. Secondly, several other possible population movements or migrations of different cultural and ethnic groups and/or different origins of certain groups have been proposed over the years (Boomert 2000; Callaghan 1993, 1995; Rodríguez Ramos 2010; Veloz Maggiolo 1991, 1993; Zucchi and Tarble 1984).

Siegel (1991) has extensively reviewed both the descriptive models of cultural development and change that are pertinent to the dispersal of humans into the Antilles from the South American mainland during the ceramic age and more recent explanatory models that have explicitly focused on questions of causation. Various materialist or economic perspectives, primarily variants of push-pull or adaptation models have been proposed to account both for the spread of ceramic bearing horticulturalist groups out of northeastern South America and into the Antilles (Goodwin 1979, 1980; Keegan 1985; Roe 1989; Rouse 1986, 1992; Siegel 1991) and the later expansion of ceramic bearing horticulturalists into the Greater Antilles and the Bahamas (Berman and Gnivecki 1993, 1995; Keegan 1985, 1992). However, as Curet (2005:29) suggests, with some notable exceptions (Keegan 1992, 1995; Siegel 1991), most of these studies can be clearly characterized as macro-scalar approaches that "have concentrated mainly on general aspects of migration without taking into consideration a number of important variables at lower levels such as migrant group size, migration type, and the structure of migrant population".

Some of the criticisms leveled by Curet (2005) have begun to be addressed on a number of fronts with a renewed interest in studying various types and forms of human mobility and migration processes at multiple scales and inferring prehistoric migrations based on a broader range of approaches often integrating different lines of archaeological, biological (genetic and phonetic), and biochemical (isotope) evidence [e.g., (Curet and Hauser 2011b; Curet 2005; Fitzpatrick and Ross 2010; Hofman et al. 2008d; Hofman and Hoogland 2011). The timing, routes, origins, and direction of migration waves and population movements are foci of current debates within the archaeology of the region, especially as they pertain to the arrival of both early (Archaic) and later (Ceramic) Age groups to the Antilles. For example, owing to the island setting of the Caribbean, colonizations and inter-island migrations required some form of ocean-going transportation technology and knowledge of seafaring. There has been renewed debate and discussion in recent years concerning the role of the sea in prehistoric human interaction in the region, particularly in regard to whether the sea united or divided the peoples of the Caribbean (Boomert and Bright 2007; Bright 2011; Curet 2004; Fitzpatrick and Anderson 2008a, b; Hofman et al. 2007a; Hofman et al. 2008a; Hofman et al. 2010; Keegan 2010; Rodríguez Ramos 2010; Torres and Rodríguez Ramos 2008).

The basic chrono-cultural model for the Caribbean and more specifically the timing (and direction) of population movements and colonizations have been debated based both on newly available radiocarbon dates and/or reassessments of published dates (Fitzpatrick 2006; Fitzpatrick et al. 2010; Pestle 2010; Rodríguez Ramos 2010; Rodríguez Ramos et al. 2010). In particular, the 'stepping-stone' model (Keegan 1995; Rouse 1989b, 1992b) for the colonization of the Lesser Antilles and Puerto Rico has been questioned in recent years. This model would seem to have some support from the principles of island biogeography (Keegan and Diamond 1987). Nonetheless, the available radiometric evidence and computer simulations of sea voyaging (Callaghan 2001, 2003) have called into question this model for the northward migrations from the South American mainland in the Ceramic Age (Fitzpatrick 2006; Fitzpatrick et al. 2010; Haviser 1997; Keegan 2000, 2010). The observation that most of the earliest dates for Saladoid deposits in the islands derive from the Leeward Islands or northern Lesser Antilles (Haviser 1997), has led some researchers (Fitzpatrick et al. 2010; Keegan 2010) to propose that these islands were settled first and that the Windward Islands of the southern Lesser Antilles may have been intentionally passed over by Ceramic Age migrants [for a similar argument for Archaic Age migrations, see (Callaghan 2010)]. This would of course contradict the "stepping-stone" hypothesis of island colonization and in fact Fitzpatrick and colleagues (2010) have used the late dates for the earliest settlement of the Grenadines to propose a "Southward Route Hypothesis" whereby the Windward Islands were initially settled from the north. Lastly, perhaps one of the most interesting models concerning Early Ceramic Age interactions and migrations is the previously discussed 'lifeline model' whereby distant new colonies attempt to maintain long-distance interactions and social relationships with parent communities as originally developed for Pacific contexts (Kirch 1988; Knight 1990). This model has also been applied to Caribbean contexts over the years (Hofman et al. 2011; Keegan 2004, 2010; Watters 1982), mainly in reference to connections between island and mainland communities although the possibility exists that connections with insular parent communities in the Antilles requires further investigation (Bright 2011).

Another hotly debated topic in Caribbean archaeology concerns the so-called 'Ostionoid expansion' that occurred during the Late Ceramic Age. This term refers to the general spread of languages, cultures, and peoples out of Puerto Rico and into the Dominican Republic, Jamaica, Cuba, the Bahamian archipelago, and the northern Lesser

Antilles sometime after A.D. 600 (Rouse 1986, 1992). Various explanations have been proposed to account for this expansion, including migration, diffusion, and transculturation, and different combinations of these processes (Berman and Gnivecki 1993, 1995; Chanlatte Baik and Narganes Storde 1986; Crock and Peterson 2004; Crock 2000; Curet 2005; Hoogland and Hofman 1993a; Hoogland and Hofman 1999b; Keegan 1992; Keegan 1995, 2000, 2006a; Keegan 1985; Rodríguez Ramos 2011; Veloz Maggiolo 1991; Veloz Maggiolo 1993). Additionally, a multitude of hypotheses have been put forward in reference to the expansion of Greater Antillean or 'Taíno'-related cultures, cultural traits, and even specific social groups from Puerto Rico into the Lesser Antilles during the later phases of the prehistoric period (Allaire 1990; Hofman et al. 2007a; Hofman et al. 2008a; Hoogland and Hofman 1999; Rodríguez Ramos 2011). For example, based in part on the presence of a ball court or *batey* at the Salt River site, St. Croix this island may have been integrated into a larger Taíno political sphere during the Late Ceramic Age (Morse 1997; Rouse 1992). Based on multiple lines of evidence, it has also been proposed that Taíno-related chiefdom societies existed on Anguilla during this period (Crock 2000; Crock and Peterson 2004). Perhaps, the most specific hypotheses concerning Late Ceramic Age migrations into the northern Lesser Antilles, have been proposed for the Kelbey's Ridge site on Saba. This site has been interpreted as a possible Taíno outpost or colony formed by colonists or refugees originating on Hispaniola (Hoogland and Hofman 1993; Hoogland and Hofman 1999) [see also (Curet 2005; Siegel 2011) concerning territorial expansion during this period].

Research into different types and forms of micro-mobility in this region have also begun to appear, as represented for example by studies of seasonal mobility and occupation amongst Archaic groups on Saba, in the northern Lesser Antilles (Hofman and Hoogland 2003; Hofman et al. 2006a). A number of recent regional and micro-regional studies of settlement patterning in the Antilles have indicated complex and variable patterns of settlement mobility [e.g., (Bright 2011; de Ruiter 2012; de Waal 2006; Torres 2012). These studies have generally demonstrated a high degree of spatial and temporal variation in the density and patterning of settlements at multiple scales. Of particular interest in terms of human mobility behavior is the apparent rapidity that settlements were established and abandoned within certain regions and time periods (de Waal 2006; Torres

2012). The most systematic assessment of settlement patterning and paleodemography has been conducted by Curet (2005) who also discusses the implications of demographic patterns at multiple scales for current models of human migrations within the ancient Antilles [see also (van Meel 2012)]. This work (Curet 2005) makes a substantial and much needed contribution to our understandings of population culture histories in the region and is exceptional for its inclusion of a more anthropologically informed theoretical basis to the concept of migration. Although Curet makes explicit use of demographic data obtained from skeletal remains on Puerto Rico, he does not address other possible lines of evidence that can be obtained from human skeletal materials. This is somewhat curious as data derived from genetic (aDNA), epigenetic (morphological), or biogeochemical analyses are all potentially highly relevant for questions concerning paleomobility generally, and population histories and migrations more specifically.

Several biodistance studies have explicitly addressed human morphological variation amongst the prehistoric inhabitants of the Antilles and the implications of these for the number of migration 'waves' and their origins. Over several decades, Alfredo Coppa and colleagues (Coppa et al. 1995; Coppa et al. 2002; Coppa et al. 2008) have developed a very extensive database of morphological variation of human populations in the Antilles based on the analyses of non-metric dental traits and has used these data to infer distinct migratory waves in the pre-Columbian period. Research in a similar vein but focused primarily on cranial morphology has addressed the issue of human population variance in the Caribbean has come to similar conclusions (Ross et al. 2002; Ross 2004; Ross and Ubelaker 2010). Both ancient (Lalueza-Fox et al. 2001; Lalueza-Fox et al. 2003; Toro-Labrador et al. 2003) and modern DNA (Martínez-Cruzado et al. 2001; Martínez-Cruzado 2002; Martínez-Cruzado et al. 2005; Martínez-Cruzado 2010) research on Amerindian skeletal material has also begin to shed light on these topics. Although the aDNA data are somewhat limited, the available evidence is generally consistent with the results of osteological and dental studies, indicating some degree of inter-population variance and possibly distinct origins for different populations (Lalueza-Fox et al. 2001; Lalueza-Fox et al. 2003) [see also (Schurr 2010)].

Very few studies of human mobility at smaller scales, such as assessing patterns of residential mobility have been conducted in the Caribbean. One of the most comprehensive assessments in this vein is represented by Keegan and colleagues' (1989; 1998) [see also (Keegan 2006)] reconstructions of Taíno political and kinship systems. Based primarily on ethno-historic documentation and ethnographic analogy combined with limited archaeological evidence, they have made a strong case for the development of avunculocal residence patterning amongst the late prehistoric Taíno chiefdoms. Curet (2002, 2006), however, has questioned whether these reconstructions are applicable to broader social, cultural, and geographic contexts in the region. In fact, although various aspects of Amerindian social organization have been addressed by Caribbeanists over the years, to date very little is known about prehistoric residence rules and behavior for the prehistoric Antilles and existing hypotheses have generally not been systematically tested against the archaeological or bioarchaeological record. One exception to this generalization is the recent study of human mobility at the site of Anse à la Gourde (Booden et al. 2008; Hoogland et al. 2010), which formed the precursor to the present study.

Residential mobility has also formed an explicit focus of recent debates about the composition and origin of individuals interred in Central Plaza burials at Early Ceramic Age (primarily Saladoid) sites in the Antilles (Keegan 2009; Siegel 2010). Siegel has developed a model of cultural continuity and change throughout the Ceramic Age sequence of the Antilles based on multiple lines of evidence. An implicit aspect of this model is that central plaza burials represent the interments of the deceased of the resident population. Keegan has recently proposed an alternative model that asserts the primacy of kinship over residence in placement and location of burials. According to his model, individuals (especially married females) would most likely be interred in the village of their clan and not necessarily the village that they were born in, or the village in which they had resided after marriage. Such a model necessitates the post-mortem mobility of the bodies (corpses) of the deceased, a possibility that Keegan asserts is supported by preliminary strontium isotope evidence from Guadeloupe, "Their study suggests that individuals who did not live at this site were buried in the cemetery" (2009:382); see also (Keegan 2010) [citing (Booden et al. 2008; Hoogland et al. 2010)]. This statement somewhat mischaracterizes the nature of the isotope evidence that only indicates a distinct natal origin for individuals identified as nonlocals and not the place of residence at death. In other words, nonlocals in this context are interpreted as individuals that have migrated sometime after the formation of the sampled tooth (in childhood) but the timing or age at which the migration occurred is unknown and even obtaining biogenic isotope values from bone material would be equivocal in this regard. In fact, Hoogland and colleagues' (2010:162) reference to post-mortem mobility was one of several hypotheses concerning the possible origins and types of mobility amongst the *local* individuals at this site (not the nonlocals).

Lastly, research focusing on migrations at smaller units of analysis (such as individuals) has also been conducted on colonial era contexts as represented by two recent isotope studies of the forced migrations of African born slaves at sites on Barbados (Schroeder et al. 2009) and St. Martin (Schroeder et al. 2012). The topics of forced migrations or slavery in the prehistoric period of the Antilles have not been thoroughly researched within the context of migration studies. Nonetheless, widespread reports of the practice of bride capture within various ethnohistoric documents [e.g., references in (Boomert 2000; Oliver 2009; Rouse 1992; Whitehead 1995b, 2011), see also (Sued Badillo 1995) for an alternative interpretation of some of these reports] merit further attention. This topic remains understudied to date but is of obvious interest for investigations of paleomobility in the circum-Caribbean region. In summary, the development of migration studies in Caribbean archaeology has somewhat paralleled the general history of migration studies in archaeology. However, owing partly to Rouse's legacy, or perhaps more accurately the continued uncritical acceptance and misapplication of his cultural-chronological framework, the culture-historical paradigm had remained dominant within Caribbean archaeology somewhat longer than it did for other regions of the world. Nonetheless, studies of interaction more generally and migration in particular remain central themes of many ongoing discussions and debates within Caribbean archaeology and have received renewed research attention in recent years from a wide variety of perspectives, scales, and approaches [see e.g., (Curet and Hauser 2011b; Curet 2005; Fitzpatrick and Ross 2010; Hofman et al. 2010; Hofman and van Duijvenbode 2011) and various chapters therein].

CHAPTER 3 ISOTOPE ARCHAEOLOGY

3.1 Introduction

In this chapter the basic principles of isotopic analysis of human remains are presented with a primary focus on those applications that are of most interest for studying human migrations and mobility from the archaeological record. Established biogeochemical methods for assessing human migration patterns based on the human skeleton can be divided into two broad analytical approaches. The first, elemental analysis, measures the absolute or relative concentrations of certain elements, such as strontium and barium, in skeletal tissues. The second, isotopic analysis, measures the isotopic composition (isotopic ratios), of specific elements within human tissues. This chapter covers the main principles and applications of isotope analyses to human provenance studies, with an emphasis on strontium isotope analyses of ancient human remains.

Strontium isotope ratios are the most commonly analyzed isotopes for archaeological provenance studies but oxygen and lead isotopes, and more recently sulfur, have also been utilized for these purposes. Carbon and nitrogen isotopes have been traditionally employed towards dietary studies. Unlike light stable isotopes such as carbon and nitrogen, heavy elements (with a higher atomic mass, such as strontium) do not undergo substantial fractionation during most naturally occurring physical and biochemical processes [although see (Knudson et al. 2010b)]. In other words, the mass differences between different isotopes of a given heavy element are much smaller than the mass differences between the different isotopes of lighter elements. This means that the isotopes of a heavy element tend to be less influenced by mass dependent effects. For strontium, even if some minor biofractionation would take place this would be corrected for via the application of a mass correction factor to the 'natural' ratio of ^{86}Sr/^{88}Sr = 0.1194. Thus, isotopic signatures of strontium within biogenic tissues are directly reflective of the local sources of biologically available Sr in a given ecosystem or environment rather than biochemical processes, such as metabolic pathways. Therefore, analysis of strontium isotope ratios in biogenic tissues is an effective tool for provenance studies, while carbon and nitrogen isotopes are more informative of dietary patterns.

3.2 Strontium Isotopes

Atoms that have the same the same number of protons (*atomic number* or *Z*) but different numbers of neutrons (*neutron number* or *N*) are called isotopes. “The isotopes of an element have identical chemical properties and differ only in their masses” (Faure and Mensing 2005). Variations in the isotopic compositions of certain elements are the result of two distinct processes: “1. the spontaneous decay of the nuclei of certain atoms to form stable nuclei of other elements and the accumulation of these radiogenic daughter atoms in the minerals in which they formed and 2. the enrichment (or depletion) of certain stable atoms of elements of low atomic number in the products of chemical reactions as a result of changes in state such as evaporation and condensation of water during physical processes such as diffusion” (Faure and Mensing 2005:3). The first of these processes accounts for most variations in isotopic ratios amongst the heavier elements, such as strontium, and the latter accounts for much of the variation in isotopic ratios amongst lighter elements such as carbon, nitrogen and oxygen.

“Strontium is a member of the alkaline earths of group IIA, which consists of Be, Mg, Ca, Sr, Ba, and Ra. The ionic radius of Sr^{2+} (1.13 Å) is slightly larger than that of Ca^{2+} (0.99 Å), which it can replace in many minerals” (Faure and Mensing 2005:75). There are four naturally-occurring isotopes of strontium (^{84}Sr, ^{86}Sr, ^{87}Sr, and ^{88}Sr) with isotopic abundances of approximately 0.56, 9.87, 7.04, and 82.53 percent respectively (Faure and Mensing 2005:3). All four of these are stable, although ^{87}Sr is radiogenic, being produced by the radioactive decay of ^{87}Rb, with a half-life of ~4.88 X 10^{10} years (Faure and Mensing 2005:3). Globally, the ratio of ^{87}Sr/^{86}Sr is variable and it varies according to three main factors, "(1) the ^{87}Sr/^{86}Sr at time the rock crystallized, $t = 0$, (2) the ^{87}Rb/^{86}Sr ratio, which is directly proportional to the Rb/Sr ratio in most cases, and (3) the time t elapsed since formation." (Bentley 2006:137).

3.2.1 Strontium Isotopes in Natural Systems

The primary sources of strontium into any particular ecosystem can be divided into geological and non-geological sources. In most contexts, the geological source is the largest contributor of strontium into plant tissues (Bentley 2006:153; Bern et al. 2005) through the primary weathering of soil minerals. However, research into various environmental systems indicates that atmospheric contributions of strontium can be quite substantial (Aberg et al. 1998; Dijkstra et al. 2003; Kennedy and Derry 1995; Kennedy et al. 1998; Kennedy et al. 2002; Pozwa et al. 2000; Pozwa et al. 2002; Pozwa et al. 2004; Vitousek et al. 1999). Non-geological sources of Sr include both the atmosphere and hydrosphere and a significant non-geological source of strontium in coastal areas comes from the sea (Hodell et al. 2004; Montgomery et al. 2003). Marine effects can be derived from sea-spray or marine-derived strontium in rainwater (Chadwick et al. 1999; Kennedy et al. 1998; Whipkey et al. 2000), or through the direct or indirect consumption of marine resources by animal organisms, including humans (Bentley et al. 2005; Price and Gestsdóttir 2006; Wright 2005). Atmospheric effects derive from many types of precipitation including not only rainfall but also atmospheric dryfall, the settling of wind-blown particulate matter (Biscaye et al. 1974; Muhs et al. 1990).

3.2.2 Strontium Isotopes- Geology

The major oceans of the Earth contain mid-oceanic ridges where erupting lava flows deposit large quantities of volcanic rock, producing ridges which sometimes extend above sea level forming oceanic islands, such as Iceland. These volcanic processes produce mid-oceanic ridge basalts or MORB, and they generally have low but somewhat variable ^{87}Sr/^{86}Sr ratios (Faure and Mensing 2005). Rocks derived from older continental crust, which has not been subducted and re-melted into the mantle for many hundreds of millions or billions of years, tend to have elevated ^{87}Sr/^{86}Sr ratios. This is because there has been sufficient time for any extant ^{87}Rb to decay into ^{87}Sr, thereby producing measurable differences in the quantity of ^{87}Sr relative to ^{86}Sr. Owing to the long half-life of ^{87}Rb, the effects of this process are most noticeable in extremely old materials, for example Pre-Cambrian cratons. However, since age is not the only variable influencing ^{87}Sr/^{86}Sr ratios, some older crustal materials do not have highly radiogenic ^{87}Sr/^{86}Sr ratios. Formations containing very low initial Rb concentrations (relative to Sr) will not substantially elevate ^{87}Sr/^{86}Sr ratios even over very long periods of time (Faure and Mensing 2005).

Oceans contain sediments derived from the continents and transported by various physical processes. The Sr isotope ratio of modern seawater has been consistently measured and appears highly homogeneous. This is due to the fact that the global mixing of seawater occurs on the order of decades whereas changes significant enough to alter the global seawater composition occur at much greater timescales (Hess et al. 1986; Richter et al. 1992; Veizer et al. 1999). Therefore, the modern marine strontium signature is calculated as ^{87}Sr/^{86}Sr (oceans) = 0.70918 ± 0.00001 (2σ) (Faure and Mensing 2005; Howarth and McArthur 1997; McArthur et al. 2001; Veizer et al. 1999). In other words, the Sr ratio of the oceans has not changed appreciably at the time scales that concern most archeologists (i.e., thousands of years).

The marine ^{87}Sr/^{86}Sr ratio does fluctuate over geological time but this fluctuation or variation has been resolved to the extent that an approximation of the ^{87}Sr/^{86}Sr signal of a marine carbonate or limestone deposit can be derived from an estimate of the time period of its formation or deposition (Hess et al. 1986; Howarth and McArthur 1997; McArthur et al. 2001; Richter et al. 1992; Veizer et al. 1999). The ^{87}Sr/^{86}Sr ratio of seawater fluctuated considerably throughout the Phanerozic, varying between ~0.7068-0.7092 (Faure and Mensing 2005). Episodes of global volcanic activity have been proposed as possible causes for temporary decreases in oceanic ^{87}Sr/^{86}Sr ratios throughout this time period (Faure and Mensing 2005).

3.2.3 Strontium Isotopes- Hydrology

The Sr composition of freshwater reservoirs, such as lakes and rivers, reflects a cumulative average of all sources of Sr to a particular drainage. These sources include atmospheric deposition and especially the movement of sediment from upstream sources by erosion. Analysis of suspended and soluble loads of freshwater indicates that their Sr isotope signals may vary both spatially and temporally within a single drainage system (Bentley 2006). As soluble and non-soluble components of soils may possess different Sr isotope ratios, analyzing both may contribute to tracking variable sediment sources for particular drainages (Probst et al. 2000).

Sedimentation rates and sources are in turn affected by a number of variables, including precipitation rates, vegetation cover, slope, and land usage to name a few. In most cases, the Sr signals of transported sediments in streams and rivers are considered to be representative of the weighted average of all upstream sources (Bentley 2006). If a particular drainage system passes over several isotopically distinct regions, it will probably contain sediments which possess variable Sr isotope ratios. These variable sources can be partly tracked by sampling a drainage system along its course and observing potential changes in Sr ratios throughout the system. In fact, analyses of Sr ratios from rivers in Europe have been utilized as a proxy for the local signals of specific drainage basins, under the not unrealistic expectation that most organisms subsisting within a certain basin or portion thereof should share similar Sr isotope compositions (Bentley and Knipper 2005; Hodell et al. 2004; Hoogewerff et al. 2001; Voerkelius et al. 2010).

While this appears to be a useful approach in continental settings, the usefulness of it in insular settings can be limited by several factors. In the Caribbean, many islands lack substantial permanent river systems, especially some of the flatter and more arid limestone islands. The larger islands of the Greater Antilles and many of the volcanic islands with high topographic relief generally receive much greater quantities of annual precipitation, producing seasonal or even year round drainages (Woods 1989; Woods and Sergile 2001). However, it is often these same places that have attracted human settlement and agricultural and industrial development over the years, which in turn tends to bring about large scale and widespread modification of the landscape and potentially profound alterations to the local hydrological cycle. This does not mean that sampling of freshwater sources has no utility in insular Caribbean settings, and in fact in some places such work might prove quite fruitful (Pett-Ridge et al. 2009). The previously mentioned concerns merely limit the possibility of relying heavily on hydrological data sources throughout the entire macro-region.

3.2.4 Strontium Isotopes- Atmosphere

Strontium from the atmosphere can be divided into broad two categories; strontium in water vapor and strontium in dryfall. Sea-spray caused by wind blowing across the surface of the oceans can transport seawater, and the Sr that it contains, into the atmosphere. Atmospheric water vapor can then be transported by currents considerable distances before precipitating back to the surface of the Earth. Dryfall refers to the falling of wind-blown particles back to earth's surface and can be quite substantial in certain regions of the world especially during the dry season and in areas that are downwind from large sources of wind-transported sediment.

A well-known example of this is the transport and deposition of large quantities of Saharan dust across the Atlantic. Large 'clouds' of Saharan dust can even be observed from space and under favorable weather conditions result in the movement of soil particles, sand, and dust across the surface of the planet (Goudie and Middleton 2001; Muhs et al. 1990). Although atmospheric sources are generally considered to be minor contributors of environmental strontium in most places, their relative contribution to overall Sr budgets is sometimes substantial (accounting for over 50% of the total measured strontium in some cases) especially in regions where soil minerals are highly weathered and/or in which the concentration of Sr in bedrock and soils is relatively depleted (Borg and Banner 1996; Kennedy et al. 1998; Vitousek et al. 1999).

The combination of multiple hydro-atmospheric processes will tend to alter or obscure strontium isoscapes (or isotope landscapes) derived solely from terrestrial or geological sources alone [herein I use the definition of isoscapes as “maps of the spatial isotopic variation of the material(s) of interest” (West et al. 2010:vi)]. This is particularly true in coastal and insular settings where the atmospheric and marine sources of Sr may contribute substantially to overall ecological (or biosphere) Sr budgets. However, non-terrestrial sources can be significant even in continental or interior settings (Gallet et al.

1998; Graustein and Armstrong 1983; Graustein 1989) and thus researchers should be cognizant of the complexities of the many potential processes and variable sources of Sr when constructing isoscapes of biologically available Sr in all contexts (Bataille et al. in press; Evans et al. 2009).

3.2.5 Strontium Isotope Ecology

Strontium often enters the food chain through the transport of weathered soil minerals into plant tissues. It then moves through the food chain as herbivores and omnivores consume plants and as carnivores consume them, and so on. Although there is a known reduction of strontium concentrations (relative to calcium) at each successive step in the food chain (Burton et al. 1999; Burton and Price 2000), this reduction does not alter the measured strontium isotope ratio. Therefore, it is possible to use simple mixing models to constrain the limits of Sr isotope ranges for given islands or regions of the Caribbean using geological Sr isotope data and that of the sea as the two main sources of Sr into local terrestrial ecosystems (Bentley 2006; Montgomery et al. 2007). In fact, any organism which subsists solely or primarily on local food resources (terrestrial and/or marine) is expected to have a Sr isotope value that falls somewhere between the marine and terrestrial values for that locale.

One of the main problems with associating a specific organism to a specific place using isotopes involves the complexities of catchments areas, places from where an organism derives most of its subsistence. The size of a catchment varies between and within species based on a wide range of factors such as: the mobility of the organism, the distribution of its primary food sources, seasonal changes in resource availability, and so on. Catchment sizes and food sources can also be highly variable between individuals of the same species, based on factors such as sex and age. These complications can be further exacerbated amongst humans where the consumption of food is conditioned by a wide variety of social and cultural processes, in particular the use and manipulation of food as a tool for social differentiation.

A few points about ecological considerations of dietary Sr require further elaboration. Life cycle changes in food sources influence Sr isotope compositions of diets if food sources change throughout an individual's life, a process which occurs amongst a wide array of species. Most mammals primarily consume their mother's milk for a certain period of time after birth. The Sr isotope composition of breast milk should be expected to be similar to the average Sr isotope composition of the mother's diet over the period of time that the milk was produced. Under certain circumstances the mother's body may draw on stores of minerals from her own tissues during the period of lactation in which case some of the Sr in her breast milk may be derived from Sr which was consumed much earlier than the period of lactation (perhaps by several years or even decades). During the process of weaning, young mammals begin to consume food sources other than mother's milk. However, the dietary breadth is not always equivalent between the juvenile and adult members of the same species, especially amongst humans. In other words, in some species, juveniles do not necessarily consume diets that are identical to their parents even after weaning has occurred (Katzenberg et al. 1996; Wright and Schwarcz 1999).

Variations in Sr isotope compositions occur between species residing in the same isotopic environment for a variety of reasons. If the entire catchment area for any two or more species falls within a single Sr isotope domain, or isotopically homogenous area, then all individuals within that area may be expected to have similar Sr signatures. However, in areas of greater isotopic (Sr) diversity, the catchment ranges of various species, or even individuals of the same species may overlap one or more distinct isotope domains. This obviously complicates the relationship between the isotopic compositions of bodily tissues and the isotopic composition of the Sr sources. In isotopically diverse landscapes, Sr concentrations and compositions may vary widely, not only between different food types but also between similar food types with distinct (biogeochemical) origins. It should also be kept in mind that distinct isotopic origins does not necessarily imply large spatial distances, as one food source may have a quite different Sr isotope composition from another nearby identical food source if there are distinct differences in the background Sr isotope budgets between them. These complications can be become further exacerbated by temporal or seasonal changes which may alter food resource acquisition patterns within and between species.

3.2.6 Strontium Isotopes- Biology

Bioapatite, commonly expressed as $Ca_{10}(PO_4)_6(OH)_2$, is the primary mineral component of human bone and dental enamel (Burton 2008). Both the hydroxyl and phosphate molecules are often be replaced by other molecules or ions such as fluorine (F) or carbonate (CO_3) (Hillson 1996). Fully formed human dental enamel is approximately 97-99% calcium hydroxylapatite (White and Folkens 2005). Because strontium and calcium are somewhat chemically similar, strontium can and does replace calcium within the crystalline structure of bioapatite (Bentley 2006). Unlike bone, enamel does not undergo substantial remodeling after maturation and mineralization ceases and is highly resistant to diagenic alteration or contamination, and thus it preserves the biogenic signal of its formation and development (Budd et al. 2000; Koch et al. 1997; Montgomery et al. 2000; Nielsen-Marsh and Hedges 2000; Price et al. 2002; Trickett et al. 2003). As the time of formation and development of human teeth are fairly well-known (Hillson 1996), the analysis of Sr isotope ratios of dental enamel will provide information concerning the geochemical environment of an individual's youth, from several months *in utero* until approximately 10-14 years of age depending on the tooth type (White and Folkens 2005).

One of the main functions of the skeletal system is its role as a sink or reservoir for minerals from which the body can draw upon when needed (White and Folkens 1999). As such, the concentrations of many minerals and their constituent elements are generally elevated in skeletal tissues relative to other bodily tissues (Larsen 1997). This is fortunate for archaeological analysis in that these minerals and trace elements exist in sufficiently measurable quantities in the very types of biological tissues most resistant to decay (teeth and bones), and thus most likely to be preserved in the archaeological record.

There are distinct differences between the processes of growth, development, and maintenance in the structure and composition of bone and teeth that are relevant for biochemical analysis (Larsen 1997; Price 1989; White and Folkens 2005). Teeth consist of several main components: crown, root, and pulp chamber. The enamel crown is nearly completely mineralized after formation. Once growth and development cease, enamel is considered an inert mineral tissue (Hillson 1996). Although some research has indicated that surficial enamel can undergo mineral exchange in both the oral and burial environment, internal core enamel appears to be highly resistant to these processes (Budd et al. 2000; Kohn et al. 1999; Lee-Thorp 2002).

Dentine is the portion of the tooth directly under the enamel crown and separated from it by the enamel-dentine junction, it is less mineralized than enamel but more so than bone (Hillson 1996). Because dentine interfaces with the pulp cavity of the root and its supply of nerves and blood vessels, it is somewhat more dynamic than enamel in that deposition and mineralization of dentine matrix may occur in response to stress to form secondary or tertiary dentine (Hillson 2005). However, it appears that this response is limited and that, unlike bone, primary dentine does not undergo substantial remodeling subsequent to initial formation and mineralization (Brudevold and Söremark 1967; Molleson 1988).

Bone represents the other major component of the skeletal system and differs from teeth in several key aspects. In general, bone is much more dynamic than dental enamel and unlike enamel it is considered a living tissue (White and Folkens 2005). Bone consists of two main phases; an inorganic mineral phase composed mostly of calcium hydroxylapatite, and an organic protein phase consisting mostly of collagen. This matrix contributes to bone's dynamic nature, allowing it the rigidity necessary for its structural and weight-bearing functions but also the elasticity to respond to stress and activity, as well as fulfilling its role as storage reservoir for various essential minerals. There are two main types of bone, cortical (dense) bone and cancellous or trabecular (spongy) bone. In general, the outer portions of most bones are comprised of a layer of dense cortical bone and the inner portions are comprised of a layer of spongy bone (Price 1989; White and Folkens 2005).

Cancellous bone is less dense and possesses greater surface area for interfacing with the circulatory system, for example within the distal ends of long bones. Because of this interface, the rates of bone accretion and absorption (remodeling) are generally much higher in spongy bone than in dense bone. Thus, bone remodeling is generally more active and rapid in spongy bone with turnover or replacement of the mineral structure occurring at various rates (Schweissing and Grupe 2003b). Owing in part to its greater density, reduced access to the bloodstream, and somewhat different function, cortical bone turnover is much slower and can take as much as several decades for most mineral replacement to occur (Larsen 1997; Price 1989; White and Folkens 2005).

In summary, enamel is essentially an inert and completely mineralized tissue once it is fully formed, while bone, because it continues to interact with the body’s metabolic and regulatory systems (although at reduced rates in older years) is dynamic and its mineral phase is continually replaced throughout an individual’s life. The implications of these distinctions are that teeth preserve a record of an individual’s biogeochemical environment during infancy and childhood, while bone contains the same information for an individual’s last few years or decades of life, depending on the type of bone (Hoppe et al. 2003).

Because the timing of formation and development of different human teeth are relatively consistent and well known it is possible to analyze the isotopic signatures from various teeth from a given individual to roughly estimate his/her age at the time of migration, if this occurred during childhood or adolescence. Also, because the replacement of bone mineral may take several years it is possible that a recent migrant may not reflect a local signal in bone tissue. The existence of an individual with a nonlocal dental isotopic signal and a bone isotopic that is either non-local or intermediate between that of his/her dental enamel and the local signal may be suggestive of recent migration prior to death.

In fact, because different tissues form at different time periods and remodel at varying rates they reflect different time aspects of an individual's life history. Serial sampling refers to the collection and analysis of different types of tissues from the same individual, for example: different dental elements (deciduous versus permanent teeth, molars versus premolars), different portions of dental elements (enamel versus dentine, or even dental calculus), and different types of skeletal elements (cancellous versus cortical bone), or even non-skeletal tissues if present (hair, skin, soft tissue). By serial sampling and analysis of different tissues from the same individual, it is possible to address questions concerning the timing or age of various life history events or processes, such as the age at which an individual moved to a distinct isotopic setting, the age at which weaning occurred, and possibly combinations of processes such as changes in dietary practices associated with migration/mobility (Grupe et al. 1999; Muller et al. 2003; Schroeder et al. 2009; Schweissing and Grupe 2003b).

3.3 Strontium Isotopes- Archaeology

It is the aforementioned specific characteristics of strontium isotope systems and their interactions within biogeochemical systems that explain their archaeological utility. This approach was originally proposed by Ericson (1985). The methodology, techniques, theory, and application of strontium isotope analyses to human provenance studies have been developed and refined over the last two decades as discussed below.

3.3.1 History of Sr Isotope Research in Archaeology

As with many advances in archaeological sciences, the basic methodological and theoretical foundations of isotopic studies were previously developed by several other related fields prior to their application to archaeology. Isotope archaeology probably owes its greatest debt to isotope geochemistry, a field that developed immensely throughout the twentieth century to address a wide array of research questions concerning the evolution and dating of geological structures within Earth and planetary sciences. Although the scale of this research is far beyond the scope of this chapter [see (Faure and Mensing 2005; Fry 2006) for extensive overviews of these topics]; it is important to note that enormous advancements in our ability to accurately and precisely measure a wide variety of isotopes within different types of sample materials had already been developed prior to the first application of isotopic analyses within archaeology. However, it is also necessary to credit applications of isotopic studies within the ecological sciences as the direct ancestor of isotopic archaeology. Successful applications of isotopic research into animal and plant biochemistry and wildlife ecology were borrowed upon heavily by archaeological scientists in the first applications of these methodological approaches to human remains from the archaeological record.

As previously stated, the first archaeological application of Sr isotope analysis to provenance studies appeared the mid-1980's. In the next few years, very little research in this vein was published until the early to mid-1990's when these methods began to be systematically applied to archaeological skeletal materials from the Americas and Europe. In the last ten years or so, many more researchers have analyzed and published Sr isotope research on archeological materials from various regions of the world. The last two decades have also witnessed a broad expansion of the types of research questions addressed by, and the theoretical aspects of, Sr isotope archaeology. Some of the main developments within this burgeoning field revolve around the way in which locals and nonlocals are identified, how local Sr isotope ranges are defined, and the extent and ways in which Sr isotope data are interpreted vis-à-vis other archaeological and isotopic data as discussed in further detail in the following sections [see reviews in (Bentley 2006; Montgomery 2010; Pollard 2012; Price et al. 2002)].

3.3.2 Determining the Local Sr Isotope Signature

Most archaeological applications of strontium isotope provenance studies rely on determining the isotopic range of a given site or region from which the sampled skeletal material is derived [see reviews in (Beard and Johnson 2000; Bentley et al. 2004; Price et al. 2002). One advantage of biogenesis is its averaging effect, which tends to homogenize local or intra-regional variation causing individuals and organisms to possess broadly similar ratios despite micro-level Sr isotope heterogeneity such as in rock and soil minerals and/or varying dietary contributions (Price et al. 2002; Sealy et al. 1991; Sillen et al. 1995; Sillen et al. 1998). This allows for a local range of Sr isotope variation to be defined for a given locality and any isotope ratios observed within a skeletal assemblage that do not fall into this range are then identified as 'nonlocal'. In this sense, nonlocal simply refers to an individual sample possessing an $^{87}Sr/^{86}Sr$ ratio that is outside of the range of local Sr isotope variation. Various methods and approaches for defining and estimating the local range are utilized, each with its own advantages and disadvantages

(Bentley et al. 2004; Price et al. 2002). Since these are an essential component of the overall methodological approach used in this project, they merit further discussion.

One method for determining if an individual is local or not, is to directly compare the strontium isotope ratios from enamel with that of bone for each individual (Price et al. 1994a). Isotope ratios of bone samples are considered to be directly reflective of the local range, under the assumption that people often die and are interred in the general vicinity of where they lived at the end of their lives. Therefore, 'locals' should have quite similar enamel and bone signals owing to lifelong residence at or near the place of birth, while nonlocals can possess enamel signatures that vary significantly from their own bone signatures. There are several potential problems with the application of this approach. For example, recent migrants whose bones have not had time to normalize or equilibrate to the local signature will complicate assessments of the local range. Although probably uncommon, certain mortuary customs involving long-distance, post-mortem transport of remains will result in similar difficulties (Keegan 2009). Lastly, and perhaps more importantly, bone is much more susceptible to diagenesis or post-mortem contamination than dental enamel and thus ratios obtained from bone may not only reflect biogenic Sr but also contributions of Sr from the burial environment (Budd et al. 2000; Chiaradia et al. 2003; Hoppe et al. 2003; Lee-Thorp 2002; Sillen and Sealy 1995).

Owing in part to these concerns, some researchers have attempted to develop statistical approaches for distinguishing between locals and nonlocals using human enamel Sr isotope data alone (Bentley et al. 2002; Ezzo et al. 1997; Grupe et al. 1997; Price et al. 1994b; Price et al. 2001; Wright 2005). These approaches rely on several assumptions; 1) that most individuals within a burial population are probably locals, in that they have spent their entire lives in and around the site or at least within the region in question, and 2) that if migrants or nonlocals are present they will comprise a minority of the individuals in any given burial population. If these assumptions can be upheld then the local range can be estimated through statistical assessment of the human enamel Sr isotope data. For example, the local range can be defined as the mean of all isotopic ratios of analyzed samples plus or minus two times the standard deviation (mean ± 2 s.d.). Any individual whose enamel ratio falls outside of this range is then considered to be nonlocal. Such a local range estimate is more likely to underestimate rather than overestimate the number of non-locals within a burial population (Bentley et al. 2004). One benefit of this approach is that it requires only one tooth per individual and does not necessitate the collection and analysis of bone samples, which may be absent, unavailable, or contaminated by diagenetic processes in many cases.

Determinations of local isotopic ranges can be derived from non-skeletal isotopic ratios as well. This is accomplished by analyzing samples of bedrock, soil, or water which are collected in and around a site and are thus presumably broadly similar to the ratios obtained from the skeletal elements of local individuals (Evans et al. 2009; Evans et al. 2010; Evans et al. 2012; Frei and Frei 2011; Hodell et al. 2004; Voerkelius et al. 2010; Wright 2005). Problems with this method include the tendency for some of these types of samples, especially whole rocks and bulk soil samples, to reflect much greater isotopic variation or heterogeneity than signatures from bones and teeth (Bentley et al. 2004; Price et al. 2002). This is probably a result of the aforementioned process of 'bio-averaging', whereby skeletal elements tend to possess signals with reduced variance compared to the possible variation of consumed resources. In addition, dietary contributions of Sr from outside the geological region will not be represented in these samples. Lastly, because of inherent differences in the weathering and solubility of various types of rocks and minerals, biological signatures may vary from those taken directly from underlying bedrock, especially if the local geology is complex and heterogeneous. In fact, this lack of correlation between geological and biological samples from the same region has been demonstrated in multiple settings (Bentley et al. 2004; Kennedy and Derry 1995; Kennedy et al. 1998; Laffoon and Hoogland 2009; Price et al. 2002; Price and Gestsdóttir 2006; Vitousek et al. 1999).

To overcome some of the limitations of the previous approaches, Price and colleagues have recommended using local faunal samples to determine local ranges of 'biologically available' strontium (Price et al. 2002). This is based on the premise that although the lithosphere is the ultimate source of strontium, it is the Sr composition of the biosphere that is most relevant for archaeologists. The choice of type of fauna varies depending on the geographical, temporal, and cultural setting (Bentley 2006; Evans et al. 2009; Price et al. 2002) but species with relatively restricted catchment ranges are required in order to be reflective of the locally available Sr signature. Migratory species are obviously excluded because their tissues are potentially representative of a much wider range of Sr sources. Suitable species include those that are relatively sedentary, those that obtain most if not all of their dietary requirements locally, those with suspected catchment ranges approximating those of humans, or species with similar dietary behavior as humans. Small terrestrial mammals have been suggested as possibly ideal in this regard (Price et al. 2002). Cattle, pigs, dogs, rodents, land snails, and others have been used or suggested in various contexts because they meet some or all of these criteria (Ericson, 1989; Knudson et al. 2004; Schweissing and Grupe 2003b; Sealy et al. 1991; Sillen et al. 1998). In addition, archaeological materials are preferable to modern ones, owing to the possibility that the latter may be contaminated by modern pollutants or fertilizers (Borg and Banner 1996; Price et al. 2002).

The bioavailable approach has several benefits including; 1) the utilization of the averaging tendencies of biological organisms, which reduces potential isotopic heterogeneity inherent in non-biological materials; 2) it does not require the use of human bone tissue; 3) local faunal materials are generally more abundant, accessible, and available than human bone; 4) assuming that fauna are local, this method reduces questions of locality and context (circularity) which plague approaches that are based on human Sr isotope data alone. Nonetheless, there are some limitations to the bioavailable approach including: the availability of appropriate samples; unknown Sr catchment represented by some proxy samples; the possibility of movement of animals or their remains, and large investments of time and resources required for extensive coverage (Bataille et al. in press; Evans and Tatham 2004; Evans et al. 2009).

3.3.3 Complications and Limitations of Strontium Isotope Analysis

Having summarized the basic methods and premises of strontium isotope analysis it is necessary to review some of the complications and limitations of this analytical tool. First, as is the case with most types of biochemical analysis of human remains, this method is destructive. This fact alone limits the application of this technique for certain archaeological materials. Most techniques for isotope analysis rely on sample processing protocols involving the complete or partial destruction of teeth and bone elements. Other techniques, such as the direct laser ablation of solid materials, as opposed to dissolution and chemical separation have been applied to both trace element (Cucina et al. 2005; Speakman et al. 2002) and isotope analysis (Balter et al. 2008; Copeland et al. 2011; Montgomery et al. 1999; Prohaska et al. 2002; Richards et al. 2008). These methods may permit analyses that are minimally destructive but as yet these have not been fully or adequately developed to obtain measurements that are as reliable as traditional wet chemistry procedures [see discussions in (Copeland et al. 2008; Copeland et al. 2010; Horstwood et al. 2008; Nowell and Horstwood 2009; Simonetti et al. 2008)]. Moreover, recent technological developments suggest that Sr isotopes can be determined on 0.1 ng of Sr equivalent to ~ 0.1 mg of enamel making the conventional approach essentially non-destructive (Koornheef et al. 2012).

Another widespread problem in most types of biochemical analyses of human remains is the potential for contamination. Ultimately, isotopic signals that are the result of biogenic and not diagenic processes are those that are of interest for most provenance studies (Budd et al. 2000; Chiaradia et al. 2003; Hoppe et al. 2003; Lee-Thorp 2002; Sillen and Sealy 1995). As previously mentioned, enamel is considered highly resistant to diagenesis and there is a general consensus that existing protocols to remove potential contaminants from enamel are sufficient in most cases (Budd et al. 2000; Hedges 2002; Hoppe et al. 2003; Lee-Thorp and Sponheimer 2003; Trickett et al. 2003). On the other hand, bone's relative resistance or susceptibility to diagenic processes varies widely depending on several factors, including; the type of bone (cortical or cancellous); preservation conditions; soil pH and moisture levels; and the protocols used to mitigate these concerns (Hoppe et al. 2003). Lastly, although biogenic signals can be preserved for considerable time in both bone and teeth, even enamel is susceptible to diagenesis in very ancient (paleontological) samples or under extremely poor conditions for preservation (Hoppe et al. 2003; Sealy et al. 1995). Fortunately, even if bone (or tooth) contamination were to take place, the effects of the diagenesis would generally be that nonlocals would be misidentified as locals (and not vice versa) causing an underestimation of migrants/migration (Price et al. 2002; Price et al. 2006).

Another potentially substantial limitation of isotope studies of migration is the potential lack of geological and isotopic variability. In the absence of spatial variability, no amount of movement or migration will be discernible with these methods. In large regions with similar geology or widespread geological homogeneity, there may be insignificant isotopic variation to identify nonlocals relative to locals. Since there is an essential spatial parameter to both geological/isotopic variation and to migration, areas of broader or more widespread homogeneity will have fewer identifiable nonlocals and potentially greater numbers of isotopically local, 'internal' migrants. Nevertheless, long-distance migrants would still be identifiable as long as they originated from a region that was isotopically distinct. Extreme heterogeneity of background isotopic variation may be similarly problematic, particularly when occurring on scales that are discordant with the distances that people usually migrate (Hodell et al. 2004). However, owing to the previously mentioned effects of bio-averaging, excessive heterogeneity of isotopic variation seems less problematic under most circumstances.

The lack of ability to identify, or more accurately the tendency to misidentify a nonlocal as such, represents a common limitation of isotope studies. As previously mentioned, the underestimation of nonlocals or migrants can also be caused by diagenesis; the lack of isotopic variation; the inability to identify local, internal, or short-distance migrants; statistical overestimation of local ranges; and the isotopic heterogeneity of baseline samples. However, the underestimation of nonlocals would seem to have fewer severe interpretive consequences than, and would generally be considered preferable to, the overestimation of nonlocals. The possibility of overestimation of the number of nonlocals is also intriguing considering the large number of nonlocals identified in some archaeological populations (Bentley et al. 2002; Bentley et al. 2003; Bentley et al. 2004).

Marine-derived strontium can influence the strontium isotope ratios in human teeth and bones in direct and indirect ways. In coastal and island settings, marine Sr can be deposited directly into terrestrial ecosystems via sea spray, rainwater, or even the use of kelp as fertilizer (Capo et al. 1998; Montgomery et al. 2007; Sealy et al. 1991; Whipkey et al. 2000). From there the marine Sr can enter the local groundwater and soils and can be incorporated into plant tissues and from there passed on to the local (terrestrial) food chain. Marine-derived strontium can also enter terrestrial food webs through the direct consumption of marine resources (e.g., seafood and sea salt) by consumers (Burton and Price 1999; Ericson 1985; Price and Gestsdóttir 2006; Sealy et al. 1991; Wright et al. 2010). However, the degree to which the consumption of marine resources can influence the $^{87}Sr/^{86}Sr$ ratios of human skeletal materials is not entirely clear. On the one hand, Sr concentrations in the sea are quite high and some types of seafood (such as seaweed, shellfish, and sea salt) also can possess high Sr concentrations (Burton and Price 1999; Montgomery et al. 2007; Wright 2005). On the other hand, although the concentration of strontium in bones and teeth is to some extent dose dependent, it is also influenced by the concentration of calcium in the diet and by trophic level effects (Burton and Wright 1995; Burton et al. 1999; Burton et al. 2003). As Burton and Price have noted (1999:235) "While seawater is high in strontium, marine diets are not". In general, amongst omnivores, plants are expected to be the largest contributors to dietary Sr, owing to the much higher levels of Sr in plant tissues relative to meat (Burton and Price 2000; Elias 1980).

Thus, substantial consumption of marine-derived Sr, both indirectly and directly, can produce a 'marine effect' where biogenic $^{87}Sr/^{86}Sr$ ratios in the tissues of terrestrial consumers are influenced by the $^{87}Sr/^{86}Sr$ ratio of seawater. The potential of this so-called marine effect to complicate the interpretation of Sr isotope results has been noted for several regions of the world (Burton and Price 1999; Ericson 1985; Evans et al. 2010; Montgomery et al. 2007; Price and Gestsdóttir 2006; Shaw et al. 2010; Slovak et al. 2009; Wright et al. 2010). Luckily, because the Sr isotope ratio of modern seawater is well documented (McArthur et al. 2001) and thus it is possible to estimate and assess the so-called 'marine effect' and its influence. In fact, some researchers have found that the $^{87}Sr/^{86}Sr$ of human skeletal material from island and coastal populations, reflect a mixture of terrestrial and marine-derived strontium, with $^{87}Sr/^{86}Sr$ values falling somewhere between these two end members (Montgomery et al. 2007; Montgomery et al. 2005; Price and Gestsdottir 2006; Wright, 2005). Furthermore, several independent methods are available to monitor and quantify possible marine influences on the $^{87}Sr/^{86}Sr$ ratios of terrestrial organisms. For example, $^{87}Sr/^{86}Sr$ ratios in terrestrial plant tissues can provide a means for assessing the relative contributions of marine Sr (via sea spray or rainfall) and bedrock weathering to the bioavailable $^{87}Sr/^{86}Sr$ of local ecosystems. Additionally, both stable isotope analysis (carbon and nitrogen) and the analysis of trace elements (such as barium concentrations) can contribute to assessments of direct marine resource consumption.

Another potential limitation of isotope analyses is that if nonlocals originate from regions (regardless of how distant) with similar isotopic signals as the local population or area, they will be misidentified as locals (false negatives). In addition, and perhaps more significantly, the isotope data itself usually cannot be used to identify a specific origin in the absence of other lines of evidence, in part because so many regions throughout the world share similar isotope ranges. Isotope results can be used to eliminate proposed or hypothesized places of origin derived from other lines of evidence and to generate hypotheses, which is how these results are most often applied (Knudson et al. 2005; Price et al. 2000; White et al. 1998; White et al. 2002). Additionally, isotope approaches are also limited to the recognition of first-generation migrants only and not their descendants (e.g., second, third, or later generation migrants) (Price et al. 2006).

In summary, acknowledgement of the limitations of traditional archaeological approaches to the study of human migrations is one of the primary reasons for the development and gaining popularity of biochemical and isotope methods. The results of several of these studies have revealed that a substantial proportion of some populations are migrants and that their associated materials (grave goods) and mortuary contexts were not necessarily good indicators of migratory behavior or differential origins. Since the analysis of material culture may be a relatively poor predictor of migration in certain cases, it would seem logical to attempt to assess and explore the possibility of migration even in the absence of material culture indicators. In other words, it is possible that migration may be evident, important, identifiable, analyzable and relevant to the general aims of archaeological research in many contexts in which there is no material culture evidence for its existence.

Nonetheless, isotope approaches alone can only identify first generation migrants and in certain cases contribute to investigations of geographic origins and cultural affinities. Therefore, such approaches are most effectively employed in conjunction with other analytical approaches such as those focusing on for example: material culture, settlement data, bioarchaeology, paleodemography, and mortuary evidence. Often, it is only from a broad-based, multi-disciplinary approach that meaningful patterns can be elucidated.

3.3.4 Archaeological Applications of Sr Isotope Analysis to Human Migrations

Analysis of strontium isotope ratios from human skeletal remains is the most commonly employed biochemical method for assessing patterns of human mobility and migrations and for exploring the geographic origins of individuals and groups. This method has been applied to address a wide array of research questions in an enormous range of archaeological contexts.

1) In Europe: to assess patterns of mobility for Linearbandkeramik (Bentley et al. 2012; Bentley et al. 2003; Bentley et al. 2002; Bentley et al. 2004; Price 2001; Price et al. 2006b; Richards et al. 2008b), Bell Beaker (Grupe et al. 1997; Price et al. 1994a, 1998), and other Neolithic (Chiaradia et al. 2003; Giblin 2009; Haak et al. 2008; Latkoczy et al. 1998; Nehlich et al. 2009; Oelze et al. 2012a; Oelze et al. 2012b; Sjögren et al. 2009; Smits et al. 2010), and Roman-period (Schweissing and Grupe 2003a; Schweissing and Grupe 2003b), and medieval (Aberg et al. 1998) populations of central, northern and western Europe; to identify the origins of "Otzi" the iceman (Hoogewerff et al. 2001; Müller et al. 2003); to investigate migrations of Neolithic and Roman peoples in England (Budd et al. 2004; Chenery et al. 2010; Eckardt et al. 2009; Evans et al. 2006a; Evans and Tatham 2004; Evans et al. 2006b; Evans et al. 2012; Leach et al. 2010; Montgomery et al. 2000; Montgomery et al. 2005; Montgomery et al. 2007; Müldner et al. 2011); to explore Norse (Viking-age) migrations into Iceland (Price and Gestsdóttir 2006), Ireland (Knudson et al. 2012), and Scotland (Montgomery et al. 2003; Montgomery and Evans 2006); to test proposed population movements to Crete (Nafplioti 2008); and to examine Neanderthal mobility in Greece (Richards et al. 2008)

2) In North America: to track migration and mobility amongst prehistoric populations from the Western (Ericson 1985), Southwestern (Ezzo et al. 1997; Ezzo and Price 2002; Price et al. 1994b), Southern (Quinn et al. 2008), and Midwestern (Beehr

2011; Price et al. 2007a) United States; to identify migrants at the ancient sites of Teotihuacán, Mexico (Price et al. 2000) and Xuenkal (Tiesler et al. 2010) in Mexico and Tikal (Wright 2005) and Kaminaljuyú (Wright et al. 2010) in Guatemala; to test hypotheses concerning the origins of individuals, elites and the supposed 'founder' of the Maya city of Copan, Honduras (Buikstra et al. 2004; Price et al. 2010); to examine the origins of sacrificial victims at various sites across Mesoamerica (Price et al. 2007b; White et al. 2007) [see also (Price et al. 2008)]; and to test the provenance and natal origins of possible African migrants from colonial cemeteries in Campeche, Mexico (Cucina et al. 2005; Price et al. 2006), the New York African burial ground (Goodman et al. 2004; Jones et al. 2003) and from slave burials in Barbados (Schroeder et al. 2009) and St. Martin (Schroeder et al. 2012); and in the Caribbean to examine prehistoric residential mobility on the island of Guadeloupe (Booden et al. 2008).

3) In South America: to trace migration and mobility patterns from various Wari, Tiwanaku, and Chirabaya affiliated sites in Peru and Bolivia (Conlee et al. 2009; Knudson et al. 2004; Knudson and Buikstra 2007; Knudson and Price 2007; Knudson 2008; Knudson and Blom 2009; Slovak et al. 2009); to determine the origins of the Juch'uypampa cave mummies from southern Bolivia (Knudson et al. 2005); to investigate the origins of Nazca (Knudson et al. 2009) and Wari (Tung and Knudson 2008, 2010) trophy heads; to examine population heterogeneity and the life histories of individuals in the Atacama desert of northern Chile (Knudson et al. 2010a; Knudson and Torres-Rouff 2009; Torres-Rouff 2003); to explore the origins of Inka groups at Machu Picchu (Turner et al. 2009) and other sites in the Cuzco Valley (Andrushko et al. 2009; Andrushko et al. 2011); and patterns of residential mobility amongst a prehistoric coastal population in Brazil (Bastos et al. 2011).

4) In Africa: to examine mobility and dietary patterns amongst Australopithecines and other early hominins in South Africa (Copeland et al. 2011; Sillen et al. 1995; Sillen et al. 1998); to study patterns of mobility and kinship amongst Holocene skeletons from southwestern Libya (Tafuri et al. 2006); to test migration models for Nubian populations in the Nile Valley (Buzon et al. 2007) and to investigate identity and life histories of Khoisan and historical-era groups (Sealy et al. 1995) and shipwrecked slaves from coastal cemeteries in South Africa (Cox and Sealy 1997).

5) In Asia: to test hypotheses concerning relationships between cultural practices and population mobility amongst the Jomon in Japan (Kusaka et al. 2009; Kusaka et al. 2011); and to examine spatial and temporal variation in patterns of residential mobility amongst hunter-gatherer, Neolithic, Bronze Age, and Roman populations from Siberia (Haverkort et al. 2008), Arabia (Gregoricka 2011), Jordan (Perry et al. 2008), Turkey (Welton 2010), Malaysia (Valentine et al. 2008), and Thailand (Bentley et al. 2005; Bentley et al. 2007b; Bentley et al. 2009).

6) In Oceania: to study Lapita migrants and migrations on Vanuatu (Bentley et al. 2007a) and the Bismarck Archipelago, Papua New Guinea (Shaw et al. 2010; Shaw et al. 2011; Shaw et al. 2009).

3.3.5 Other Applications of Sr Isotope Analyses

In addition to the aforementioned applications of Sr isotope analyses, this methodological approach is widely utilized in various other fields such as forensics, animal ecology, and (within archaeology) artifact provenance studies. Forensic applications of isotopic analyses (Ehleringer et al. 2010; Pye 2004) rely on the same basic parameters and principles as archaeological applications, and vary mainly in that they can be applied to more recent human remains (Beard and Johnson 2000) and thus benefit from the higher likelihood of preserved soft tissues, or even to living subjects (Font et al. 2012). Forensic Sr isotope applications are fairly recent and are primarily limited by problems associated with the global movement of agricultural commodities and food products in modern times. The consequences of these tendencies are that many individuals consume an enormous array of foods of highly variable and unknown origins and that both the types of foods and their origins may change significantly throughout a person's life. All of which tends to obscure and complicate one of the basic underlying premises of the Sr isotope approach, i.e., the assumed relationship between an individual’s biogenic Sr isotope signal and the Sr isotope signal of their geographic origin(s).

The application of isotopic analyses, including Sr, to determine the origins of modern food and water has become quite widespread in recent years (Voerkelius et al.

2010). This is particularly true in Europe where issues of food origins and the ability to independently assess authenticity claims have led to attempts to source a wide variety of consumer products, from wine and cheese, to meat and honey (Camin et al. 2007; Schellenberg et al. 2010). In addition, the possibilities of isotopic analyses have been explored recently from a law enforcement perspective. This is partly due to the enormous potential of provenience studies (including isotope approaches) to independently test the suspected origins of illicit drugs and even illegally harvested timber (Galimov et al. 2005; Kagawa et al. 2008; West et al. 2009). Other forensic applications of isotope analyses for the purposes of law enforcement, include the sourcing of confiscated raw ivory and goods manufactured from ivory (van der Merwe et al. 1990; Vogel et al. 1990).

Applications of isotopic analyses within the field of animal ecology, and specifically in reference to animal migrations and mobility, have also greatly expanded in recent years [e.g., (Hobson and Wassenaar 2008; Hobson et al. 2010) and references therein]. The underlying principles are generally the same as archaeological applications although most ecological research in this vein is focused on examining the migration patterns of living organisms, often based on the analysis of tissues samples that can be acquired without killing the organism, e.g., feathers, fur, claws, horns, antlers, and eggshell. It should be noted however, that some applications of isotopic provenance studies have been directed towards paleontological contexts, including analyses of samples from Australopithecines (Copeland et al. 2011; Sillen et al. 1995) and extinct species of mammoth and mastodon (Hoppe et al. 1999; Hoppe 2004).

To date most archaeological applications of Sr isotope analyses have been applied to human remains to study various aspects of human movement. The same method can also be applied to any material or artifact that has sufficiently preserved quantities of biogenic strontium. For archaeological samples, the main restriction derives from our confidence (or lack thereof) in the authenticity of the sampled Sr, in other words whether or not the Sr being measured is biogenic or diagenic. The point being that a wide variety of archaeological materials are potentially suitable for Sr isotope analysis, either alone or in conjunction with various other traditional methods for the sourcing of artifacts and materials. Although limited in scope to date several recent studies have shown that strontium isotope analyses can be applied to provenance studies of non-skeletal materials such as wood, maize, carbonized grains, glass, shell, and wool (Benson et al. 2003; Degryse et al. 2010; English et al. 2001; Frei et al. 2009; Heier et al. 2009; Henderson et al. 2005; Shackleton and Elderfield 1990; Vanhaeren et al. 2004).

3.4 Light Stable Isotopes

Early research into the use of stable isotopes for dietary reconstruction dates to the late 1970's and early 1980's (DeNiro and Epstein 1978; DeNiro 1985; Schoeninger and DeNiro 1982, 1984; Schoeninger 1985; van der Merwe and Vogel 1978; Vogel and van de Merwe 1977). These studies clearly demonstrated a relationship between the isotopic composition of an animal's tissues and the isotopic composition of its diet. Archaeological applications of these methods soon followed and initial research provided promising results for the future of paleodietary studies. Subsequent field and laboratory studies however, highlighted the existence of a number of complex and complicating factors (Ambrose 1990, 1991; Ambrose and Norr 1993; Ambrose and Katzenberg 2000). The last thirty years have witnessed a tremendous amount of research involving archaeological applications of stable isotope analyses to paleodietary reconstruction, including advances and developments in methodological and theoretical aspects of these perspectives (Ambrose 1990; Ambrose et al. 1997; Ambrose et al. 2003; Balasse et al. 2002; Keegan and DeNiro 1988; Le Huray et al. 2006; Richards et al. 2002; Schoeninger 2009; Schroeder et al. 2009; Schwarcz et al. 2010; Thornton et al. 2011). Carbon and nitrogen isotope analyses are now routinely applied to archaeological human remains for the purpose of elucidating past dietary practices, albeit with a greater appreciation of the scope and limitations of these approaches. A brief summary of the principles of oxygen and carbon isotopes analyses are provided below and highlight issues that are relevant for migration research in the Caribbean.

3.4.1 Carbon Isotopes

There are three naturally occurring isotopes of carbon (^{12}C, ^{13}C, and ^{14}C) with relative proportions of 98.9%, 1.1%, and <0.0001%, respectively. ^{14}C is radiogenic being produced by the radioactive decay of ^{14}N when subjected to cosmic radiation in the atmosphere. ^{14}C isotope analysis has a long history within archaeology for the purpose of absolute dating of organic materials since the first development of the method by Libby and colleagues in 1949 (Arnold and Libby 1949). It is important to note that in order to properly interpret radiocarbon data arrays, the isotope ratios of ^{13}C /^{12}C are routinely analyzed when samples are submitted for ^{14}C dating. This means that it is possible to obtain relevant information on paleodietary practices in conjunction with radiocarbon data, often at little additional expense. Because of the principles of mass dependent fractionation, the ratio of ^{13}C /^{12}C is affected by a number of natural chemical and physical processes and thus varies between the environment and the body tissues of different organisms (Katzenberg 2008). ^{13}C /^{12}C ratios are often reported as delta (δ) values in parts per thousand (‰) relative to an international standard (Pee Dee Belemnite, a marine carbonate fossil).

Carbon isotope analyses of enamel and bone apatite and bone collagen have been successfully applied to paleodietary studies for several decades. Carbon isotope values from collagen ($\delta^{13}C_{co}$) and apatite ($\delta^{13}C_{ap}$) reflect different aspects of consumption, with $\delta^{13}C_{co}$ primarily reflecting sources of dietary protein and $\delta^{13}C_{ap}$ reflecting an average of whole diet (Ambrose and Norr 1993; Krueger and Sullivan 1984; Lee-Thorp et al. 1989). Carbon isotope analyses can also be conducted on either bone or teeth, with the former providing information on long term dietary patterns and the latter providing information concerning dietary consumption patterns during childhood. Carbon isotope values of human skeletal carbonate ($\delta^{13}C_{ca}$) reflect the isotope composition of dietary sources of carbon. Carbon is incorporated into plant tissues via three distinct photosynthetic pathways (C_3, C_4, and CAM) and plants utilizing C_3 versus C_4 pathways possess distinct $\delta^{13}C$ signals in their tissues (Bender 1971; Katzenberg 2008). In the Caribbean, C_3 plants have more negative $\delta^{13}C$ values, averaging approximately -25.5‰ and C_4 plants have less negative $\delta^{13}C$ values of around -9.5‰ (Pestle 2010). Owing to the effects of fractionation there is an offset in $\delta^{13}C$ between an individual's diet (the consumed) and an individual's skeletal tissues (the consumer). The degree of fractionation between enamel or bone $\delta^{13}C_{ap}$ values and diet is somewhat variable ranging from ~9.6‰ in rats to as high as 14.6‰ for cattle (Ambrose and Norr 1993; Howland et al. 2003; Passey et al. 2005). As $\delta^{13}C_{ap}$ is generally reflective of whole diet, and strongly influenced by the consumption of fats and carbohydrates, it can be used to infer the relative contributions of different categories of plant resources (C_4 versus C_3) to an individual's diet.

For this study, carbon isotopes in dental carbonate were analyzed to assess intra- and inter-regional differences in sources of dietary carbon and to help constrain the possible origins of individual immigrants at multiple scales. A large body of carbon and nitrogen bone isotope data from indigenous populations of the Caribbean has been developed over the last few decades (Laffoon and de Vos, 2011; Norr, 2002; Pestle, 2010; Stokes, 1998). At a macro-regional level, $\delta^{13}C_{ap}$ values display somewhat limited variation and indicate relatively modest contributions of C_4 plants to prehistoric Antillean diets. At archipelagic or insular scales, spatial patterning of bone collagen $\delta^{13}C$ and $\delta^{15}N$ values indicates some regional variation in dietary practices within the Antilles possibly as a result of biogeographic principles (Stokes 1998, 2005). For example, there is limited overlap in $\delta^{13}C_{co}$ and $\delta^{15}N$ clusters between the Greater and Lesser Antilles. The higher $\delta^{13}C_{co}$ and $\delta^{15}N$ values amongst the populations of the Lesser Antilles reflect a greater reliance on marine protein resources (owing to the relative paucity of terrestrial fauna on these smaller islands) relative to the Greater Antilles. Despite some degree of regional clustering of bone apatite ($\delta^{13}C_{ap}$) in the Antilles, the spatial patterning is much less distinct than the general pattern for collagen ($\delta^{13}C_{co}$) with a higher degree of overlap in the ranges of values between most islands and regions (Pestle 2010; Stokes 1998).

3.4.2 Oxygen Isotopes

Oxygen isotopes of skeletal tissues are primarily influenced by the isotopic composition of consumed water but are also influenced by the water in consumed food, food itself, as well as thermophysiology (Daux et al. 2008; Longinelli 1984; Luz et al. 1984; Podlesak et al. 2008). The primary source of consumed water for most ancient populations is expected to be locally obtained drinking water which should correlate with meteoric and groundwater sources in most Amerindian contexts in the Antilles. Globally, meteoric $\delta^{18}O$ varies spatially primarily according to geographical and climatic variables, with $\delta^{18}O$ generally decreasing with increasing altitude, latitude, and distance from the coast or source of atmospheric water vapor (Bowen and Wilkinson 2002; Gat 1996). At smaller spatial scales, in tropical regions, rainfall regimes are primary factors influencing the spatial variation of $\delta^{18}O$ in meteoric water (Dansgaard 1964). Although there are broad similarities in rainfall regimes throughout the tropics, there is also substantial variation in the geographic and climatic conditions that influence $\delta^{18}O$ variation and clear spatial patterning in $\delta^{18}O$ exists at regional and local scales.

Oxygen isotope analysis of human skeletal tissues has also shown potential for archaeological investigations of human migration and residential mobility in various regions of the world (Bentley and Knipper 2005; Budd et al. 2004; Knudson 2009; Montgomery et al. 2005; Prowse et al. 2007; Schwarcz et al. 1991; White et al. 1998; Wright et al. 2010). $\delta^{18}O$ measurements can be conducted on the carbonate (CO_3) and/or phosphate (PO_4) components of bioapatite, which have been shown to produce different but comparable results in unaltered samples (Chenery et al. 2012). The direct comparison of $\delta^{18}O_c$ and $\delta^{18}O_p$ values requires either the conversion of one type of oxygen isotope value to the other or a conversion to drinking water oxygen isotope values. Although several formulae for converting these values have been proposed recently, there is still some debate about their application, accuracy, and compounded errors (Bell et al. 2010; Chenery et al. 2012; Millard and Schroeder 2010; Pollard et al. 2011). Additionally, oxygen isotope analyses of human skeletal tissues can be conducted on either bone or enamel. Owing to the much higher susceptibility of bone to diagenesis, bone oxygen isotope results should be used with caution. Enamel is considered much more resistant to diagenetic contamination than bone and as such enamel isotope results are considered to be more reliable (Hedges 2002; Hoppe et al. 2003; Lee-Thorp and Sponheimer 2003; Trickett et al. 2003). Enamel and bone isotope data also provide different information concerning provenance. In humans, dental enamel of most permanent teeth mineralizes during childhood (Hillson 1996) and does not undergo substantial remodeling throughout life and is therefore reflective of the biochemical environment of an individual's childhood origin. Bone continuously remodels so that bone isotope values reflect the last years or decades of life and are less informative of natal origins.

Oxygen isotope analysis of enamel carbonate has been successfully applied to human remains from Barbados to distinguish between first generation (African) and later generation (Barbadian) slaves at the colonial period cemetery of Newton Plantation (Schroeder et al. 2009). At this site, first generation (forced) migrants from Africa possessed clearly distinct $\delta^{18}O$, and in some cases distinct $\delta^{13}C$ and dental modification practices, from locally born slaves. Owing to broadly shared environmental and climatic parameters influencing the spatial patterning of oxygen isotopes within the Antilles, we expected relatively limited variation in $\delta^{18}O$ amongst the indigenous populations of the region. For example, all of the sites in this study are within a few kilometers of the coast, at or near sea level. These similarities in geographic setting essentially eliminate two of the primary sources of variation in $\delta^{18}O$ of rainwater, namely distance from coast and altitude. Another possible, but unlikely, source of variation between our sample populations is latitude, which ranges from approximately 10° North from the most southerly site in Trinidad to 21° North at the most northerly site in Cuba.

Temporal variation at multiple scales, from seasonal or annual fluctuations in the amount of rainfall, to long-term climate change, represents another source of $\delta^{18}O$ variation. Paleoclimate research has documented long-term changes in environmental and climatic conditions in the Caribbean over the last several thousand years (Beets et al. 2006; Curtis et al. 2001; Hodell et al. 1991; Peros et al. 2007) although the degree of variation in $\delta^{18}O$ represented by these proxy data over the time period represented in our study (~ AD 600-1600) appears minimal relative to other potential sources of variation. Differences in rainfall regimes probably represent one of the largest sources of variation in meteoric $\delta^{18}O$ within the Antilles. Prevailing winds are generally from the northeast, and on the islands with high topographic relief there is substantial orthographic precipitation producing generally wetter conditions on the northeast coasts (for example the El Yunque rainforest on Puerto Rico) relative to the southwest coasts of these islands.

3.5 Summary

Traditionally, isotope analyses of human remains have been divided into paleodietary applications utilizing carbon and nitrogen isotopes and paleomobility applications utilizing strontium and/or oxygen isotopes. Increasingly, integrated approaches based on multiple isotope analyses have been systematically applied to human skeletal populations from different regions of the world (Bentley et al. 2007a; Knudson and Price 2007; Montgomery et al. 2005; Price et al. 2010; Sealy et al. 1995; Turner et al. 2009; Wright et al. 2010) to assess various aspects of individual identity. These multi-isotope approaches are deemed highly complementary because 1) as dietary patterns often display spatial variation, they can also contribute to assessments of geographic origins (Dupras and Schwarcz 2001; Müldner et al. 2011); and 2) dietary practices can change as the result of migrations or movements between diverse cultural or ecological areas (Knudson et al. 2010a; Sealy et al. 1995). Although, most applications of carbon and nitrogen isotope analyses to human remains in the Caribbean have explicitly focused on paleodietary reconstructions, several recent studies have begun to utilize $\delta^{13}C$ and $\delta^{15}N$ data to investigate issues of identity and individual origins (Schroeder et al. 2009; Varney 2007). This study utilizes a multiple isotope approach that is primarily based on strontium isotope analysis of dental enamel from a large number of human (and biosphere) samples, supplemented by oxygen and carbon isotope analyses of dental enamel from a subset of the total human sample population. These isotope results are also interpreted in the context of published carbon and nitrogen isotope data generated from prehistoric human bone material in the Caribbean.

CHAPTER 4 METHODS AND TECHNIQUES

4.1 Introduction

In this chapter, I present different aspects of the overall methodological approach taken in this study. I begin with a detailed discussion of the sampling design and sample collection strategies, pertaining first to the selection of bioavailable samples (animals and plants) and then to human samples for Sr isotope analysis. This is followed by a presentation of the sample processing protocols employed in this research project for the different sample types and materials. Next, the laboratory methods and procedures for the separation and purification of strontium are provided. Then, I discuss the measurement of strontium isotope compositions using Thermal Ionization Mass Spectrometry (TIMS), including the results of the analyses of standard reference materials and total procedural blanks. Finally, I present the protocols and procedures for the sampling, processing, and measurement of oxygen and carbon isotope ratios in human dental enamel samples via gas source Isotope Ratio Mass Spectrometry (IRMS).

4.2 Sample Collection Strategies

The selection of appropriate ancient human skeletal assemblages from the Caribbean region was an important consideration for addressing the research questions of this study. One of the primary goals was to collect samples from a wide range of geographic, cultural, and chronological settings within the Caribbean region. In order to make comparisons between different groups it was necessary to collect and analyze skeletal assemblages from different islands within the region. However, due to a variety of reasons (from variable conditions of preservation to varying histories of archaeological research) not all regions of the Caribbean possess large, systematically excavated, pre-Columbian skeletal assemblages. For example, some islands have not been subjected to extensive, research-oriented archaeological investigation while others have been the foci of research but have not yielded large skeletal collections to date. For this project, we focused on the inclusion of large assemblages from controlled contexts, e.g., from which relevant and necessary contextual data were available. Contextual data in this sense refers primarily to demographic (sex and age); mortuary (location, type, and positioning of burials and grave inventories); chronological (radiocarbon and/or relative dating from associated materials); and dietary (stable isotope, paleobotanical, and zooarchaeological results) data.

4.2.1 Collection of Faunal and Botanical Samples

As discussed in Chapter 3, most attempts to interpret strontium isotope results derived from human remains rely on assessments of local ranges of Sr isotope variation. This can be accomplished through various means and for this project we chose to incorporate a number of lines of evidence into our local range estimates. Price and colleagues (2002) have proposed that the remains of certain species of archaeological fauna may provide the most reliable measures of local Sr isotope variation for a given site. Price has also suggested a ranking of various sources of local Sr isotope data with archaeological fauna representing the most robust source (Price et al. 2002).

Archaeological faunal remains are considered representative of local signatures under the assumptions that certain species have restricted feeding ranges, that they are obtaining the vast majority of their subsistence resources (and hence strontium) locally, and that archaeological fauna are much less likely to have consumed imported foodstuffs or environmental pollutants relative to modern faunal samples (Bentley 2006; Price et al. 2002). Modern fauna can be used if archaeological faunal remains are unavailable but are considered somewhat less reliable sources of data owing to the possibility that modern fauna may be consuming food products that have been moved substantial distances through human agency and/or owing to potential sources of modern contamination including a number of widespread environmental pollutants, fertilizers, pesticides, herbicides, and so on.

Macro-botanical remains are rarely preserved in significant quantities in archaeological deposits, especially in tropical contexts, and thus are not considered as a realistic source of Sr isotope data within an extensive sampling strategy. Although, where available, they may constitute another possible source of local Sr data. Modern botanical remains can be utilized for local range assessments but greater care must be taken with sample collection to avoid the previously mentioned problems concerning the ubiquity and widespread use of various modern chemicals and potential anthropogenic-induced environmental changes.

Thus our main sources of information for defining local strontium isotope ranges come from several sources, these include analysis of locally derived samples of: 1) archaeological fauna, 2) modern fauna, 3) and modern flora. Other sources of data are derived from the published literature on Sr isotope variation in the Caribbean derived from geochemical analysis of various geological samples (whole rock, mineral, and soil) samples (Roobol and Smith 1980; Wadge and Wooden 1982). These data are utilized in conjunction with the statistical analysis of patterns in the main data set derived from Sr isotope analysis of human dental enamel.

The vast majority of faunal remains included in this project consist of dental enamel samples of rodents from archaeological deposits and from land snail shells, both archaeological and modern. The rodent remains primarily come from rice rat and hutía remains (*Oryzomys sp*. and *Capromyidae*, respectively) and were chosen based on several parameters. These include the assumptions that: 1) owing to their ubiquitous presence, they were not widely transported from island to island or region to region; 2) they have fairly restricted subsistence ranges; 3) when available they will often consume human food refuse, and thus consume similar foods as humans; and 4) there is evidence that rodents (and possibly also snails) themselves were consumed by humans in the ancient Caribbean (deFrance et al. 1996; Newsom and Wing 2004). In other words, we propose that rodent remains from archaeological refuse deposits represent animals that were probably living and subsisting locally (most likely the same island, and possibly the same catchment or habitat) as the humans living at the site and thus most likely shared in common a similar subsistence base despite potential differences in dietary breadth. Furthermore, it is likely that if these creatures were captured locally that they were also consuming products from house gardens and midden or refuse deposits and they may have eventually ended up in a site's deposits via the 'dinner plate'.

Modern and archaeological land snail shells of various species were chosen based on the same parameters and assumptions as the rodent remains. They are however, even more ubiquitous and thus even less likely to have been moved from island to island by humans. In addition, land snail shells are still readily available in many areas of the Caribbean, and from a logistical perspective are easy and inexpensive to find, collect, and process. In many cases where archaeological faunal remains were absent or unavailable, modern land snail shells were collected, primarily from extant archaeological sites or uncultivated areas, and are considered to be fairly reliable representatives of local Sr isotope signatures.

Fortunately, we were able to collect a number of faunal remains from all of the sites/regions from which we have collected and analyzed human remains. Therefore, we have robust datasets for local range estimations for most of these skeletal collections. However, an important aspect of this project was to develop a database of biosphere Sr isotope variation for the greater circum-Caribbean region and thus we have attempted to make initial assessments of this variation for most of the Caribbean islands and certain areas of the adjacent coastal mainland, including also islands and regions from where human remains were not available or were not analyzed. Nevertheless, there are several islands and areas within the Caribbean region from which no samples were collected owing to limitations of time, resources, and/or logistical concerns.

In order to broaden our sample collections and to make them more comparable we chose to collect and analyze botanical samples from all of the islands and coastal regions included in this study. This was also done to provide auxiliary or secondary lines of evidence in contexts where faunal and human remains had been incorporated into the study and to provide an initial baseline of Sr variation and ranges in islands/regions from where no other evidence was available. The collected botanical specimens were primarily grasses (family *Poaceae*) but other types of botanical samples (e.g., tree leaves) were also collected in a few instances. In fact, for botanical samples the choice of species is somewhat less important than for faunal sample collection as any plants within a small, geologically homogenous region should share *broadly* similar Sr isotope ratios. However, some variation does exist between certain species sharing the same ecosystem and even within individual specimens, owing to variable conditions within the local hydrological system, fluid dynamics, soil matrices, and so on (Dijkstra et al. 2003; Pozwa et al. 2000; Pozwa et al. 2002; Pozwa et al. 2004).

Another potential limitation of using botanical samples relative to faunal samples to determine local Sr range estimations is that botanical samples primarily reflect the localized geology of the soils from which they derive their nutrients along with variable contributions from atmospheric sources (Bentley 2006). Thus they lack one of the other main benefits of faunal samples, the tendency of 'bio-averaging' (Price et al. 2002). Any local variations of Sr isotope signatures tend to become 'averaged out' within the tissues of animals as they consume various foodstuffs from the local environment and incorporate trace elements into their bodies, making the Sr values within their tissues more directly comparable to that of human consumers (Price et al. 2002).

Despite these limitations and the previously mentioned potential issues concerning modern environmental contaminants/pollutants, several studies have concluded that the strontium within plant tissues is primarily derived from local soil geology and thus should be broadly reflective of local strontium isotope variation (Bentley 2006). For this reason, we have incorporated them into our analysis with the caveat that these data are considered to be somewhat less reliable than other sources used in this project and that the potential influences of the various environmental parameters need to be taken into consideration in terms of sample selection strategies.

To minimize the potential that the collected botanical samples had been directly subjected to contamination through the application of fertilizers, pesticides, herbicides, or industrial pollutants we generally avoided collecting samples from areas of either urban development or commercial cultivation. These restrictions focused our sample selection and collection primarily to rural areas, for example: trails, forested woodlands, open pastures, inter-property fence-lines, and so on. Our sampling strategy was also influenced by several other important variables. First and foremost, for islands that are less geologically homogenous, we attempted to collect botanical (and where possible faunal) samples from multiple geological regions in order to broaden our coverage and detect intra-island isotopic variations.

Other sampling parameters attempted to account for intra-island variation of strontium isotope signals owing to variable rates of atmospheric contributions of strontium from marine-derived rainwater or sea-spray (Bentley 2006; Price and Gestsdóttir 2006). Therefore, particularly for the more geologically homogenous regions and islands, we also attempted to collect samples based on altitude, distance from coast, leeward/windward sides, and overall coverage. The aim of this sampling strategy was to characterize intra-island isotope variation owing to varying marine effects as opposed to variability in underlying geology per se. In fact, the island of Saba was chosen as a case study for this approach as it is a very small (~13 km^2) and rather geologically homogenous island. Saba is primarily composed of geologically young volcanic bedrock with low-lying areas covered by Quaternary alluvium (van Soest et al. 2002). We systematically and intensively collected over 50 faunal and botanical samples from Saba for the purpose of elucidating the dynamics of marine effects and determine the relative contributions of various strontium sources to the local island ecosystem (Laffoon and Hoogland 2009).

In summary, our sampling strategy for the collection of comparative and representative strontium isotope data for the greater Caribbean was both systematic and opportunistic. We based our sample selection decisions on the suggestions of other prominent researchers in this field, namely that archaeological faunal remains represent the most reliable source of this type of data. Concerted efforts were made to collect archaeological faunal remains, with a specific focus on dental enamel from native rodents and land snail shells, for any site for which we also analyzed human remains. Modern faunal samples (land snail shells) were also collected, even if archaeological samples were available, to broaden our sample set.

Lastly, botanical samples were collected, under strict parameters, from nearly every island of the Caribbean to provide a secondary base-line to constrain the local bioavailable Sr isotope ranges. These baselines can be further refined by future research but provide us with the necessary data for initial attempts at determining potential geographical origins for human individuals identified as nonlocals within our sample set. It is also hoped that other researchers, not only archaeologists but also geologists and ecologists, can make use of this Caribbean Strontium Isotope Database to be constructed with the extensive data produced by our research. For example, potential applications include research into the provenance of widespread indigenous Caribbean wood-carvings (Ostapkowicz et al. 2009) or investigations of the geographic origins of individuals interred in mixed population colonial era cemeteries (Goodman et al. 2004; Jones et al. 2003; Price et al. 2006).

4.2.2 Collection of Human Dental Samples

For human dental samples, we chose to sample permanent (adult) premolars when present and in good condition, i.e., whole and intact with no large carious lesions. If not present, we sampled any tooth that was available and in good condition with priority placed on first and second molars, then incisors and canines. Third molars were generally avoided unless no other tooth was available because the time of formation and mineralization of M3's occurs later in life relative to most other teeth, with crown formation only beginning around 7-13 years of age (Hillson 1996; White and Folkens 2005) such that they are less obviously reflective of the geochemical environment of early childhood. In fact, any tooth will work from the perspective of our analysis but the identification and interpretation of localness and migration is more problematic for third molars, owing to the somewhat increased likelihood that the individual may have moved during their early childhood years, movement which would not be identified if occurring before the formation of the third molars. In total, more than 60% of the human dental samples are premolars with the remainder represented by a combination of other dental elements.

Permanent teeth were preferentially sampled (see Appendix B), even for children, unless they were not present or not sufficiently mineralized and thus more susceptible to diagenic contamination of the dental enamel by the burial environment. In general, we expect that children will be less mobile than adults, owing to the fact that having died in childhood they had less time (and opportunities) within their relatively brief lives to have migrated. However, this is a hypothesis that needs to be tested. Similar research into past human mobility from a biogeochemical perspective (Cucina et al. 2005; Goodman et al. 2004) suggests that children are generally less mobile than adults. However, as some children have in fact been identified as nonlocals or migrants, this point remains a rough generalization that probably varies according to the mobility system of the population in question. Nonetheless, we propose that for many contexts the Sr isotope signatures from the remains of children are more likely to be representative of the local isotopic signature than not and thus they can provide an independent assessment of the local range. For this reason, the inclusion of a small number of dental samples from children and infants (including deciduous teeth) was also a component of our sampling strategy. Lastly, relevant information concerning the sample locations for human skeletal materials including detailed descriptions of site histories, contexts and settings are presented in chapter 5.

4.3 Strontium Isotope Analyses: Sample Processing

As the procedures for processing different types of samples (human, faunal, botanical) and different sample materials (enamel, shell, plant tissues) vary, these will be discussed separately. However, after the preliminary sample processing and chemical treatments, all samples are subjected to the same procedures for strontium extraction and isotope analysis. All sample processing was done under controlled conditions at the Faculty of Earth and Life Sciences, The VU, Free University of Amsterdam, The Netherlands. The processing of dental enamel from humans and rodents is essentially the same and so both will be included in this section. If the selected tooth was still covered in soil matrix, it was sonicated for 1 hour in Milli-Q water before processing was begun but this step was only necessary for a small number of samples. For most samples mechanical cleaning and removal of the outer surface (soil, calculus, staining) and outer-most layers of enamel was sufficient to reveal the inner core enamel from which the enamel was extracted for later analysis. The cleaning and extraction of the enamel was accomplished by means of a variable speed dental micro-drill, specifically a Minilor Perceuse M1 hand-held drill with an AFX DC regulated power supply (0-15V, 2A) outfitted with a diamond-tipped rotary burr.

All cleaning procedures were performed wearing protective gloves and a laboratory coat in a designated room away from the clean lab. The work station was cleaned using ethanol and Milli-Q water, and dried with compressed air (the university compressed air supply is filtered and dried to ensure cleanliness and minimal water content). The drill bit was cleaned by successive placement into 1) ethanol, 2) Milli-Q water, 3) 0.15 N HCl, 4) Milli-Q water, and 5) dried with compressed air. This process was repeated twice and was performed for each surface cleaning of the tooth and then again prior to mechanical enamel removal. A specific surface of the tooth was chosen for sample extraction and this area was then thoroughly cleaned using the drill to abrade away any superficial deposits including calculus, soil, stains, and the first several microns of outer enamel. The inner core enamel is readily identifiable owing to its milky-white color and homogenous texture. Usually only the area of the surface around the sample extraction site was cleaned but if necessary the entire surface of the crown and sometimes even the root was cleaned to prevent loose particles from contaminating the extracted enamel sample.

The workstation and drill were then re-cleaned as previously described and the tooth itself was blown clean using filtered, compressed air to remove any remaining dust or dirt. Approximately 1-5 mg of enamel (about the size of a small dental filling) was then extracted by directly abrading the exposed inner core enamel with the drill bit following the protocols of Knudson (2008). The enamel powder was collected on a fresh sheet of weighing paper and then transferred to a pre-cleaned/pre-treated 1 ml centrifuge tube, weighed, and then taken to the clean lab for chemical treatment and processing.

All lab hardware (teflon and quartz beakers, pipette tips, centrifuge tubes, etc...) was pre-cleaned following the methodology outlined in designated sections of the *Laboratory for Geochemical Analysis* (a class 100 clean laboratory). Except where stated, hardware was leached in 6-7 N HCl in a laminar flowhood for several hours to several days depending on container material type, rinsed with demi-water and then Milli-Q water, leached in 3N HNO3, re-rinsed with Milli-Q water and then dried, sealed, labeled, and weighed for later use.

Land snail shells were either drilled or broken by hand within the sample bags and the fragments were sonicated in Milli-Q water for one hour, rinsed with Milli-Q water, dried, weighed, and then transferred to clean 30 ml Teflon beakers before being taken to the clean lab for further processing (see below).

Plant samples were dried immediately after collection by setting them in the sun, drying over a vent, microwaving, or with a hair-dryer. After transport, bagged samples were frozen for several days and if necessary, dried again on aluminum foil in a drying oven at 50 ^{o}C for 1-2 days to remove all moisture and arrest any decay. Approximately one gram of plant leaf or stem was then removed and placed into a pre-cleaned, sealed titanium crucible. The dried plant samples were ashed within a (Heraeus model) muffle furnace at 500 ^{o}C for 12 hours and then allowed to cool. Ashed samples were then transferred to pre-cleaned 30 ml PFA vials under a laminar flow-hood and weighed again before being taken to the clean lab for further processing (see below).

Dissolution procedures vary between enamel, shell, and ash (plant) samples and each of these will be discussed separately. All chemical procedures were performed under controlled conditions within a laminar flow-hood within a specially designated clean lab (class 100), using specific laboratory procedures for the minimization of sample contamination, including the use of protective gloves, sleeves, eyewear, footwear, and lab coats. All centrifuge tubes, PFA vials, beakers, and pipette tips were pre-cleaned within the clean lab, to remove potential contaminants using previously discussed procedures.

Ash samples were processed as follows: 1) Ash samples were weighed within pre-weighed and pre-cleaned vials; 2) Samples were dissolved in 10ml of concentrated, distilled nitric acid (14N) and then dried down on a hotplate at 120 ^{o}C for around 12 hours. This step was repeated twice; 3) Samples were then dissolved in 2 ml of conc. HNO_3 and 200 μl of H_2O_2 and then dried down again on a hotplate. This step was repeated; 4) samples were re-dissolved in 3N HNO_3, centrifuged at 10,000 rpm for 4 minutes and the supernatant was removed and placed into a new pre-weighed, pre-cleaned vial; 5) Samples were then dried down and re-nitrated with 500 μl of 3N HNO_3 and reweighed; 6) A 10% aliquot was removed for trace element analysis by ICP-MS; 7) The samples were centrifuged and then loaded onto cation exchange columns pre-loaded with strontium-specific resin for isotope separation (see below for details of strontium separation procedures).

Enamel samples are chemically processed somewhat differently than those of ashed botanical materials. As dental enamel consists of approximately 97-99% calcium hydroxylapatite, there are fewer steps required to eliminate the presence of organic components within the sample matrix compared to ashed plant samples. Enamel samples from both human and faunal remains were processed as follows: 1) Powdered enamel was dissolved briefly (20-30 minutes) in 0.5 ml of acetic acid (to remove extant exogenous calcium carbonate), centrifuged at 12,000 rpm for four minutes, and the liquid portion removed and discarded; 2) Samples were washed in 0.5 ml of Milli-Q, centrifuged again, and the supernate removed and discarded; 3) Samples were nitrated with 0.5 ml of 3N HNO_3 and then dried down; 4) A 10% aliquot was removed for future trace element analysis by ICP-MS; 5) Prior to strontium separation, samples are dissolved for 30-60 minutes in 3N HNO_3 and then centrifuged at 12,000 rpm for 4 minutes and then loaded onto pre-prepared strontium separation columns.

Land snail shell samples differ from enamel samples in that they consist primarily of calcium carbonate and thus are processed in a slightly different manner. The procedures for chemical treatment of shell samples are identical to that of enamel samples except that they are not initially subjected to an acetic acid wash and instead are simply rinsed with de-ionized, de-mineralized (Milli-Q) water.

The separation of the strontium component of the samples from other elements in the sample matrix after chemical dissolution is accomplished by running the nitrated samples through specially designed separation (cation exchange) columns. These columns consist of hand-blown quartz glass columns with a 0.8 ml loading reservoir and a tapered column with a small glass frit material at the bottom. These columns are pre-treated/cleaned and then loaded with (~0.12 ml) strontium-specific, crown-ether resin (Eichrom) slurry, which is specifically designed to bind only to strontium. After thorough cleaning of the resin columns, the samples are loaded onto the columns and as the liquid passes over the resin, Sr nitrate molecules bind to the resin while allowing other elements to pass through the column. Milli-Q water is later loaded onto the column which alters the pH as it passes through the column, thereby altering the binding sites and allowing the strontium to be released and pass through the column and be collected in pre-cleaned vials.

The steps for column preparation and strontium separation are as follows: 1) glass columns are normally stored in 3N HNO_3 but prior to column preparation, they are rinsed with Milli-Q water and placed onto a pre-cleaned holding rack; 2) A resin slurry (~0.12 ml), of equal parts Eichrom Sr Spec resin (100-150 um diameter) and Milli-Q water, is then loaded into the column reservoir and allowed to settle into the tapered bottom; 3) The resin is then cleaned by washing alternately with 3N HNO_3 and Milli-Q water, three times each; 4) The resin is then pre-conditioned with 0.5 ml 3N HNO_3 (to ensure that the pH within the column is ideal for the strontium-binding capacity of the resin); 5) The pre-prepared samples (~0.4 ml) are then loaded onto the columns; 6) The samples are washed over the resin by sequentially adding 0.2 ml of 3N HNO_3, five times and then with a final wash of 0.8 ml 3N HNO_3 (this is doubled for ash samples which tend to be 'dirtier' in the sense that they potentially contain more organic components that can interfere with the separation process); 7) After the nitric acid pre-fraction has totally passed through the columns, the pre-fraction collection vials are replaced by pre-cleaned 5 ml collection vials and 0.8 ml of Milli-Q water is added to the column reservoir; 8) The strontium fraction is then collected, dried down on a hotplate, and then as a final step nitrated and dried down twice with concentrated HNO_3. Strontium samples are then ready for loading onto filaments for isotope analysis via TIMS.

4.4 TIMS - Thermal Ionization Mass Spectrometry

Several methods for the analysis of strontium isotopes exist and different types of mass spectrometry can be utilized for the analysis of strontium isotopes from human and animal remains to address various research questions (Balter et al. 2008; Bentley et al. 2007a; Booden et al. 2008; Nowell and Horstwood 2009; Richards et al. 2008; Simonetti et al. 2008). The most common means of measuring strontium isotope compositions of these material types are ICP-MS and MC-ICP-MS (in solution mode or through the direct ablation of solid-state samples via the coupling of a laser to the mass spectrometer) and TIMS. The use of chemical separation procedures and isotopic analysis via TIMS represents the longest and most widely used method for strontium isotope analysis in archaeological contexts (Ezzo et al. 1997; Grupe et al. 1997; Price et al. 1994a; Price et al. 1994b).

This approach was taken within this research project for a variety of reasons. Several decades of analysis via TIMS, has indicated that this robust method routinely produces precise, reliable, and consistent results (Nowell and Horstwood 2009). TIMS is also relatively inexpensive, especially if one prepares, processes, and analyzes their own samples. Furthermore, the purported advantages of LA-ICP-MS, namely minimization of sample destruction and speed of sample processing relative to other factors, particularly data quality, have not been borne out by recent research. More explicit discussions of the pros and cons of various methods of strontium isotope analyses, can be found in (Copeland et al. 2008; Copeland et al. 2010; Nowell and Horstwood 2009; Simonetti et al. 2008).

4.4.1 TIMS - Filaments

Strontium isotopes ratios within samples were measured on a TIMS by using annealed rhenium ribbons mounted onto metal sample loading brackets. Sample strontium is imbedded within a tiny ceramic bead of tantalum salts, which is loaded onto the filament and eventually into the TIMS machine. The ceramic bead thus generated reduces the rate of strontium evaporation, causing the Sr to evaporate at higher temperatures. This higher temperature causes greater thermal ionization and thus provides higher ionization efficiencies.

The first step in this process is to make rhenium filaments onto which the sample can be loaded and then placed into the machine where it can be heated through the application of an electric current (all previously used Re is removed and the filament holder is cleaned with a file or an abrasive drill). This is accomplished by welding a ~1.2 mm strip of rhenium ribbon onto the filament loading bracket using a high-precision welder with a current of 4 amps. ‘Filaments’ in this terminology consist of a small metal loading bracket with a thin rhenium ribbon welded onto it.

The metal brackets themselves and their associated plates and shields are all reusable but the ribbons themselves are not. The hardware (brackets, plates, and shields) are pre-cleaned with the following protocol: 1) The hardware is washed by scrubbing the surface with a combination of demi-water and powdered aluminum, and then rinsed thoroughly with demi-water; 2) Then the hardware is boiled in demi-water for 25 minutes and then boiled in Milli-Q water for 25 minutes; 3) The hardware is then dried in an oven at 100 ^{o}C for 1 hour.

The filaments are then further cleaned by removal of contaminants (from the air and water) by subjecting them to high temperatures at vacuum; this is known as 'out-gassing'. The out-gassing procedure consists of loading the filaments into a designated chamber within a ThermoScientific Bakeout Device. This machine de-pressurizes the internal chamber containing the filaments to a pressure of $< 2 \times 10^{-6}$ bar and applies a high current to all of the filaments. This increases the surface temperature to 1.5-2.0k ^{o}C and thus evaporates and/or ionizes any surface contaminants on the Re filament. This step is essential because it is necessary to remove (as much as possible) any potential source of strontium other than the sample which is to be analyzed. These steps and others are thus designed to provide confidence that the measurements produced are derived from the sample itself and not from other sources.

4.4.2 Loading Samples

Strontium samples were loaded onto the prepared filaments according to the following procedures. 1) dried samples were dissolved in 2 µl of 3 N HNO_3; 2) filaments were attached to a specially designed loading device which allows a current to be passed through the filament; 3) a 1.1 A current is applied to the filament and a small amount of parafilm is melted onto the filament in two places to produce 'dams' that prevent the loaded sample from spreading across the entire filament; 4) the current is reduced to 0.9A and 2 µl of $TaCl_5$ and 1 µl of H_3PO_4 is placed onto the filament; 5) 2 µl of nitrated sample (or standard) are then placed onto the filament and the mixture is allowed to dry down; 6) the current is sequentially increased to 1.2, 1.5, and 2 amps to dry down the sample, burn off the parafilm, and evaporate the phosphoric acid, respectively; 7) the sample is heated to a dull red color to fully dry the sample; 8) the loading bracket with samples is then placed onto a loading turret which is subsequently placed into the source chamber of the TIMS and at least one external standard (NBS-987) is analyzed with every 12 samples.

4.4.3 TIMS – Operating Parameters

All samples were analyzed for strontium isotope composition with a thermal ionization mass spectrometer (TIMS, ThermoFinnigan MAT 262 RPQ plus) at the Faculty of Earth and Life Sciences of the VU, Free University Amsterdam, The Netherlands. The source chamber with loaded samples (and standards and blanks) is pumped down to a vacuum of $< 8 \times 10^{-8}$ torr and a current is slowly applied to the appropriate filament. Samples are generally run at a current of 2.5-3.2 amps, producing temperatures of roughly 1400-1600 ^{o}C. The $TaCl_5/H_3PO_4$ mixture, within which the sample is loaded, creates a tiny ceramic-like bead which causes the strontium atoms to ionize at higher temperatures and thus tends to increase the ionization efficiency compared to previous methods that use only H_3PO_4. The ionization is accomplished thermally, hence the name TIMS, and after a brief interval to permit the burning off of any contaminants (including any residual rubidium), Sr isotope analysis can begin.

The ionization process generates charged particles that can then be manipulated via electromagnetic forces. The ion beam is thus focused and the particles spatially separated by mass such that ions of different masses can be collected and measured via Faraday collectors within the instrument. To avoid biases generated from potential differences between collector cups, for the first year of the project samples were measured with a dynamic triple-jumping method. All measurements were automatically corrected, using an exponential correction factor, to an ^{86}Sr/^{88}Sr value of 0.1194. Measurements were only accepted when the ^{85}Rb/^{86}Sr ratio was below 0.0002, indicating minimal presence of mass interference from rubidium. A minimum of 60 ratios per sample were collected, more if necessary, with a goal of obtaining a standard error of 0.000010 (2σ) or less for each sample. A small percentage (<3%) of samples produced standard errors (2σ) > than 0.000020 and were re-analyzed, thus samples included herein yielded signatures with a standard error of < 0.00002 (2σ). After the first year, samples were measured in static mode once it became clear that measurement precision of ±0.00002 was insubstantial in terms of the regional Sr isotope variations.

4.4.4 TIMS – Standards

Each set of samples on the TIMS included one or more standards, in addition to about 10-12 samples and blanks. For external reproducibility and quality control, we used the certified strontium carbonate ($SrCO_3$) reference material (NBS/NIST) SRM-987. Repeat measurements of the international standard over the period of analyses yielded a mean $^{87}Sr/^{86}Sr$ value of 0.710250 ± 0.00003 (1σ, n=81). Over the course of the project, samples and standards were analyzed using two different analytical modes. Analyses of the international standard (SRM-987) in dynamic mode produced more consistent results with a mean $^{87}Sr/^{86}Sr$ value of 0.710231 ± 0.000008 (1σ, n=27) that is within error of the accepted value and a lower standard deviation. Thus all samples analyzed in dynamic mode were not corrected (see Appendix A and B). Over the three year duration of the project, analyses of the international standard (SRM-987) in static mode produced slightly more variable results with a mean $^{87}Sr/^{86}Sr$ value of 0.710259 ± 0.000033 (1σ, n=54). This period included changes in collector performance that led to drift in the Faraday cups used for Sr isotope analysis. These changes caused transient variations in the values of the standard increasing the variance in the standard data. Consequently, all samples analyzed in static mode were normalized (in reference to the in-run value of the external standard) to the generally accepted $^{87}Sr/^{86}Sr$ value for the standard reference material of 0.710240.

4.4.5 TIMS – Blanks

For each series of samples that underwent chemical processing and strontium separation at least one total procedural blank was analyzed to test for the presence of ambient or intrusive strontium which may have potentially contaminated any of the reagents, hardware, or samples. Total procedural blanks were spiked after strontium separation with calibrated ^{84}Sr spike [serial code # 20080117]. Analyses of ^{84}Sr/^{86}Sr ratios were conducted with a minimum of one block (10 single scans) in static mode with the TIMS and the overall strontium concentration was calculated using the principles of isotopic fractionation (Faure and Mensing 2005). Over the course of our analyses, total procedural blanks yielded Sr concentrations typically less than 200 pg. Such low concentrations are considered negligible and insignificant relative to the Sr concentrations of the samples themselves, with loaded samples ranging from roughly 0.2 to 1.0 μg. Thus the typical sample contains at least a thousand times more strontium than the typical blank.

4.5 Carbon and Oxygen Isotope Analyses

Samples of human dental enamel from fifty individuals from eight different sites were analyzed for this study. Premolars were sampled when possible as their enamel crowns develop and mineralize roughly between the ages of two and six (Hillson 1996; White and Folkens 1999). Other teeth were sampled when suitable premolars were unavailable. Sampling focused on enamel which has been shown to be less susceptible to diagenic contamination than bone (Budd et al. 2000; Hoppe et al. 2003). Teeth were mechanically cleaned and approximately the first several microns of surficial enamel was removed to expose the inner core enamel which was removed using a hand-held drill dental drill equipped with a diamond-tipped burring tip. No additional pretreatment step was used but diagenic alteration of the enamel was not expected as previous analyses had revealed no correlation between strontium concentrations (ppm) and strontium isotope compositions. Contamination was also monitored via measurements of uranium concentrations via ICP-MS and were consistently low (<1 ppm). Carbon and oxygen isotope compositions were measured on a Finnigan DeltaPlus Isotope Ratio Mass Spectrometer following reaction of the carbonate sample with H_3PO_4 (100%) and isolation of the produced CO_2 on a Gasbench II universal automated interface (Faculty of Earth and Life Sciences, VU University, Amsterdam). Long term analyses of the NBS-19 international calcite reference standard yielded a reproducibility for $\delta^{13}C$ and $\delta^{18}O$ of <0.1‰ and <0.2‰, respectively. All $\delta^{13}C$ and $\delta^{18}O$ values referenced herein are reported in the δ notation, in parts per thousand (‰) relative to the international PDB (Pee Dee Belemnite) standard.

CHAPTER 5 MATERIALS, SITES AND SETTINGS

5.1 Introduction

In this chapter, I provide background contextual information on the sites included in this study. First, I present a short overview of the geographic setting of the Caribbean in general, including some notes on terminology. Then I present a concise description of each of the archaeological sites from which human skeletal materials were sampled including a brief introduction to their geographic, chronological, and cultural contexts with emphases on the burial populations. This chapter concludes with some remarks concerning the quantity and quality of relevant contextual information for the sites and sample populations included in this study.

5.2 Geographic Context of Study Area

The Caribbean region is comprised of a series of archipelagoes that lie in a sort of stepping stone fashion, south and southeast of Florida, east of Central America, and north of the northern coast of South America (Figure 1). The three main archipelagoes are: 1) the Bahamian archipelago; 2) the Greater Antilles; 3) the Lesser Antilles (Figure 2). The Bahamian archipelago (comprised of the separate island nations of The Bahamas, and Turks and Caicos) contains hundreds of small islands and cays, located off of the north coast of Hispaniola and to the south and east of Florida. The Greater Antilles consist of the larger islands of the western Caribbean basin these include the islands of Puerto Rico, Hispaniola, Cuba and Jamaica. The Lesser Antilles consist of a series of small islands, oriented roughly north-south and located between the Orinoco River delta of northeastern and the Anegada passage separating the Virgin Islands from Puerto Rico. The Lesser Antilles are also often further subdivided into the Leeward Islands in the northern end of the island chain and the Windward Islands in the south. Trinidad, and to a lesser extent Tobago, which lies quite near the northern coast of South America, is geologically part of the mainland and is often considered as part of the cluster of continental islands which lie in a west-east row along the southern Caribbean Sea. The western end of this chain comprises the Leeward Antilles, a less formal grouping that includes such islands as Aruba, Curaçao, Bonaire, Isla Margarita, Las Aves, and Los Roques.

There are a number of different terms and names for the various islands and archipelagoes within the study area that are sometimes used interchangeably despite their distinct meanings and origins. For the sake of clarity and consistency, I will provide short summaries of the terminology used herein. First, the word 'Caribbean' is often used to refer to the large group of islands that separate the Caribbean Sea from the Gulf of Mexico and the Atlantic Ocean. In the strictest sense this usage does not include the islands of the Bahamian archipelago or Barbados, which are technically in the Atlantic Ocean, or the Leeward Antilles. The more inclusive term the 'West Indies', generally refers to all of the islands that lie within the Caribbean Sea including these islands and island groups. The word 'Antilles' in general is an intermediate term referring to all of the islands of the Caribbean with the exception of the Bahamian archipelago. To complicate matters further, there are numerous other islands and islets along the Central American coastline that lie within the Caribbean Sea and thus are also technically Caribbean islands.

In the present work, I will use the following terminology: 1) the 'Caribbean' or 'insular Caribbean' to refer to all of the islands of the West Indies (including the Bahamian archipelago); 2) the 'Antilles' to refer to the Greater and Lesser Antilles (including Barbados, Trinidad, and Tobago), and the Leeward Antilles; 3) the 'Antilles (*sensu stricto*)' to refer to only the Greater and Lesser Antilles (excluding Trinidad, Tobago, or the Leeward Antilles); and 4) the 'circum-Caribbean' or 'Caribbean region' to refer to the insular Caribbean plus all of the mainland coastal areas that abut the Caribbean Sea.

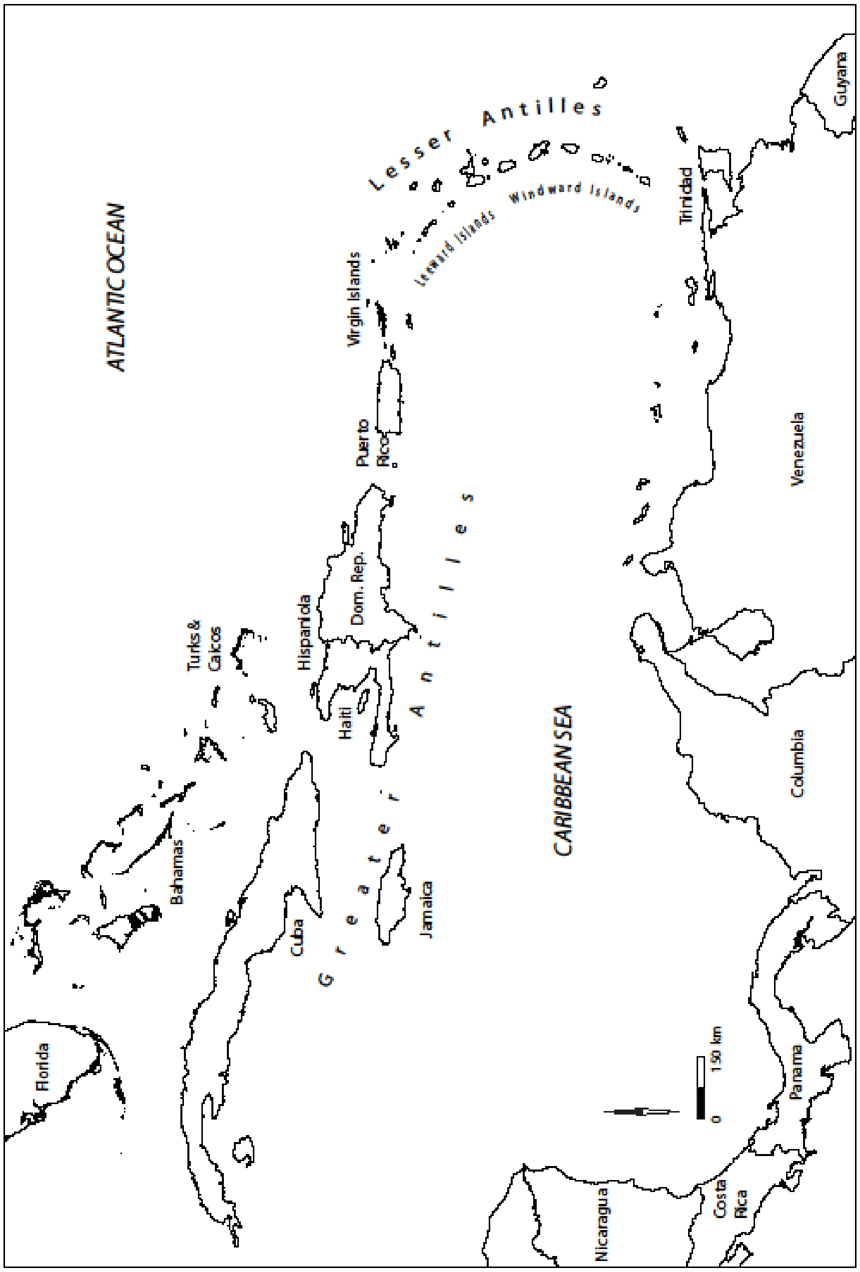


Figure 1 Map of the Caribbean Region.

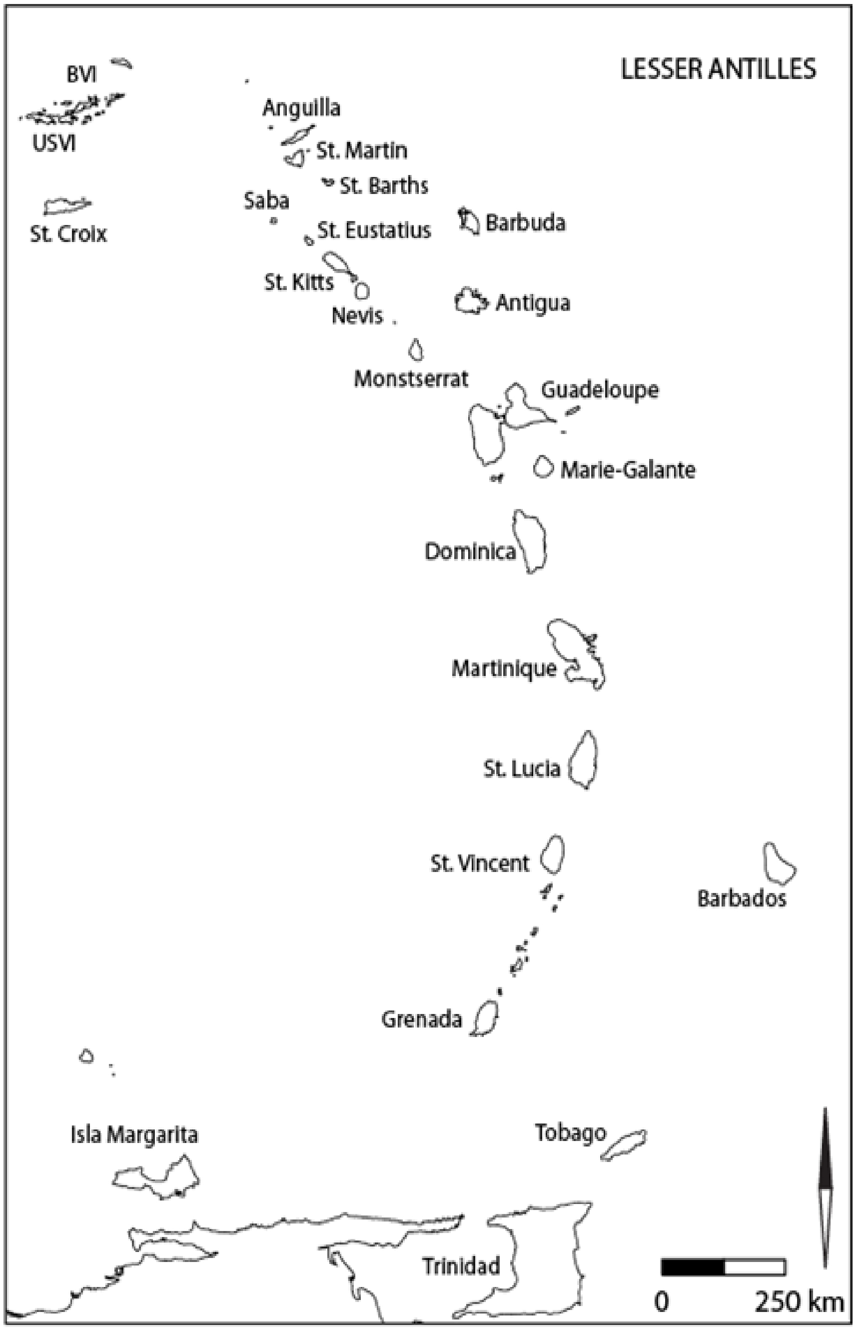
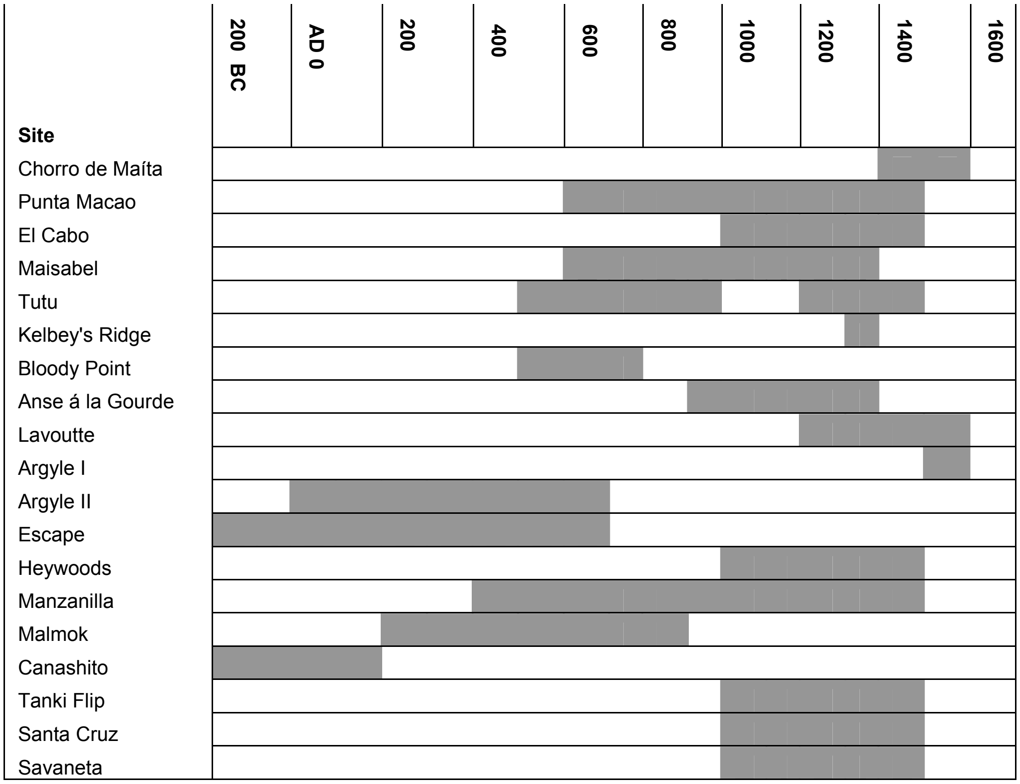


Figure 2 Map of the Lesser Antilles.

Table 1: Site chronologies showing approximate dating of skeletal assemblages



5.3 Site Settings and Skeletal Assemblages

In this section I provide descriptions of the site settings for each of the skeletal assemblages included in this research project: 1) El Chorro de Maíta, Cueva de los Muertos, and Potreno del Mango- Cuba; 2) Punta Macao, El Cabo, and Bartolo- Dominican Republic; 3) Maisabel- Puerto Rico; 4) Tutu- St. Thomas (U.S. Virgin Islands); 5) Kelbey's Ridge 2 and Spring Bay- Saba; 6) Bloody Point- St. Kitts; 7) Anse à la Gourde- Guadeloupe; 8) Lavoutte and Giraudy- St. Lucia; 9) Argyle I, Argyle II, Escape, and Buccament West- St. Vincent; 10) Heywoods- Barbados; 11) Manzanilla- Trinidad; and 12) Malmok, Canashito, Santa Cruz, Savaneta, and Tanki Flip- Aruba (Figure 3). These site descriptions focus primarily on the geographic location, history of discovery and research, site type, dating of occupation, and any available information about the burial populations pertaining to mortuary practices, demography, and previous isotope analyses. The temporal contexts of the skeletal assemblages are highly variable and span the time period from approximately 200 B.C. to A.D. 1600 (Table 1). However, the majority of these skeletal populations are associated with the Late Ceramic Age with a large proportion dating to roughly A.D. 1000-1500.

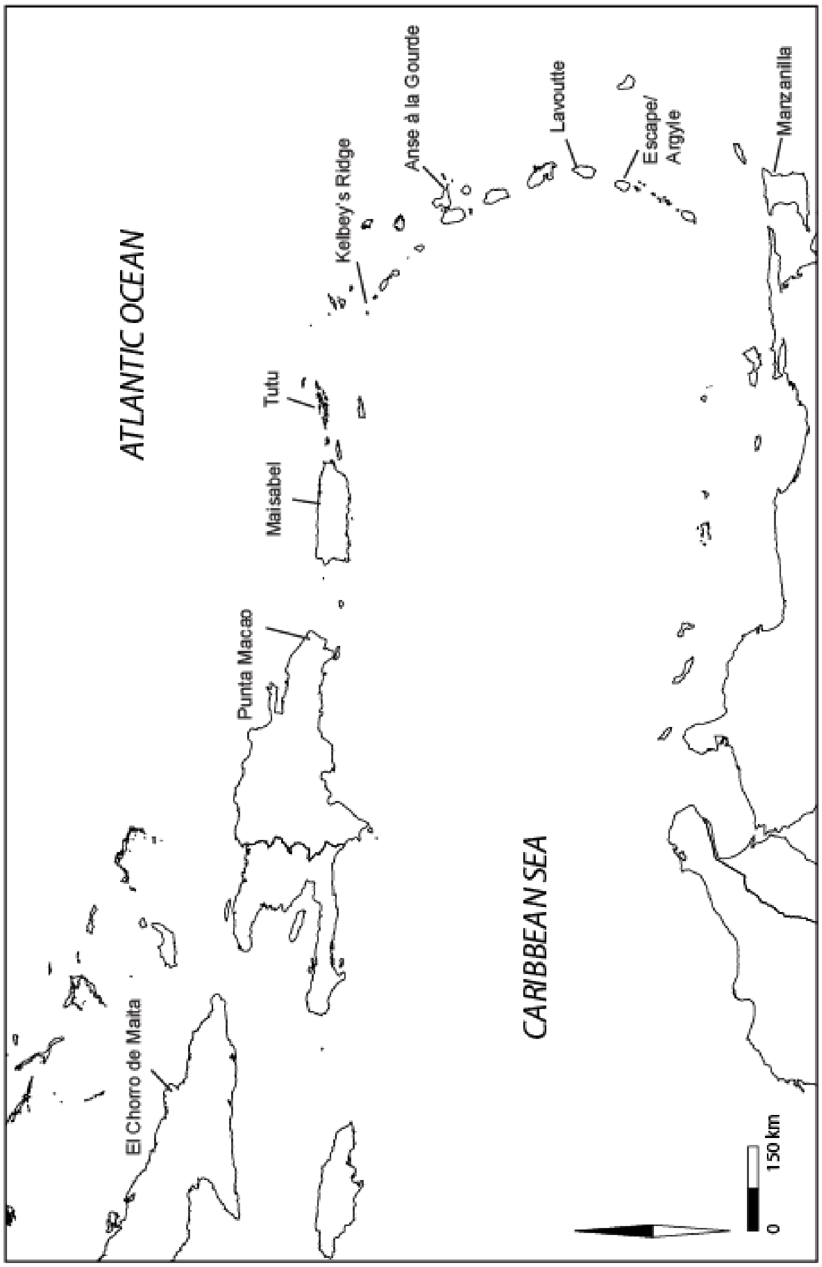


Figure 3 Map of the Caribbean indicating the location of the major sites included in this study.

5.3.1 El Chorro de Maíta- Cuba

The site of El Chorro de Maíta is located in northeastern Cuba in the province of Holguín. The site lies on the slope of a hill known as Cerro de Yaguajay, approximately four km from the coast. The site is composed of a large settlement characterized as a "*Fase agricultores*" (Guarch Delmonte 1990) or "*Etapa agoalfarere*" (Tabío 1984) cultural type. The site was first scientifically assessed by Irving Rouse in 1941, who reported on the nature of the site itself and the provenance of archaeological materials discovered there (Rouse 1942). Most of the ceramic assemblage is assigned to a local variant of the Meillacan Ostionoid subseries (Rouse 1992; Valcárcel Rojas 2002).

A large cemetery was excavated in the west central portion of the site in the 1980's by the Departamento Centro Oriental de Arqueología under the direction of José M. Guarch Delmonte (Guarch Delmonte 1996). Non-funerary spaces were also revealed by these excavations and these portions of the site have been interpreted as the remains of an indigenous village that surrounded the burial area (Guarch Delmonte 1996). In both the cemetery and surrounding areas, small quantities of European materials were discovered together with indigenous materials (Guarch Delmonte 1996). The European materials primarily consist of ceramics, metals, and the remains of domestic pigs (*Sus scrofa*) and point to continued use of the site and cemetery into the early colonial period (the 16th and early 17th centuries). Subsequent excavations have also been carried out by Roberto Valcárcel Rojas in collaboration with researchers from the University of Alabama (Persons et al. 2007; Valcárcel Rojas and Rodríguez Arce 2005; Valcárcel Rojas et al. 2010) and have recovered additional indigenous and European materials from the site including more European ceramics dating to the early colonial period.

The remains of at least 108 individuals were reported by the original excavator (Guarch Delmonte 1996). The initial osteological analysis of the site's skeletal assemblage was carried out in the 1980's by Manuel Rivero de la Calle and colleagues (1990). This initial analysis focused primarily on the physical characteristics of the human remains in addition to the associated grave materials. Physical anthropological analysis revealed the widespread occurrence of frontal-occipital cranial modification with all of the adult skeletons, except for burial no.36, no.22, and no.45. Interpretations of ancestry based on cranial morphology and stature were also posited. The burial population was reported to be of native (Amerindian) ancestry with a few notable exceptions. For example, burial no.36 appears to be a modern intrusive burial. Additionally, burial no.22 is represented by a cranium, associated with a small quantity of post-cranial fragmentary bone, and the facial and craniometric traits of this individual were interpreted as being European (Rivero de la Calle et al. 1990:85).

A more recent osteological analysis was carried out by Dr. Darlene Weston in 2010 in the context of the NWO-VICI project (Valcárcel Rojas et al. 2011; Weston 2010b). Utilizing updated standards and procedures for the reporting of skeletal remains, this study was more broadly focused and has revealed new information on this burial population especially with regard to its composition, ancestry, cranial and dental modification practices. This study (Weston 2010b) identified the presence of at least 133 individuals and significant alterations were also made to the age and sex distributions reported by the original investigators.

Estimations of ancestry were made possible by the use of craniometrics for three individuals: nos. 22, 45 and 81. Comparisons of standard cranial measurements were made between (Howell's) reference populations and these individuals using FORDISC 3.0. The cranium of no.45 scored most similar to an African male, the cranium of no.22 scored most similar to a White male, and the cranium of no.81 scored equally similar to an African female and a Hispanic female, a pattern that would be consistent with an individual of mixed ancestry (Valcárcel Rojas et al. 2011). It should be noted that these results reflect the diverse ancestries of the people of Cuba in the colonial period (Valcárcel Rojas et al. 2011).

An analysis of the practice of intentional cranial modification at El Chorro de Maíta was executed by Anne Van Duijvenbode (Valcárcel Rojas et al. 2011; van Duijvenbode 2010). This study used a sample of the entire burial assemblage, consisting of 54 individuals: 42 adults, five adolescents and seven juveniles. Intentional cranial modification is present in approximately 80% of the sample, with the vast majority of the modified group possessing the same head shape; fronto-occipital parallel modification (Valcárcel Rojas et al. 2011). The overall pattern at El Chorro de Maíta is that a large percentage of the population possesses modified crania and amongst them there is little variation in the type of modification employed. Individual no.72B is the only exception to the homogeneity of shapes within the sample. This female has fronto-occipital modification of the vertical subtype. This individual was also unique in terms of her funerary treatment, having been buried in an unusual position (facing down with a large stone on top of the legs). The different shape of the skull and its uniqueness compared to other pre-Columbian skeletal assemblages in the Caribbean are consistent with a foreign origin (Valcárcel Rojas et al. 2011).

In addition to the dissimilar type of intentional cranial modification, this individual also presents a clear case of intentional dental modification, which was identified during a dental anthropological study of the human remains from this cemetery, conducted by Hayley L. Mickleburgh (Valcárcel Rojas et al. 2011). A clearly distinct form of intentional dental modification was recorded for individual no.72B (the only one observed for this assemblage). This modification was performed only on the upper incisors and canines, and no other teeth were affected. A small number of cases of intentional dental modification have been reported in the Caribbean region, but in all cases these have been identified as individuals of African origin. The form of dental modification amongst these isolated African cases is clearly different from that of individual no.72B. Both the resulting form and the techniques employed in the modification of no.72B are more consistent with patterns reported for prehistoric Mesoamerican populations. In fact, this type is most similar to types which are found in Post-classic contexts from Guatemala, Honduras, and particularly Belize. No other individuals with this type of intentional dental modification have been reported to date for the prehistoric Antilles. The presence of this unique (for the Antilles) type of dental modification, in combination with both the distinct cranial modification and mortuary treatment of no.72, lends further support to the notion that this person is an immigrant, probably of Mesoamerican origin (Valcárcel Rojas et al. 2011).

Radiocarbon dates obtained directly from human bone material have been reported for several burials and more dates are currently pending. Several of the currently available radiocarbon dates span the period immediately before and after initial contact (i.e., ~AD 1500) and thus it is not possible at this time to clearly distinguish between preand post-contact burials based on these data alone (Valcárcel Rojas et al. 2011). A large number of burials contained small metal tubes that recent metallurgical analysis have identified as brass aglets (Cooper et al. 2008; Martinón-Torres et al. 2007; Martinón-Torres et al. 2012; Valcárcel Rojas et al. 2010). Brass is a metal first brought to the Americas by Europeans and thus all burials containing brass clearly date to the post-contact period. Based on the presence of various materials and objects of European origin (e.g., brass artifacts, pig remains) and the presence of 'Christian-type' burial practices (extended position with arms crossed), Valcárcel Rojas (2012) has identified at least 32 individuals that date to the post-contact period. Although the remainder of the burials has yet to be more securely dated, he has proposed that the entire burial population might date to the post-contact or colonial period (Valcárcel Rojas 2012).

Three additional human dental samples were obtained from two sites in the vicinity of El Chorro de Maíta. The first, Cueva de los Muertos, is a cave site located in the limestone hills less than two kilometers from El Chorro. Numerous human skeletal remains have been uncovered from the cave over the years. Relatively little contextual data from this site is available but it thought to have possibly represented a burial place for residents of settlements from the surrounding area (Valcárcel Rojas 2012). The second, Potreno del Mango, is a small site located to the southeast of El Chorro de Maíta near the eastern tip of Cuba. Teeth from these two sites were collected and analyzed in an attempt to determine the spatial extent of the local Sr isotope range at El Chorro de Maíta.

5.3.2 Punta Macao and El Cabo- Dominican Republic

Punta Macao is a settlement and burial site located in the province of La Altagracía, on the eastern coast of the Dominican Republic. The site is multi-component but seems to predominantly date to the Late Ceramic Age with radiocarbon dates indicating a main period of occupation and use around A.D. 640 to 1300. The presence of the site was originally reported as early as the 16th century (Las Casas 1992) and it has been explored by a large number of Caribbean archaeologists and researchers over the last century including De Booy, Rainey, Veloz Maggiolo and Ortega, and more recently by a team from El Museo del Hombre Dominicano. The largest excavation of the site to date was carried out by Marcio Veloz Maggiolo and Elpidio Ortega (1972), who characterize the site as a large farming village of great proportions, which in its later levels corresponds to the Taíno period in the Greater Antilles. The cemetery itself was not thoroughly investigated until 2004, when it was excavated by a team from the Museo del Hombre Dominicano prior to the construction of a golf course. Besides the burials themselves, the site has also yielded a broad array of ceramic vessels and ceremonial objects (Ortega et al. 2003; Távarez María and Luna Calderón 2007; Távarez María 2008; Veloz Maggiolo and Ortega 1972). The ceramic assemblage is dominated by the Boca Chica style, with lesser quantities of Ostiones ware and another termed the 'Macao' style, which is believed to be transitional between Boca Chica and Ostiones (Veloz Maggiolo and Ortega 1972).

In total, fifteen burial pits were excavated from the southern portion of the site and a physical anthropological analysis of the Punta Macao skeletal assemblage has been recently conducted (Távarez María and Luna Calderón 2007; Távarez María 2008) [see also (Ulloa Hung 2008)]. This study focused on recording skeletal indicators of age and sex, cranial modification, stature, foodways, and pathologies. Twenty six individuals were identified in total, including eight juveniles and eighteen adults, of which eleven are males; six are females, and one of indeterminate sex (Távarez María and Luna Calderón 2007). Most interments are primary burials although some are composite burials containing the remains of adults with the partial or complete remains of one or more juveniles. In addition to a Chicoid ceramic vessel covering the cranium of burial no.2, grave goods were found in association with nine burials and primarily consist of fragmented ceramics, and unworked shell, bone, and lithic remains. The burial positioning was variable, but supine was the most common position and all individuals had flexed lower limbs. Burial orientation was also highly variable. Of the individuals possessing modified crania, tabular oblique was the prevalent form. Available radiocarbon dates obtained from three individuals, along with associated ceramic materials indicate that the burial assemblage primarily dates to the Late Ceramic Age.

El Cabo is also a Late Ceramic Age settlement site located on the far eastern coast of the Dominican Republic. This site was known to the archaeological community since at least the 1970's (Ortega 1978) and was subjected to small-scale investigations in subsequent years. Recently, large-scale excavations of the site were carried out by a team of archaeologists from Leiden University, under the direction of Menno Hoogland and Corinne Hofman, in collaboration with the Museo del Hombre Dominicano (Hofman et al. 2006b; Hofman et al. 2008b; Samson 2010, 2011). Analyses of the material remains revealed the presence of both Chicoid and Ostionoid ceramics and indicate that this multi-component site was likely inhabited for several centuries from roughly the 7th to early 16th centuries A.D., although the houses date to between the 9th and 16th centuries (Hofman et al. 2006b; Hofman et al. 2007b; Hofman et al. 2008b; Samson 2010, 2011; St. Jean 2008). Excavations of the site revealed a very large number of postholes cut into the underlying bedrock; the analyses of these have revealed that many of these are the remains of house structures that underwent multiple cycles of renewal and reconstruction throughout the occupation of the site (Samson 2010).

During excavations of the domestic areas, four primary burials were encountered and excavated. One of the burials is of an infant (or neonate) interred within a post-hole. The other three burials are adults with one possibly associated with house structure #6, while the other two were located in midden deposits. Adult burials are primary interments in small oval pits in flexed position (Hoogland and Hofman, pers. comm. 2011). Grave goods include a pink *Chama sarda* bead and a boat-form vessel may also be associated with one of the burials. The skeletal material has not been subjected to intensive osteological analysis or radiocarbon dating, although based on associated materials the burials seem to date to the Late Ceramic Age. Given the scale of the excavations and the size and intensity of occupation at the site, one might expect to find more than a few burials. The small size of burial population may reflect the possibility that the deceased were mostly buried outside of the settlement itself, for example in a nearby cemetery or perhaps more likely within the multitude of cave systems found in the karstic region of the country (de Booy 1915).

Bartolo is a small site located within a few kilometres of El Cabo in the eastern Dominican Republic that was documented during a visit by Hoogland and Hofman in 2007 and in two recent surveys in the region (Johnson 2009; Olsen Bogaert 2004). The site has not been systematically excavated but surface remains include fragmented Chicoid ceramics and human skeletal materials (Johnson 2009). A single human tooth collected from the surface was sampled for this study for comparison with the El Cabo and Punta Macao collections.

5.3.3 Maisabel- Puerto Rico

Maisabel is a multi-component settlement site located near the center of the northern coast of Puerto Rico. Early investigations of the site were conducted by the Instituto Cultura Puertorriqueña under the supervision of Ovidio Dávila Dávila and uncovered the remains of several midden deposits and a large Saladoid component. Large scale excavations of the site were also conducted by the Centro de Estudios Avanzados de Puerto Rico y el Caribe and the Centro de Investigaciones Indigenas de Puerto Rico under the direction of Peter Roe and continued by Peter Siegel in collaboration with the latter. These excavations revealed the presence of both Saladoid and Ostionoid components at the site and indicated a continuous occupation over a millennium throughout much of the Early and Late Ceramic Ages (Siegel 1989b; Siegel and Roe 1991; Siegel 1992, 1996, 1999, 2010).

Excavations yielded 34 burials in total, of which two are secondary interments and the rest are primary. Twenty four burials were located in the central area of the site, interpreted as the central plaza of an indigenous village (Siegel 1992). Ten additional burials were also discovered in a macro-block near posthole features, possibly associated with an Ostionoid house structure (Siegel 1992). Radiocarbon dating of the burials in the central plaza indicates that it was in use throughout the entire occupation of the site from roughly A.D. 200-1100, and based on uncalibrated radiocarbon dates from the skeletal material Siegel (1992) recognizes two main groups within this population. The majority of the burials are associated with an earlier Saladoid period occupation and a smaller number to a later Ostionoid period occupation. Additionally, most of the burials in the central plaza cemetery seem to be associated with the earlier Saladoid period, while most of the burials found outside of the cemetery seem to be associated with the Ostionoid. Siegel has interpreted the presence of the cemetery within the central plaza area as an indication of its central role as a sacred locus (or *axis mundi*) of social and ritual activities (Siegel 1989b, 1992, 1996, 1999). The shift over time (from the Early to Late Ceramic Age) in the location of burials from the central plaza to more domestic spaces at this site and other Ceramic Age sites have been noted by many other observers (Curet and Oliver 1998; Hofman and Hoogland 2004; Keegan 2009; Righter 2002; Siegel 1999) and have contributed to ongoing discussion concerning temporal variation in mortuary practices and to broader debates concerning socio-cultural change in the region (Curet and Oliver 1998; Keegan 2009; Siegel 2010).

An osteological analysis of the burial assemblage was originally carried out by Budinoff (1991) in which she reported not only sex and age estimations but also demographic inferences derived from these patterns, in addition to stature estimations and detailed descriptions of certain pathologies and their implications for general health conditions amongst the population. More recently, the burial assemblage was re-analyzed in the context of the VICI-project with similar goals, utilizing slightly different methods and procedures for estimations of age and sex and the diagnosis of pathological conditions by a Darlene Weston and a research team from Leiden University (Weston and Schats 2010). This more recent analysis indicates the presence of 35 individuals, of which 27 are adults and eight are juveniles. Of the adults, there are 16 males, eight females, and three of indeterminate sex. Clearly, there is a sex bias in this population with more than twice as many males as females.

Stable isotope analyses of human bone materials from Maisabel have been carried out by Anne Stokes (1998, 2005). Based on the results of carbon and nitrogen isotope analysis of bone collagen and carbon isotope analysis of bone apatite, she was able to reconstruct certain aspects of diet at his site. The stable isotope results from Maisabel indicate: 1) the consumption of both terrestrial and marine resources but that the latter was the larger source of dietary protein; and 2) that although C_3 plants were the primary source of dietary energy C_4 plants were also an important component of the diet. Stokes (2005:199) also notes that “the Maisabel individuals had very diverse diets, which are not reflected in mean values. Individual choice or potentially some other factor such as hierarchy or age was responsible for the observed diversity”.

5.3.4 Tutu- St. Thomas, U.S. Virgin Islands

Tutu is a large, multi-component habitation site located in an inland valley of eastern St. Thomas, U.S.V.I. about two km from the east coast (Righter 2001). The site was excavated by a large team of investigators prior to development of the land for use as a shopping centre in the 1990's (Righter 2002). These excavations revealed the presence of a large village with a central plaza area surrounded by domestic structures and refuse middens. There were apparently two main distinct occupations at Tutu; one dating to the Early (Cedrosan Saladoid) and the other to the Late (Chican Ostionoid) Ceramic Age (Righter 2002). Ninety two radiocarbon dates in total have been obtained from the Tutu archaeological village site and these indicate that it was settled as early as the first century A.D. and ultimately abandoned by circa A.D. 1500. There is little evidence for occupation between A.D. 950 and A.D. 1150 (Righter 2001, 2002) suggesting that the site may have been abandoned and resettled multiple times.

Over 40 burials dating to both time periods were discovered and have been subjected to intensive and extensive archaeological analyses, including osteological, trace elements, and stable isotope analyses amongst others (Farnum and Sandford 2002; Larsen et al. 2002; Norr 2002; Sandford et al. 2002). Based on associated ceramic materials and 27 radiocarbon dates obtained directly from human bone material, nine of the skeletons are associated with a late extension of the Saladoid period, dating to roughly A.D. 450-960, while the remainder are associated with a later Ostionoid occupation, dating to around A.D. 1170-1535 (Sandford et al. 2002). Village structure and burial customs are characterized by both continuity and change (Righter 2001). The early occupation consists of a roughly horse-shoe shaped ring of dispersed structures, located on a flat knoll with a central open space. The late occupation was generally more circular and that the location of the central plaza may have shifted over time as the village structure shifted to the north and northeast (Righter 2001, 2002).

In terms of mortuary practices at Tutu, evident changes between the earlier and later phases are attributed to changes in the social, political, economic, and ideological realms (Curet and Oliver 1998; Hofman et al. 2001b; Siegel 2004). All early period burials (dated to between A.D. 450 and 640) were accompanied by partial or complete pottery vessels, two of which were foetal remains interred within complete ceramic bowls (Righter 2001, 2002). In contrast, to the early period burial assemblage, only two late period burials (dated to between A.D. 1200 and 1500) are interred with ceramic vessels and these are both of infants (Sandford et al. 2002). Another important temporal distinction is that only one of the 24 late period skeletons was buried in the central burial precinct, while the other 23 were buried in apparent family groups, clustered in exterior areas of domestic structures, and sometimes aligned with exterior house posts (Righter 2002). The shifting patterns of mortuary practices and their association to changes in socio-political and economic patterns are very similar to those found at the site of Maisabel, Puerto Rico (Siegel 1992, 1996, 1999, 2010).

Paleobotanical analyses has revealed that although the inhabitants relied on a mixed diet of plants and terrestrial and marine animals throughout the site's occupation, there were some clear differences in resource exploitation between the earlier and later inhabitants (Pearsall 2002; Piperno 2002). Trace element concentration analysis was performed on human femoral bone samples and soil samples from the Tutu site (Farnum and Sandford 2002). Using multiple techniques, these researchers found no widespread or substantial contamination of the elements Strontium (Sr) or Barium (Ba). These results provide greater degrees of confidence in the interpretation of the isotopic analyses of these remains and indicate that the elemental concentration data may be useful contributors to dietary reconstructions at this site. Human remains from the later Ostionoid component possessed higher Sr to Ba bone concentrations than the remains from the earlier Saladoid component (Farnum and Sandford 2002). This pattern is consistent with a shift towards less reliance on terrestrial food resources in later periods, although this shift still falls within the mixed marine and terrestrial consumption range Price (Burton and Price 1999, 2000). No further correlations were discovered between bone elemental concentrations and biological sex or age at death (Farnum and Sandford 2002).

Analyses of carbon (C) isotopes from bone collagen and apatite carbonate and nitrogen (N) isotopes from bone collagen were also conducted on a subset of the Tutu skeletal assemblage (Norr 2002). These results are in accordance with other lines of evidence indicating a broad-based subsistence strategy and mixed reliance on marine and terrestrial resources. The overall general dietary pattern is homogenous throughout the sample population indicating shared dietary practices between males and females, adults and children (Norr 2002). In contrast to the trace element study, the isotopic results revealed no major shift in diet between the earlier and later periods (Norr 2002). Comparisons with published dietary isotope results from other contemporaneous sites in the Caribbean show that the ancient inhabitants of Tutu generally consumed less terrestrial resources than most Greater Antillean populations but less reef, and more pelagic, marine resources than most Lesser Antillean populations (Norr 2002; Stokes 1998).

Physical anthropological and dental analyses of the Tutu skeletal materials revealed several interesting patterns of health and disease (Larsen et al. 2002; Mickleburgh 2006; Sandford et al. 2002). Generally poor oral health and relatively high frequencies of carious lesions were reported for this population, the latter probably attributable to the consumption of starch-rich foods, such as manioc (Larsen et al. 2002; Mickleburgh 2006). A slight decrease in caries rates from the early to later period may be associated with the proposed greater reliance on marine resources in the later period, as previously discussed(Larsen et al. 2002; Mickleburgh 2006). Osteological analysis of the skeletal remains also revealed widespread lesions consistent with those produced by treponemal disease. The conditions of most lesions were suggestive of a chronic condition but the late occupation skeletons appear to be more frequently and severely afflicted (Sandford et al. 2002). In fact, the rate of incidence and prevalence of skeletal indicators of treponematosis are both high relative to those reported for other similar Caribbean skeletal assemblages (Schats 2010).

In total, the Tutu skeletal sample is comprised of 20 subadults and 22 adults, with adults defined as those individuals with an estimated age at death of 16 years or older (Sandford et al. 2002). Of the adults, six are males and fourteen are females, while biological sex could not be determined for the other two adult individuals. Based on the previously discussed AMS dates, adult skeletons from the early period consist of one male, seven females, and one of indeterminate sex. The dating of these early period burials overlaps substantially with the proposed time period of the Cedrosan Saladoid. A

Saladoid designation for this burial assemblage is also confirmed by the presence of Saladoid pottery in most of the graves. The fact that many of the AMS dates post-date the traditionally conceived ending of the Saladoid chronology (Rouse 1992) probably indicates that the Saladoid period lasted much longer than previously recognized, a notion that has gained traction in recent years (Pestle 2010; Rodríguez Ramos 2007; Rodríguez Ramos et al. 2010). Dated adult skeletons from the late period include five males and seven females (Sandford et al. 2002). All of the dates from the late period skeletons fall within the Chican Ostionoid time period.

5.3.5 Kelbey's Ridge 2 and Spring Bay 1c- Saba

Kelbey's Ridge 2 is a Late Ceramic Age site located near the northeast coast of Saba and was excavated by a team from Leiden University in the 1980's under the direction of Menno Hoogland and Corinne Hofman (Hofman and Hoogland 1991; Hoogland and Hofman 1993; Hoogland 1999). The main occupation of the site is dated to the Late Ceramic Age (A.D. 1250-1350), as evidenced by the presence of Chican Ostionoid ceramics. Excavations revealed the presence of at least five house structures, in addition to multiple hearths and burials. The house structures are approximately round in shape with maximum diameters of between five and eight meters. The terrain slope and differential posthole depths suggest that the structures may have been built on elevated platforms. Several of the structures seem to have been rebuilt on roughly the same spot over a relatively brief period of occupation and two of these contain evidence for subsequent use as cooking structures (Hofman and Hoogland 1991, 2011; Hoogland and Hofman 1993; Hoogland 1996; Hoogland and Hofman 1999).

Multiple lines of evidence point to the existence of nonlocal, foreign, or exotic influences at this site. The decorated portion of the ceramic assemblage is represented by the Boca Chica style that is typical of late prehistoric groups from Hispaniola and Puerto Rico. A snuff-inhaler made of manatee bone and carved into the shape of a fish was found in association with one of the burials. This item of ritual paraphernalia is also more typical of the material culture of Taíno groups of this period. Additionally, a jadeite axe and two *zemis* made of coral have also been discovered at Kelbey's Ridge. The presence of nonlocal, possibly Taíno-affiliated, artifacts and materials at this site have been explained as the expansion of Taíno societies toward the Lesser Antilles driven by a combination of socio-politico-ideological and economic incentives (Hofman and Hoogland 2011; Hoogland and Hofman 1993; Hoogland and Hofman 1999). These various lines of evidence have led the excavators of the site to propose several hypotheses concerning the origins of this population and the nature of the relationships between groups occupying Saba, the northern Lesser Antilles, and the eastern Greater Antilles (Hofman and Hoogland 2011; Hoogland and Hofman 1999). Firstly, a group (or groups) fleeing from socio-political instability in the Greater Antilles may have settled in the northern Lesser Antilles at this time. This expansion could have included the migration of small groups of Taíno colonists or settlers, resulting in the eventual inclusion of parts of the northern Lesser Antilles into a Taíno interaction sphere. This hypothesis finds support from Curet's (Curet 1992:289) proposal that the migration of Chicoid groups to the Lesser Antilles and elsewhere might be associated with decreases in population observed for the Chican Ostionoid period of Puerto Rico. Secondly, the incorporation of the smaller islands of the northern Lesser Antilles (like Saba) into a larger social-political-ideological system may have been the result of a desire to establish a supportive outpost, base, or gateway community in order to control one of the major routes of exchange between the Greater Antilles and the Lesser Antilles and mainland South America (Hofman and Hoogland 2011; Hoogland and Hofman 1999).

The Kelbey's Ridge skeletal assemblage was recently subjected to a thorough osteological analysis using standard procedures. All references to age, sex, pathology, and health conditions described herein are derived from the skeletal report of this analysis (Weston 2010a). The overall patterns of this small population are characterized by an over-representation of juveniles. Pathological evidence points to strenuous lifestyles and very poor dental health for most of the adults (Weston 2010a). The burial assemblage is composed of seven burials comprising eleven individuals, of which eight are juveniles and three are adults. The adult and juvenile burials are characterized by the interment of the deceased in a flexed, nearly seated position within confined burial pits. Interestingly, Kelbey's Ridge has provided the only case of cremation reported to date for the Lesser

Antilles. Two of the seven burials are composite burials containing the remains of both an adult and a juvenile. All seven burials are located in the habitation area, within or around the house structures (Hoogland 1999). Grave goods are rare and in addition to the inhaler mentioned above, consist of hollow bird bones (that may have served as the inhalation tubes), and stone and coral artefacts.

Spring Bay (1c) is a small component of a Ceramic Age habitation site, located near the Kelbey's Ridge site along the northeast coast of Saba (Hofman and Hoogland 1992; Hofman et al. 1987). The site is comprised of a large midden area, primarily containing food refuse, and the site appears to have been possibly occupied and abandoned multiple times since its initial settlement in the Early Ceramic Age. Excavations revealed a single burial of a child in a flexed position in one of the late components of the midden. Chican Ostionoid type pottery was found associated with the burial and radiocarbon dating of the skeletal remains indicates a similarly late date (~A.D. 1450) and that the individual was contemporaneous with the Kelbey's Ridge 2 population (Hofman and Hoogland 1992; Hofman et al. 1987).

As part of her dissertation research, Anne Stokes (1998) carried out stable isotope analyses on the human skeletal materials from these two sites on Saba. This study included carbon isotope analyses of both bone collagen and apatite as well as nitrogen isotope analysis of bone collagen. Based on these results, Stokes (1998:203) concluded that "the protein portion of the diet was derived from a mixture of terrestrial and marine animals" and that "most carbohydrate in the diet was based on C_3 plants".

5.3.6 Bloody Point- St. Kitts

Bloody Point is a Ceramic Age settlement located on the western (leeward) coast of the island of St. Kitts. The site was excavated by an international team supervised by Starr Farr in the 1990's which revealed the presence of both Early and Late Ceramic Age assemblages (Farr 1996). The site's primary phase of occupation is roughly contemporaneous to the well-known site of Golden Rock on the neighbouring island of St. Eustatius (Versteeg and Schinkel 1992). Several burials were excavated from the site and these displayed a variety of burial treatments including flexed and extended burials, and single and multiple burials (Farr 1996). A small number of radiocarbon dates obtained from human bone indicate that at least some of the burials date to the later occupation of the site (Farr 1996). Dental samples from four adult individuals were sampled for Sr isotope analysis.

5.3.7 Anse à la Gourde- Guadeloupe

The multi-component settlement site of Anse à la Gourde, Guadeloupe is located in the eastern part of the island of Grande-Terre on the Pointe de Chateaux peninsula. The peninsula was densely occupied with larger settlements, hamlets and special workshop areas from Saladoid to post-Saladoid times, suggesting a multi-village organization was at place in the area for several centuries (de Waal 2006; Hofman et al. 2001a; Hoogland et al. 2010). The site itself was excavated by a team of researchers from Leiden University and the Archaeological Service of the Direction Régionale des Affaires Culturelles of Guadeloupe (DRAC) in the 1990's under the direction of Corinne Hofman, Menno Hoogland and André Delpuech (Delpuech et al. 2001; Hofman et al. 1999; Hofman et al. 2001a; Hoogland et al. 2001; Hoogland et al. 2010).

An initial Early Ceramic Age occupation (dated to A.D. 500-700) is attested to by the presence of Cedrosan Saladoid ceramic deposits. The earlier component is located closer to the sea and this area was apparently more affected by regional climatic changes, sea level rise, and related reconfigurations of the coastline and reefs in front of the settlement possibly resulting in temporary abandonment of the site (Beets et al. 2006) The settlement was fully reoccupied around A.D. 900 and remained so until roughly A.D. 1400. The Late Ceramic Age occupation partly overlays the previous Saladoid settlement, however, great parts of the latter were lost due to the retreat of the coastline (Beets et al. 2006). During this period, at least three clear occupation phases are discernible in the archaeological record (i.e., A.D. 900-1100, A.D. 1100-1250, and A.D. 1250-1400). The ceramic assemblages of these occupation phases are evidenced by the presence of Mamoran/ Troumassan Troumassoid to early and late Suazan Troumassoid materials. The ceramic assemblages overall display a high diversity of influences and also include Cayo and Morne Cybèle stylistic traits (Delpuech et al. 2001; Hofman et al. 1999; Hofman et al. 2001a; Hoogland et al. 2001; Hoogland et al. 2010).

At least 24 different structures, comprising houses and associated domestic structures, and more than 80 burials, relate to three phases of the Troumassoid occupation (Hoogland et al. 2001; Hoogland et al. 2010). The considerable palimpsest of features points to the reconstruction of houses and the burying of community members on the same spot for centuries (Bright 2003; Delpuech et al. 2001; Hofman et al. 2001b; Hoogland et al. 2001; Morsink 2006). These structures are located next to a vacant space, which probably functioned as a plaza for the community and are enclosed by midden deposits in a doughnut shape. The subsistence remains recovered from the midden areas evidence the heavy reliance on fish and shellfish complemented in minor instances with land crab and terrestrial (Grouard 2001). Exploitation was focused in the vicinity of the settlement and predominantly oriented towards the lagoon, its coral reef and the estuary zone. The numerous grinding stones and ceramic griddles point to the processing and consumption of root crops; like manioc, sweet potato, yams, and zamia.

Local clay sources on the Pointe des Chateaux evidently were exploited for the manufacture of the pottery and numerous local sources were also exploited for the manufacture of lithic and shell implements (Knippenberg 2006; Lammers-Keijsers 2007). The presence of many nonlocal artefacts points to the integration of this community in a broader network of exchange tying together local, micro-regional, and macro-regional interaction spheres. For example, flint from Long Island, Antigua and greenstone and calci-rudite from St. Martin (Knippenberg 2006) indicate the incorporation of the local community in a social network that existed since the Archaic Age and was maintained throughout the Late Ceramic Age (Hofman et al. 2007a; Hofman et al. 2010; Hofman et al. 2011; Hofman and Hoogland 2011). Evidence of long distance exchange is represented by possible fragments of jadeite celts, that may have come from the Greater Antilles (Cuba or Dominican Republic) or even possibly from as far as Guatemala (García-Casco et al. 2009; Harlow et al. 2006; Schertl et al. 2012). Furthermore, there are a few examples of decorated bone fragments from exotic species such as armadillo and opossum (Grouard 2001). These are all quite uncommon in sites in the Lesser Antilles and were likely introduced directly from the South American mainland (Giovas et al. 2011; Newsom and Wing 2004).

The burials at Anse à la Gourde occur in clusters of three to ten burials and are closely associated with house structures (Hofman et al. 2001b; Hoogland et al. 2001). The burials seem to be exclusively associated with the Troumassoid occupation of the site (~A.D. 1000-1350). Burial pits are often located in close proximity to post-holes cut into the bedrock and some burials were found within post-holes themselves, indicating likely associations with specific structures or 'houses' (Bright 2003; Delpuech et al. 2001; Hofman et al. 2001b; Hoogland et al. 2001; Morsink 2006). A wide variety of mortuary practices have been identified at this site including both primary and secondary burials, and single and composite burials (Hoogland et al. 2001; Hoogland et al. 2010). Detailed analysis of taphonomic processes, anatomical positioning, and burial contexts indicate that many of the interred may have been wrapped (possibly in a hammock) prior to interment and in some cases there is also evidence for desiccation of the corpse and for post-burial manipulation of the corpse in an open grave (Hoogland et al. 2001; Hoogland et al. 2010).

A minimum of 99 individuals have been reported from approximately 86 burial features, meaning that many of the graves contain the remains of more than one individual (Weston 2011a). The skeletal assemblage consists of 18 subadults and 89 adults of whom 31 are males, 40 are females, and 18 are of indeterminate sex (Weston 2011a). The burial population is composed primarily of adult individuals with relatively few juveniles. The general underrepresentation of children within the burial population may indicate that they possessed a different social status in life and death and that their bodies received distinct mortuary treatment than adults, possibly being disposed of elsewhere outside the village (Hoogland et al. 2010). Pathological lesions consistent with treponemal disease were observed amongst this population (Schats 2010). Dental anthropological analyses of the dentitions from this population revealed both dietary patterns and the use of teeth as tools (Mickleburgh 2006). Stable isotope analysis of human skeletal material from Anse à la Gourde found indications of a mixed diet of terrestrial and marine protein food resources (de Vos 2010; Stokes 1998) and little indication of intra-societal differences in dietary practices relative to age or sex (de Vos 2010; Laffoon and de Vos 2011).

5.3.8 Lavoutte and Giraudy- St. Lucia

The Late Ceramic Age site of (Anse) Lavoutte is located in Cas-en-Bas along the eastern coast of northern St. Lucia. The midden area of this site was subjected to extensive excavations by Ripley and Adelaide Bullen in cooperation with Eric Milton Branford of the St. Lucia Archaeological and Historical Society in the 1960's (Bullen and Bullen 1970). Based on the ceramic materials, the Bullens (1970) concluded that the site's occupation dated to the Suazey period, spanning from about A.D. 800 to 1500. Portions of a large, distinct, ceramic figurine of a seated female figure, known as the 'Lady of Lavoutte', was discovered by local workers and ultimately brought to the attention of Ripley Bullen. Another portion of this artifact was uncovered by subsequent excavations in addition to a number of other unique, highly decorated figurines and a *guaíza*-like artifact. The discovery of these objects, in addition to materials believed to be of Greater Antillean origins, and the size and location of the site led the Bullens to propose that the settlement represented a Carib ceremonial center (Bullen and Bullen 1970). This assertion was later explored by Louis Allaire (Allaire 1999) who determined that much of the supposedly exotic material was probably locally-made but that the presence of such ceremonial paraphernalia and Taíno-derived iconography in the Lesser Antilles may indicate attempts by local leaders to acquire and project power and influence [see also (Allaire 1990)].

A smaller-scale excavation was carried out in the 1980's by a team of archaeologists from the University of Vienna under the supervision of Herwig Friesinger (Fabrizii-Reuer and Reuer 2005). This work expanded on investigations of the refuse deposits and also uncovered three human burials. In 2009 and 2010, a large-scale rescue excavation of the site was carried out by Leiden University under the direction of Corinne Hofman and Menno Hoogland in collaboration with the St. Lucia Archaeological and Historical Society and the Museum of Natural History, Gainesville (Hofman and

Branford 2011; Hofman et al. 2012). This most recent fieldwork focused on the portions of the site which were most vulnerable to impending damage from human and natural processes. In the course of this work, more than forty burials were discovered and systematically excavated within a relatively small portion of the site.

The spatial relationship and proximity of the burial features to the post-holes of structures suggest that the burials were likely placed within the settlement in or near house structures. Although primary interment is the most common burial form, wide variation exists for many aspects of the overall burial treatment. For example, several composite burials are comprised of a complete set of remains of one individual interred with the partial remains of other individuals (disembodied crania in at least two cases). Burial pits were generally small and oval or round in shape, with the majority of individuals facing to the east. Radiocarbon dates are available for twelve of the individuals from this skeletal population and appear to cluster into three distinct periods [A.D. 1150-1300, A.D. 1300-1400, and A.D. 1400-1600] (Hofman et al. 2012).

The majority of the radiocarbon dates obtained thus far from human bone materials fall roughly between A.D. 1200 and 1500. This evidence is in accord both with the Bullens' (1970) original proposition that the main occupation of the site dates to the Late Ceramic Age, and the preponderance of Suazoid materials within the ceramic assemblage. Osteological analyses of the human remains were conducted by Darlene Weston and included estimations of sex, age, and pathological conditions. Analysis of patterns of cranial modification, and analysis of patterns of dental wear also carried out by Anne van Duijvenbode and Hayley Mickleburgh, respectively. A skeletal report of this burial assemblage has been generated from this study and forms the basis for the data presented herein (Weston 2011b). In total, the skeletal assemblage consists of 53 individuals, of which five are juveniles and 48 are adults. Of the adults, there is an equal distribution of 14 males and 14 females, while the sex could not be determined for another 20 individuals based on the generally poor condition of the much of the skeletal remains. The age distribution shows an under-representation of juveniles, a pattern similar to that found at the site of Anse à la Gourde, Guadeloupe and may be partially attributed to differential mortuary treatment based on age at death (Hofman et al. 2001a; Hoogland et al. 2010).

Lastly, Giraudy is a Ceramic Age site located in southeastern St. Lucia near the coast. The site was initially excavated by Ripley and Adelaide Bullen in collaboration with Eric Branford and uncovered numerous ceramic fragments in addition to various artifacts of shell, bone, and stone (Bullen et al. 1973). These early excavations also revealed the two major occupations at the site based on the presence of a 'modified' or Late Saladoid and a Suazan Troumassoid component. Further excavation of the site was conducted in 2004 by a team of researchers from Leiden University and the Florida Museum of Natural History, under the direction of Corinne Hofman and Menno Hoogland, and William Keegan, respectively (Hofman et al. 2004). Their excavations yielded additional material remains including a large number of pottery fragments and food refuse, in addition to a shell axe, spindle whorls, and human remains including a single human tooth that was sampled for this present study.

5.3.9 Escape, Argyle I, Argyle II, and Buccament West- St. Vincent

The adjacent sites of Argyle I, Argyle II, and Escape are located on the southeastern (windward) coast of the island of St. Vincent. Although known to the archaeological community for several years, large-scale excavations of these sites were only carried out in recent years as part of mitigation efforts corresponding to the construction of an international airport.

The Argyle (I) site was excavated by Leiden University under the direction of Corinne Hofman, Menno Hoogland and Arie Boomert, with participation of Alistair Bright, Angus Mol and Hayley Mickleburgh in 2009 and 2010. The site dates to the late prehistoric and early colonial period, and has been interpreted as an Island Carib village (Hoogland et al. 2011a; Hoogland et al. 2011b). Identified site structures consist of several small round house structures and a larger oval structure thought to have been a 'men's house' (Hoogland et al. 2011a). European materials, including glass seed beads dating to the 16th and 17th centuries, were also recovered from the site as well as Cayo pottery, confirming the association with this ceramic style with the Island Carib occupation of the Lesser Antilles (Allaire 1994; Boomert 1986, 2011; Hoogland et al.

2011a). In addition to numerous post-holes and other features, two excavated burial pits contained extremely weathered and fragmented human remains, mostly comprised of dental elements.

The Argyle (II) site is a large multi-component site located to the southwest of the Argyle I site on the southeast coast of St. Vincent. Ongoing excavations at the site have been conducted by Kathy Martin and Royden Lampkin of the St. Vincent and the Grenadines National Trust since 2010 and have been continued by the SVG Public Archaeology program since 2011 under the direction of Margarita Guzman and Jode Mackay. The large amount of cultural remains and identified features at this site indicate that it may have been a large Amerindian settlement, with an occupation spanning from the Early Ceramic (Saladoid) to Late Ceramic (Suazoid) Ages (de Guzman and Mackay 2011). Excavations in 2010, also uncovered several burials in flexed position, some containing items of personal adornment such as stone beads. In 2011, an additional 21 burials were identified of which 11 were fully excavated. Mortuary practices at the site were highly diverse as indicated by the presence of primary and secondary burials, and both flexed and extended burials. Grave goods, such as lithic materials (flakes and debitage), stone beads and pendants, and ceramic remains including a complete Saladoid vessel were fairly common (de Guzman and Mackay 2011).

Escape is a large, multi-component site located north of the Argyle sites along the riverbank and was mitigated by Iosif Moravetz of Bison Historical Services and Richard Callaghan of the University of Calgary in 2009 and 2010. The site occupation spans both the Early and Late Ceramic Age as attested to by the presence of 'modified' or late Saladoid and Suazoid ceramics (Moravetz and Callaghan 2011). However, the main occupation of the site dates to the Saladoid period, based on ceramic chronology and initial radiocarbon assays of associated materials. Excavations revealed a large number of post-holes, and several structures of varying shapes and sizes have been identified (Moravetz and Callaghan 2011). In addition to the post-hole features, at least 36 burials have been excavated to date from the central portion of the site near some of the identified structures. A wide range of mortuary treatment was also identified, including flexed, semi-flexed, and extended positioning of the body. Most of the burials are primary although a small number of secondary deposits were also documented. Additionally, the burials were relatively rich in grave goods, with a fairly large number of burials containing at least one artifact and several graves containing multiple burial inclusions. Grave goods consist of beads and pendants made from shell and stone (the latter representing a wide variety of raw materials including some that appear to be manufactured from nonlocal semi-precious stones); axes and flakes; and ceramic materials including a whole Saladoid vessel. Although none of the skeletal material has yet to be radiocarbon dated, the burials are assumed to have been deposited during the Saladoid occupation of the site based on the associated cultural remains and grave goods (Moravetz and Callaghan 2011).

The site of Buccament West is located in Buccament Bay on the southwestern coast of St. Vincent. Earlier excavations of the site and surrounding area have been conducted by the Bullens and more recently a single burial was excavated by Royden Lampkin and Kathy Martin of the St. Vincent National Trust. The burial consists of the skeletal remains of one human individual in addition to faunal bone material (possibly from a dog) placed in a large ceramic vessel (Kathy Martin, pers. comm. 2011). The chronological and cultural context of the burial is unknown at this time.

Unfortunately, systematic osteological analyses of the skeletal assemblages from these sites have yet to be carried out. Hopefully this much needed research will be conducted in the near future. In the meantime, relatively little contextual data are available for these skeletal materials other than the temporal, spatial, and cultural contexts of the site itself.

5.3.10 Heywoods- Barbados

The site of Heywoods is situated on the northwest coast of Barbados, near Speighstown, along the modern shoreline and near a former mangrove marsh (Drewett 1995; Hinds et al. 1999). The site had been known to the public through the writings of several historians and small-scale testing of the site carried out by Peter Drewett in the 1980's and early 1990's (Drewett 1991, 1995). Salvage operations of the site were carried out in the mid-1990's as the construction of a new marina at the site yielded large quantities materials.

Rescue excavations were supervised by Maureen Bennell with the assistance of Ronald Hinds; while May Hill Harris has collaborated on various aspects of the project, especially the ceramic analysis.

These excavations revealed the presence of a large multi-component habitation site, spanning from the pre-ceramic to late ceramic periods. The main Ceramic Age occupation seems to date from the late Saladoid to early Troumassoid periods (Harris 2003). Interesting finds at this site include large quantities of faunal and ceramic remains, including several wells comprised of stacked bottomless pots that probably served as water collection and storage features; high densities of features; and even preserved wooden posts and carved wooden ceremonial artifacts (Hinds et al. 1999). During the 1994 field season, at least six separate burials were excavated, one of which included lithic materials and a highly decorated bottomless vessel. In addition to these finds, several burials were also identified both in association with house structures dating to the Saladoid period and in the later Suazoid component of the site. Burials were mostly flexed and grave goods were uncommon, with one individual grave containing two stone beads (Drewett and Bates 2000). To date, an extensive skeletal report has yet to be published on the burial assemblage from Heywoods and the cultural-chronological context of the individual burials remains unclear.

5.3.11 Manzanilla- Trinidad

The site of Manzanilla is located on the central eastern coast of Trinidad near Cocos Bay and adjacent to the northern end of Nariva Swamp. Recent archaeological research at the site was initiated by a small survey and test excavations carried out by Leiden University in 1997 (Boomert et al. 1997). Preliminary results indicated that the site was a suitable setting for future investigations of Amerindian settlement practices (Nieweg and Dorst 2001). Large-scale, horizontal excavations were first carried out in 2001 and were later extended in 2003, 2004, 2006 and 2007 (Dorst et al. 2003; Dorst et al. 2004; Dorst and Altena 2005; Dorst 2006, 2008). These excavations were directed by Marc Dorst working in collaboration with, and the support of, both the Department of History of the

University of the West Indies and the National Archaeological Committee of Trinidad and Tobago.

Archaeological features and materials at the site seem to date to two distinct periods of habitation: 1) an earlier, Saladoid component of the Late Palo Seco period (AD 350-650) and; 2) a later, Araquinoid period component (AD 650-1400) (Dorst 2007, 2008; Jansen and Dorst 2007). The Saladoid deposits mainly consist of the lower portions of a large midden area. At least nine burials have been discovered which are believed to be associated with a late Palo Seco period occupation of the site (Altena 2007). The Araquinoid deposits are represented by middens, two house structures, and at least twenty burials (Altena 2007). Limited radiocarbon dating has been performed to date but available results from analyses conducted by the University of Groningen and Trent University of Calgary confirm that at least some of the structures and associated burials date to the later Araquinoid periods, circa A.D. 1010 to 1410 (Dorst 2006, 2008).

To date, at least 43 burials have been identified and 21 have been fully excavated and documented (Dorst 2008). Many of these are double, multiple, or composite burials and thus the minimum number of individuals represented far exceed this number. Enormous variability in mortuary treatment is evidenced by variation in burial type (primary, secondary, composite); burial position (flexed, semi-flexed, and extended); and burial orientation (no dominant direction of orientation) (Altena 2007; Baetsen 2003; Jansen and Dorst 2007). Very few burials have associated grave goods, although the limited grave goods discovered to date are rather distinct in several ways. These grave goods include a small number of shell beads, probably representing items of personal adornment. One burial contains the remains of a juvenile interred in the posthole of a residential structure with a shell pendant carved in shape of a jaguar’s canine tooth; and a translucent, notched, quartz pebble (Altena 2007). Burials were also found within the central posts of the same structure. A large stone axe and a greenstone frog pendant were both found in close proximity to two burials (Dorst et al. 2004; Dorst 2006, 2008).

The excavators have noted two important general patterns related to the differential funerary treatments of the Saladoid Late Palo Seco and Araquinoid complexes. The earlier Saladoid burials appear to be clearly clustered in association with a midden, this cluster may represent a communal burial area (Altena 2007; Jansen and

Dorst 2007). The older burials are all in an extended supine position (with two exceptions), lack grave goods, and lack evidence for post-inhumation manipulation of the corpse (Altena 2007; Jansen and Dorst 2007). By contrast the burials assigned to the later Araquinoid complex are associated with two structures and are believed to be buried in clusters within or around multi-family houses (Altena 2007; Jansen and Dorst 2007). The later period burials display a greater degree of variability in mortuary treatment, most notably with widespread evidence for post-inhumation manipulation of the corpse. Evidence for leaving the corpse for extended periods of time within open grave pits and the movement or removal of skeletal elements, especially of long bones and crania, is explained as reflecting elements of death rituals (Altena 2007) and is very similar to patterns of funerary behaviour in other contemporaneous Amerindian burial contexts (Boomert 2000; Hofman and Hoogland 2009; Hoogland 1999; Hoogland 1997; Hoogland et al. 2001; Kraan 1998; Sandford et al. 2002; Sannen 2006).

5.3.12 Malmok, Canashito, Santa Cruz, Savaneta, and Tanki Flip- Aruba

Malmok is a preceramic (Archaic) burial site located on the northwestern coast of Aruba. Excavations of the site were primarily conducted by a team of researchers under the direction of Aad Versteeg (Versteeg 1991b, 1993). A large, roughly oval-shaped shell midden was identified and partially excavated, in addition to numerous burials. Radiocarbon dating of shells from the midden and burial area indicate that the two areas are roughly contemporaneous and date to approximately the first several centuries A.D. Extensive horizontal excavations of the site did not yield any features or other evidence of permanent structures (Versteeg 1991b, 1993). Earlier excavations at the site uncovered a number of burials and forty more burials were excavated from the burial area adjacent to the salina (Tacoma 1991; Versteeg 1991b, 1993). Osteological analysis of the skeletal remains was conducted by Jouke Tacoma (Tacoma 1991; Versteeg 1991b, 1993). Burials occurred in clusters of roughly three to seven individuals with males often placed in the center of the clusters. This spatial patterning has led the investigators to suggest that these clusters may represent household groups and that the central male burials may represent headmen (Versteeg 1991b, 1993). Burial treatment was somewhat variable, although most interments were primary, flexed, and oriented east-west. A large number of burials were covered with large limestone blocks or turtle carapaces and a red dye was observed on the cranium of several individuals (Versteeg 1991b, 1993).

Canashito is a preceramic (Archaic) rock-shelter (or *abri*) located on the slope of Ceru Canashitu in central Aruba. Recovered remains at the site are primarily food refuse with a preponderance of shell material, in addition to several burials. A single radiocarbon date from one of the skeletons yielded an uncalibrated date of 2210 ±95 BP (Tacoma 1991). This early date and the lack of ceramic materials at the site indicate that it is probably associated exclusively with an Archaic Age occupation (Gould 1971). Five human burials were excavated by Ringma in 1950, and similar to the Malmok burial assemblage, these burials are arranged in a cluster around a central male adult burial (Tacoma 1991; Versteeg 1999). Other similarities to Malmok include the presence of a large limestone rock in one burial and the tightly flexed positioning of most of the skeletons. Osteological analysis conducted by Tacoma also indicate general morphological similarities between the Malmok and Canashito skeletal assemblages, including dolichocranic (long) and acrocranic (high) cranial shapes, possibly indicating similar ancestries for these populations (Tacoma 1991).

Santa Cruz is a large ceramic period (Dabajuroid) settlement site located in central Aruba. Excavations of the site were conducted by Leiden University and the Archaeological Museum Aruba in 1991 and 1992 under the supervision of Aad Versteeg (Versteeg 1999). Available radiocarbon dates indicate that the main occupation of the site occurred around A.D. 950-1250, although the site may have been inhabited until the contact period (early 16th century). Excavations uncovered as many as 31 burial features in nine distinct clusters, including many composite burials containing multiple individuals. Positioning and orientation of the burials were highly variable and grave goods were relatively common including several items of personal adornment (Versteeg 1999). Osteological analysis of the human remains recovered at the site was conducted by Jouke Tacoma (Tacoma 1991).

Savaneta is a large Ceramic Age (Dabajuroid) settlement site on the southwestern coast of Aruba. The main occupation of the site dates to roughly A.D. 950-1250, making the occupation contemporaneous with the Santa Cruz and Tanki Flip habitation sites, and it may have similarly remained inhabited until the contact period. Excavation of the site was conducted by Boerstra in the 1970's and revealed the presence of human burials (Versteeg et al. 1997; Versteeg 2001). Unfortunately, the original field notes have been lost and thus very little contextual information concerning the site as a whole or of the human skeletal materials is available.

Tanki Flip is a large ceramic period (Dabajuroid) habitation site located in northwestern Aruba, several kilometres inland. Early excavations at the site were conducted under the supervision of Boerstra in 1977. This excavation yielded a large number of human skeletal remains (Versteeg and Rostain 1997; Versteeg, et al. 1997). The site was later excavated by a team from Leiden University and the Archaeological Museum of Aruba in 1994 and 1995, under the supervision of Aad Versteeg (Versteeg et al. 1997). Based on the spatial patterning of recorded postholes, multiple house structures were documented at this site. The primary occupation of the site dates to roughly A.D. 950-1250, and thus it is contemporaneous with the Savaneta and Santa Cruz sites, and it may have also remained in use up to the period of contact (Versteeg and Rostain 1997; Versteeg 1999). Seven composite burials were excavated and the remains of at least 15 individuals were identified. Four of the burials are associated with one of the house structures. Several of the graves are urn burials containing human skeletal remains placed inside of an inverted ceramic burial vessel. One of these burials contained the remains of at least seven individuals placed in an urn covered by an inverted ceramic bowl (Versteeg and Rostain 1997; Versteeg 1999).

5.4 Summary

In summary, the animals and plants sampled for Sr isotope composition as part of the biosphere mapping component of this research project were collected from over 30 different islands throughout the Caribbean region. Most of the faunal remains derive from archaeological sites systematically excavated by various research teams working in the region over the last few decades. These archaeological faunal remains are supplemented by modern animal samples (primarily land snails) and modern plants (primarily grasses) systematically collected by the author and members of the Leiden Caribbean Research Group over the last few years. The sampling locations were strategically chosen to represent the widest possible range of geographic and geologic settings for each island included in the present study.

The human skeletal remains sampled for multiple isotope analysis as part of the human provenance component of this research project derive from a large number of sites located on twelve different islands in the Caribbean region. Most of the burial assemblages were strategically selected based on the size of the skeletal population, the amount of available contextual information, and to represent a wide range of spatial and temporal contexts. A limited number of smaller skeletal populations and isolated burials were also opportunistically sampled to provide baseline data for comparative analysis of Sr isotope variation in the region. Most of the of the skeletal populations included in this study derive from systematic archaeological excavations carried out by the Leiden Caribbean Research Group and other large-scale archaeological research projects conducted over the last few decades.

Site selection is biased based on the aforementioned criteria of large sample size and availability of relevant contextual information. Nonetheless the quantity and quality of available contextual data was highly variable between sites. For example, most of the larger skeletal populations derive from sites that have been extensively and intensively studied from multi-disciplinary research designs focused on the analysis of a broad array of materials and lines of evidence. Most of the larger skeletal populations have also been recently subjected to osteological analysis (or reanalysis) using updated and standardized procedures for the scoring and recording of skeletal traits for estimations of sex and age. Additionally, stable isotope analyses and paleodietary reconstructions have also been conducted for some of these skeletal assemblages. In contrast, for some of the sample populations, not only has no osteological analysis been carried out to date but in several cases little or no contextual information has been published and some site reports are not available thereby limiting the interpretations of the results and data presented herein. Nonetheless, I have included the analyses of these smaller and less well-studied collections for comparative purposes and in the hope that relevant information will become available in the future.

CHAPTER 6 RESULTS

6.1 Introduction

The analytical components of this project are comprised of 1) strontium isotope analysis of several hundred ancient and modern faunal and floral samples to assess the spatial variation of strontium isotopes in the Caribbean biosphere; 2) strontium isotope analysis of several hundred human dental enamel samples from over a dozen sites from throughout the Caribbean archipelago to examine patterns of ancient human mobility; and 3) carbon and oxygen isotope analyses conducted on a subset of the human sample population to assess the utility of using multiple isotopic datasets in the identification of nonlocal immigrants and the exploration of their origins. This chapter presents the results of these isotope analyses beginning with the strontium isotope results from plant and animal samples to assess ranges of local biosphere strontium isotope variation. Next, the human Sr isotope results are presented, first in terms of the overall dataset and then per site. Finally, the carbon and oxygen isotope results from a subset of the human sample population are presented.

6.2 Biosphere Strontium Isotope Results

Strontium isotope analysis was conducted on 288 biosphere samples including 152 plant samples (all modern) and 136 animal samples (117 archaeological and 19 modern). Of the plant samples, 146 are various species of grasses (Poaceae) and six are leaves from small bushes or trees. Of the animal samples, all 19 modern and 33 of the archaeological samples, are various species of land snails. The remaining 84 animal samples are teeth from various species of rodents, such as hutía (Capromyidae), rice rat (Oryzomyini), and agouti (*Dasyprocta sp*.)

The faunal and floral samples derive from 30 different islands plus several locations on the Venezuelan coast. A basic statistical summary of these results is provided in Table 2 and relevant sample information is listed in Appendix A [see also (Laffoon et al. 2012a)]. Strontium isotope results of fauna and flora samples are displayed as a relative probability diagram with a histogram showing the relative frequencies of $^{87}Sr/^{86}Sr$ ratios (Figure 4). These results are also plotted onto a map of the Caribbean (Figure 5) and displayed as boxplots (Figures 6 and 7). The biosphere $^{87}Sr/^{86}Sr$ ratios range from 0.70475 to 0.71152, with a mean of 0.70827 and a median of 0.70845.

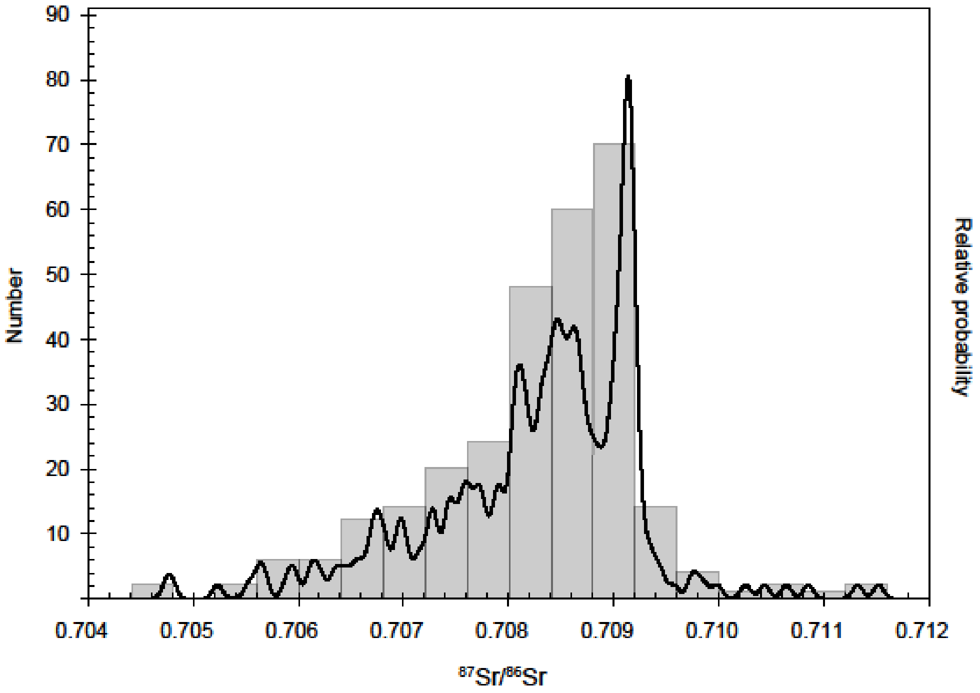


Figure 4 Relative probability diagram and histogram of biosphere $^{87}Sr/^{86}Sr$ data.
Note: a blanket error of 0.0001 was applied to all measurements to construct the density curve.

Table 2: Statistical summary of biosphere $^{87}Sr/^{86}Sr$ data from the Caribbean per island/region

Region	n	Mean	Median	Minimum	Maximum	S.D.
Anguilla	12	0.70907	0.70911	0.70872	0.70925	0.00016
Antigua	13	0.70851	0.70851	0.70775	0.70913	0.00040
Aruba	5	0.70844	0.70861	0.70764	0.70913	0.00072
Barbados	1	0.70918	0.70918	0.70918	0.70918	na
Barbuda	9	0.70917	0.70915	0.70909	0.70928	0.00006
Basse-Terre	10	0.70663	0.70672	0.70480	0.70872	0.00115
Bonaire	5	0.70864	0.70852	0.70806	0.70915	0.00046
Cuba	14	0.70823	0.70846	0.70595	0.70898	0.00077
Curaçao	10	0.70862	0.70885	0.70802	0.70915	0.00050
Dominican Rep.	7	0.70865	0.70868	0.70821	0.70914	0.00037
Grande-Terre	10	0.70915	0.70914	0.70910	0.70921	0.00004
Grenada	5	0.70689	0.70682	0.70622	0.70740	0.00047
Jamaica	3	0.70877	0.70879	0.70855	0.70897	0.00021
Les Saintes	2	0.70791	0.70791	0.70744	0.70838	0.00067
Marie-Galante	4	0.70917	0.70915	0.70914	0.70923	0.00004
Martinique	11	0.70738	0.70702	0.70634	0.70898	0.00082
Nevis	5	0.70731	0.70760	0.70670	0.70789	0.00055
Puerto Rico	18	0.70792	0.70857	0.70523	0.70916	0.00133
Saba	50	0.70821	0.70837	0.70644	0.70920	0.00056
St. Barths	4	0.70840	0.70849	0.70761	0.70903	0.00066
St. Croix	5	0.70782	0.70791	0.70678	0.70864	0.00071
St. Eustatius	8	0.70821	0.70836	0.70726	0.70897	0.00063
St. John	6	0.70839	0.70850	0.70754	0.70905	0.00058
St. Kitts	8	0.70778	0.70786	0.70673	0.70862	0.00062
St. Lucia	11	0.70830	0.70830	0.70761	0.70900	0.00053
St. Martin	11	0.70819	0.70815	0.70714	0.70916	0.00078
St. Thomas	6	0.70801	0.70809	0.70741	0.70864	0.00052
St. Vincent	8	0.70659	0.70651	0.70566	0.70812	0.00075
Tobago	5	0.70726	0.70734	0.70475	0.71026	0.00211
Trinidad	16	0.70955	0.70934	0.70832	0.71152	0.00090
Venezuela	6	0.70999	0.70976	0.70935	0.71085	0.00061
TOTALS	*288*	*0.70827*	*0.70845*	*0.70475*	*0.71152*	*0.00102*

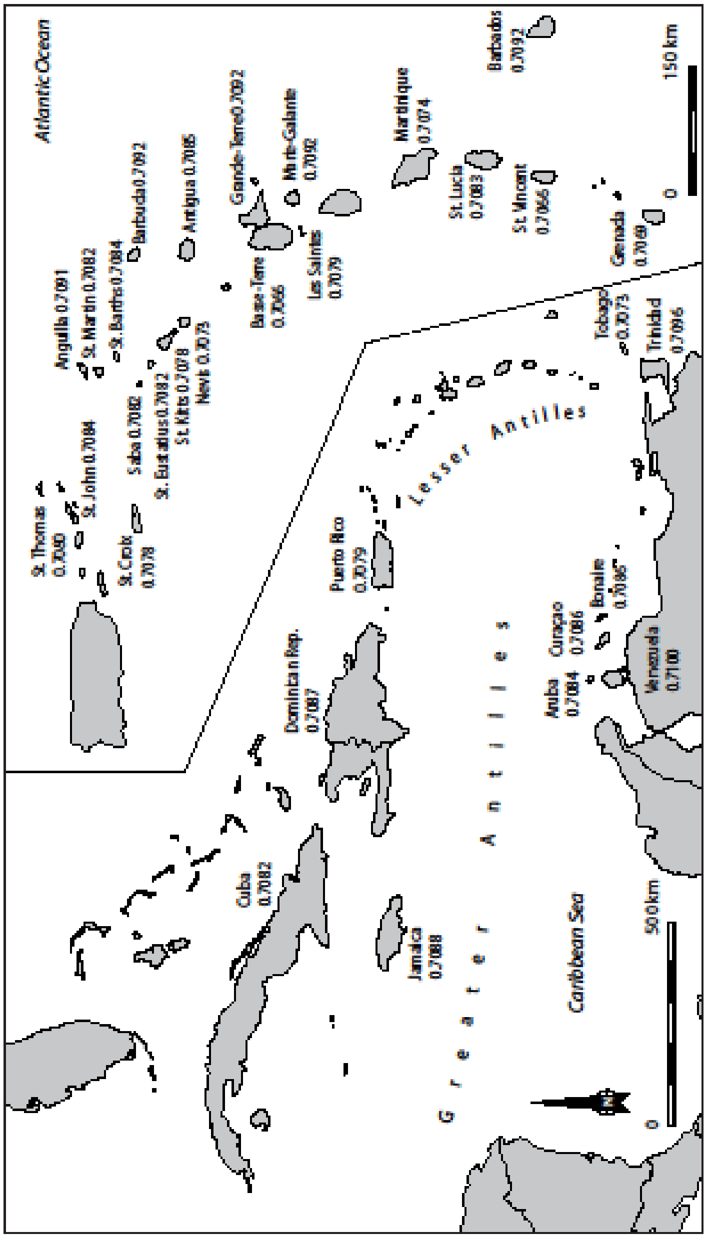


Figure 5 Map of the Caribbean displaying mean biosphere $^{87}Sr/^{86}Sr$ per island/region.

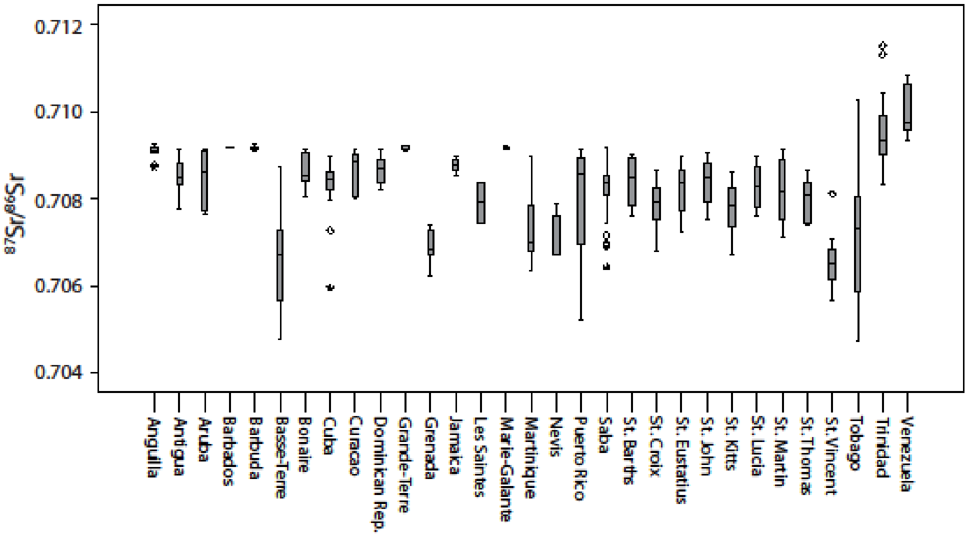


Figure 6 **Boxplot of biosphere ^{87}Sr/^{86}Sr data by island/region.**
Key: mid-lines represent medians, shaded boxes represent lower and upper quartiles, whiskers represent 1.5 IQR, circles are outliers, and stars are extreme ratios, circles are outliers, and stars are extreme ratios.

The underlying geology for each sample location was determined by reference to the U.S. Geological Survey Open-File Report 97-470-K of the Caribbean region, compiled by French and Schenk, and relevant geological literature (Dengo and Case, 1990; Donovan and Jackson, 1994). Descriptive statistical analyses of the dataset were performed on the five main geological groupings presented in Table 3. After assigning each sample to a geological subregion, I assessed the variation of biosphere ^{87}Sr/^{86}Sr by calculating several measures of variance, using a Student *t*-test to examine if the means varied significantly between each subregion. Results of comparisons between mean ^{87}Sr/^{86}Sr ratios per geological subregion are presented in Table 4. Means are deemed significantly different if *t* is less than 0.05. Biosphere ^{87}Sr/^{86}Sr data per region are displayed as boxplots in Figure 7. A description of the patterning of the Sr isotope results for each geological subregion is presented below.

Table 3: Statistical summary of biosphere ^{87}Sr/^{86}Sr data by geological subregion
Key: VI = Volcanics and Intrusives - Antilles; OL = Older Limestone - Antilles; RL = Recent Limestone - Antilles; SD = Sedimentary Deposits - Trinidad and Venezuela; MD = Metamorphic Deposits - Trinidad and Venezuela.

Subregion	N	Minimum	Maximum	Mean	Median	S.D.
VI: Antilles	162	0.70475	0.70920	0.70774	0.70803	0.00093
OL: Antilles	50	0.70728	0.70916	0.70846	0.70854	0.00047
RL: Antilles	54	0.70872	0.71026	0.70913	0.70914	0.00019
SD: T&V	16	0.70832	0.71152	0.70939	0.70934	0.00072
MD: T&V	6	0.70944	0.71132	0.71041	0.71054	0.00070

Table 4: Results of Student *t*-test comparing the mean biosphere ^{87}Sr/^{86}Sr ratios of different geological subregions in the Caribbean
Note: * indicates *t* probability less than 0.05

SITES	OL: Antilles	RL: Antilles	SD: T&V	MD: T&V
VI: Antilles	0.00072	0.00140	0.00165	0.00267
	167	194	20	6
	<0.0001*	<0.0001*	<0.0001*	0.00014*
OL: Antilles		0.00068	0.00093	0.00195
		64	19	6
		<0.0001*	0.00011*	0.00080*
RL: Antilles			0.00026	0.00127
			16	5
			0.17720	0.00671*
SD: T&V	mean difference			0.00101
	deg. of freedom			9
	t probability			0.01483*

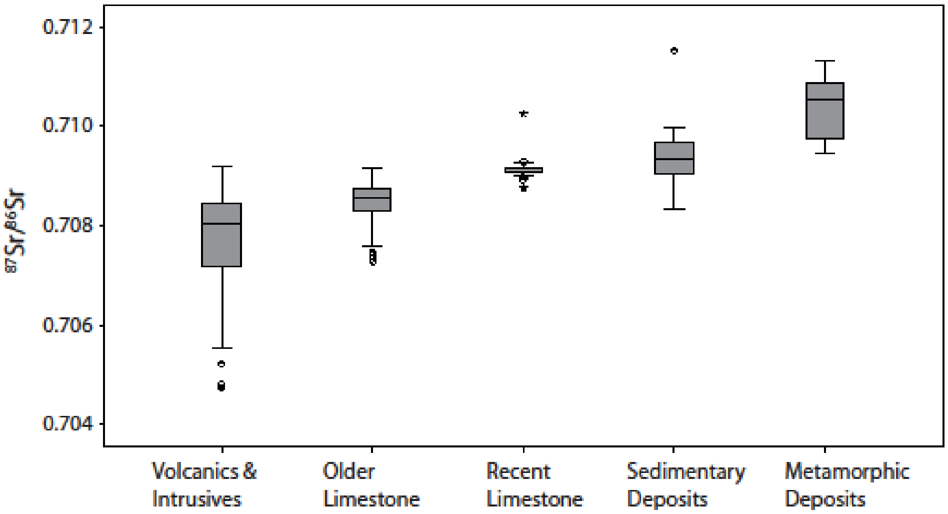


Figure 7 Boxplot of biosphere ^{87}Sr/^{86}Sr variation by geological subregion. Key: mid-lines represent medians, shaded boxes represent lower and upper quartiles, whiskers represent 1.5 IQR, circles are outliers, and stars are extreme ratios, circles are outliers, and stars are extreme ratios.

Several samples derive from areas with underlying deposits of intrusive rocks, in particular Mesozoic and Cretaceous plutons and ultramafic rocks from the islands of Tobago, Cuba and Puerto Rico, and possess the lowest ^{87}Sr/^{86}Sr ratios of the dataset. Sr isotope results from areas of primarily volcanic bedrock including locations in the Volcanic Caribbees, the Greater Antilles, and the Southern Caribbean islands, display low ^{87}Sr/^{86}Sr ratios and form the largest portion of our sample set. Mean ^{87}Sr/^{86}Sr from plants and animals originating from areas dominated by intrusive and volcanic rocks in the Caribbean is 0.70774 ± 0.00186 (2σ).

The range and variance of biosphere ^{87}Sr/^{86}Sr ratios from this region are larger than would be expected based solely on the underlying geology, which is dominated by basalts and andesites with smaller deposits of tuffs and pyroclastic flows primarily dating from the Miocene to Quaternary. Geochemical research of Lesser Antillean island arc magmatism indicates that the region should possess surface deposits that are dominated by mantle derived Sr. Sr isotope results from analyses of whole rocks and rock minerals from volcanic deposits in the Volcanic Caribbees are generally less than 0.707 (Borg and Banner 1996; Davidson 1987; Roobol and Smith 2004; van Soest et al. 2002; Wadge and Wooden 1982; White and Patchett 1984) [see also GEOROC database-http://georoc.mpch-mainz.gwdg.de/georoc/Entry.html]. The large differences between underlying geology and biosphere $^{87}Sr/^{86}Sr$ in volcanic areas probably result from inputs of non-geological Sr into local terrestrial environments. Marine Sr is the most likely cause of this effect, being introduced via sea spray into local soils. The $^{87}Sr/^{86}Sr$ results from this subregion overlapped substantially with those of Cretaceous to Miocene limestones. A small degree of overlap exists between this subregion and both the Recent Limestone and Sedimentary Deposits but there is no overlap with Metamorphic Deposits.

Mean $^{87}Sr/^{86}Sr$ of samples from areas underlain by older (Cretaceous to Miocene) limestone is 0.70846 ± 0.00093 (2σ) and these data typically fall within the range of expected ratios based on comparisons with Sr isotope seawater curves with younger limestones possessing higher $^{87}Sr/^{86}Sr$ ratios than older ones. However, there was not always exact agreement between individual measured ratios and expected ratios based on published seawater curves. Influences of marine Sr will be less detectable in these areas with only small differences in $^{87}Sr/^{86}Sr$ between geological (terrestrial) and non-geological (marine) sources of Sr and the generally high Sr content of the underlying limestones. In addition to the aforementioned overlap with the Volcanic and Intrusive subregion, a minor degree of overlap in $^{87}Sr/^{86}Sr$ ratios was present between this subregion and both the Recent Limestone and Sedimentary Deposits but not between this subregion and Metamorphic Deposits.

Recent limestone deposits dating from the Pliocene to Quaternary are expected to possess $^{87}Sr/^{86}Sr$ ratios similar to modern seawater. The mean $^{87}Sr/^{86}Sr$ of animals and plants from areas of geologically recent limestone is 0.70913 ± 0.00038 (2σ) and matches this expectation with little variance and a relatively small Sr isotope range compared to the other subregions. A limited overlap was present between the $^{87}Sr/^{86}Sr$ ratios of this subregion and the other subregions with the exception of the Metamorphic Deposits.

Samples from Cretaceous and Tertiary marine sedimentary deposits and continental Quaternary alluvium (southern Trinidad and coastal Venezuela) yielded highly variable but mainly elevated $^{87}Sr/^{86}Sr$ ratios relative to the bulk of our sample set, mean $^{87}Sr/^{86}Sr = 0.70934 \pm 0.00145$ (2σ). These elevated but variable Sr isotope ratios are in general agreement with expectations based on their associated geological terrains with marine strata expected to display variable $^{87}Sr/^{86}Sr$ dependent upon age, while alluvial deposits eroding from continental rocks possess somewhat elevated $^{87}Sr/^{86}Sr$ signals relative to both volcanics and marine limestones. This subregion overlapped to some extent with all four of the other subregions as it represents a mixture of different types of sedimentary deposits from throughout the Tertiary and Quaternary.

Samples derived from metamorphic provinces (northern Trinidad and Venezuela) yielded the most radiogenic $^{87}Sr/^{86}Sr$ ratios in the sample population, mean $^{87}Sr/^{86}Sr$ is 0.71041 ± 0.00141 (2σ). This range in $^{87}Sr/^{86}Sr$ is in line with expectations based on the geological terrains, with metamorphic rocks generally expected to possess higher $^{87}Sr/^{86}Sr$ signals than volcanic rocks or limestone within this study area. $^{87}Sr/^{86}Sr$ ratios from this subregion overlapped slightly with the Sedimentary Deposits subregion of Trinidad and Venezuela but not with the other three Antillean subregions.

Certain aspects of the distribution, variation and patterning of the biosphere Sr isotope data merit further elaboration. First, it is worth noting that the largest peak in ratios clusters around the ratio of modern seawater of 0.7092 (Figure 8). This peak is expected based on the maritime settings of the sampling locations, all of which are within around ten kilometers of the coast and are thereby likely exposed to marine-derived strontium. In addition, many of the samples derive from areas dominated by recent limestone geologies that also possess Sr isotope ratios similar to modern seawater. Clearly, $^{87}Sr/^{86}Sr$ ratios vary in their relative frequencies in the environment and are not equally distributed spatially. Owing to the effects of the oceans, e.g., their homogenous $^{87}Sr/^{86}Sr$ ratios and the frequent occurrence of bedrock formed by marine deposition, $^{87}Sr/^{86}Sr$ ratios of approximately 0.7092 are probably by far the most common on a global scale even in terrestrial ecosystems.

The relative distribution of the biosphere $^{87}Sr/^{86}Sr$ dataset displays several smaller peaks in ratios below 0.7092 that taper off towards ratios approaching ~0.705. This pattern is also expected based on geological expectations and Sr isotope systematics. For example, on a global scale $^{87}Sr/^{86}Sr$ ratios below about 0.702 are extremely rare providing an absolute cut off in biosphere ^{87}Sr/^{86}Sr ratios. These lower ^{87}Sr/^{86}Sr ratios are especially characteristic of measurements obtained from the analyses of rock and soil samples in volcanic settings. In fact, a relative probability diagram of geological ^{87}Sr/^{86}Sr ratios in the Caribbean would display much higher frequencies of ^{87}Sr/^{86}Sr ratios falling near the lower end of this range. However, as previously discussed, the ubiquitous presence of marine-derived Sr in terrestrial island ecosystems elevates the ^{87}Sr/^{86}Sr ratios of the plants and animals living on these islands to ratios that are intermediate between that of the underlying geology and that of the sea.

Another interesting pattern in this dataset is the sharp drop-off in ^{87}Sr/^{86}Sr ratios above 0.7092 and the locations of the small number of samples with these more radiogenic ratios. Within the biosphere Sr isotope dataset, ratios above 0.7092 are relatively rare and ratios above 0.7094 are extremely rare. The latter group is almost entirely comprised of samples that do not originate from the Antilles per se, but from the continental islands lying off of the coast of South America (Trinidad and Tobago) or from the mainland itself (Venezuela). In these settings, the opposite pattern to that of the Antilles prevails in that the baseline geological ^{87}Sr/^{86}Sr ratios are elevated relative to that of the sea and thus most plants and animals from the mainland coast or continental islands possess ^{87}Sr/^{86}Sr ratios that are intermediate between the sea and the somewhat more elevated ratios of the associated continental geology. Thus, the inclusion of a larger number of samples from these islands or from the mainland would surely have shifted the distribution of the Sr isotope results to a larger representation of ^{87}Sr/^{86}Sr ratios higher than 0.7092. One implication of these overall patterns is that an ^{87}Sr/^{86}Sr ratio of approximately 0.7094 represents the maximum limit of biosphere ratios for the Antilles (*sensu stricto*). Further implications of the spatial patterning of this dataset are discussed in the following chapter.

Lastly, I regard faunal remains in general and dental enamel samples from small terrestrial mammals as more reliable proxies for local Sr isotope variation than other sample types. Comparisons of the fauna and flora Sr isotope data reveal broad similarities in terms of the variance and distributions of the two datasets. In order to quantify these differences I compared the difference in means for paired animal and plant samples obtained from the same sampling location. The mean pair-wise difference between fauna and flora from the same sampling location is 0.00028 (n =12). This difference is small relative to the overall range of Sr isotope ratios for most sites included in this study. However, in a small number of cases, there are larger differences in ^{87}Sr/^{86}Sr ratios between paired faunal and floral samples at the site-level. Nonetheless, comparisons of means, medians and ranges of ^{87}Sr/^{86}Sr ratios between fauna and flora samples at larger scales (islands as opposed to sites) also reveals a substantial degree of correspondence between the two datasets.

6.3 Human Strontium Isotope Results

In this section I present the strontium isotope results from the analyses of human dental enamel samples from Caribbean archaeological assemblages. I begin with a short discussion of the entire dataset and then discuss the results from each individual region and site individually. Strontium isotope results were obtained from 360 individual samples from 26 sites on 12 different islands. These results and relevant sampling information for these individuals are presented in Appendix B. Strontium isotope results of human samples are displayed as a relative probability diagram with a histogram showing the relative frequencies of ^{87}Sr/^{86}Sr ratios (Figure 8). The mean ^{87}Sr/^{86}Sr ratios per region are plotted onto a map of the Caribbean (Figure 9). A summary and basic descriptive statistics of the human Sr isotope results are presented here first by island (Table 5 and Figure 10) and then by site (Table 6 and Figure 11). Additionally, the entire human and biosphere strontium isotope datasets are compared (Figure12).

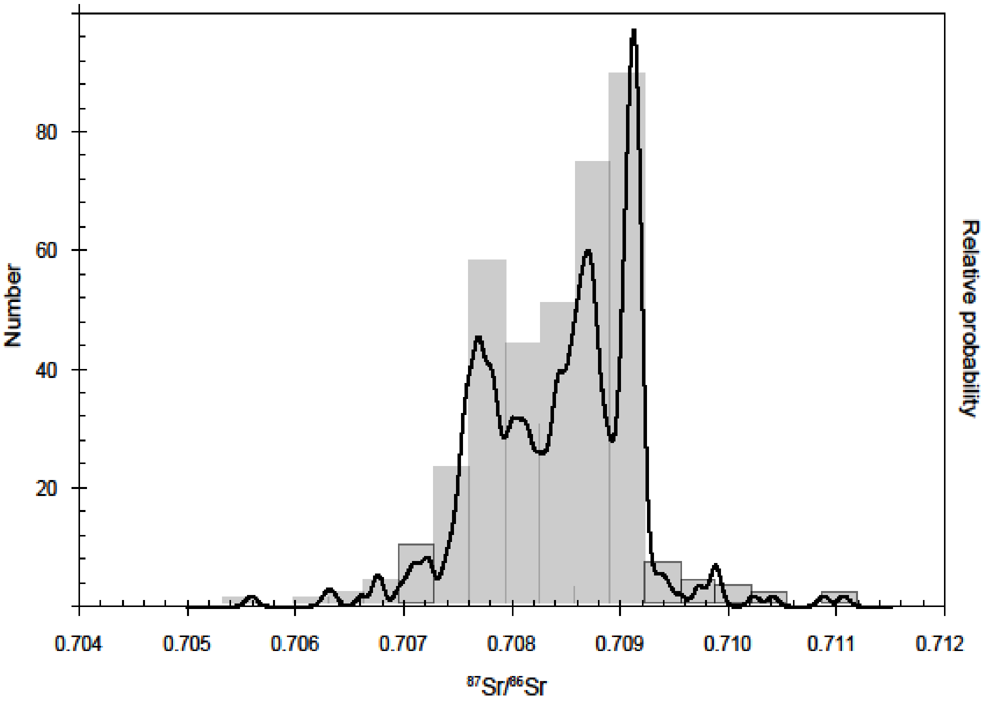


Figure 8 **Relative probability diagram and histogram of human $^{87}Sr/^{86}Sr$ data.** Note: a blanket error of 0.0001 was applied to all measurements to construct the probability curve. One extreme (high) $^{87}Sr/^{86}Sr$ ratio from Manzanilla, Trinidad not displayed at this scale

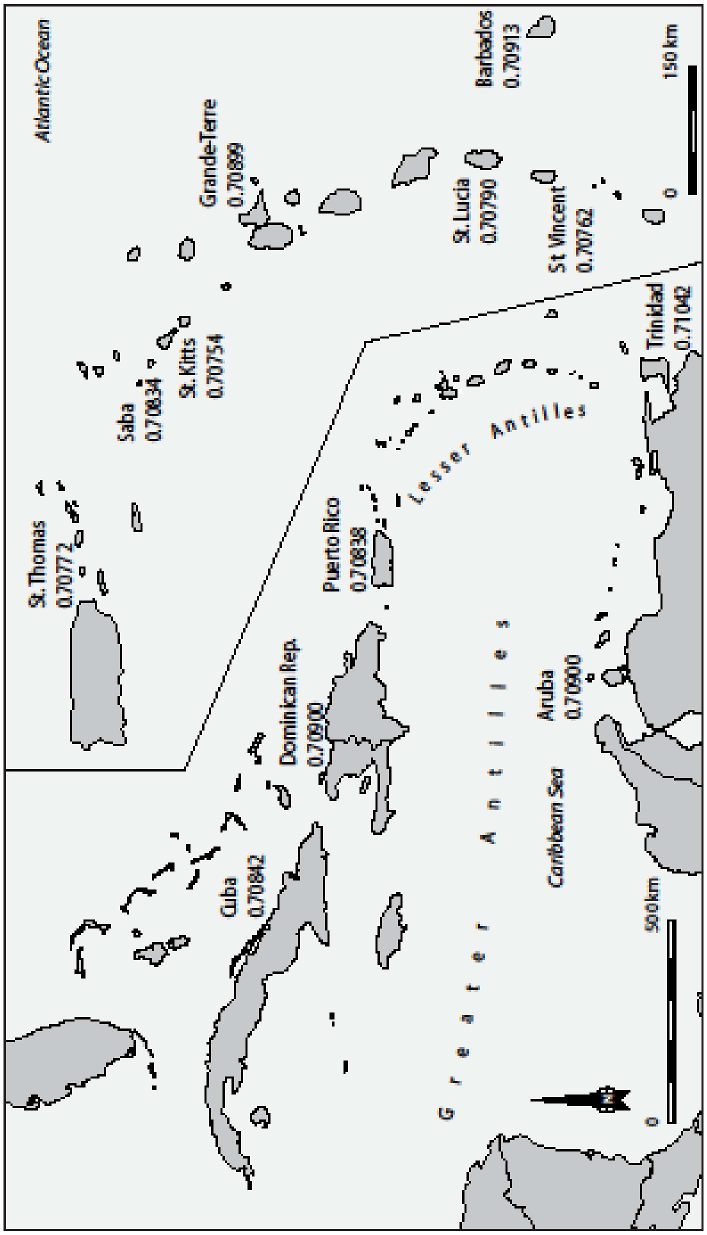


Figure 9 Map of the Caribbean displaying mean human $^{87}Sr/^{86}Sr$ per island.

The human $^{87}Sr/^{86}Sr$ ratios within this study range from 0.70559 to 0.72179, with a mean of 0.70847 and a median of 0.70855. This range is comparable to, but much larger than, the absolute range of biosphere $^{87}Sr/^{86}Sr$ (0.70475 to 0.71152). This difference is expected if some portion of the human sample population originated from outside of the study area. The removal of two extreme human outliers greatly reduces the overall range of human $^{87}Sr/^{86}Sr$ ratios (0.70559 to 0.71045) to one that is more consistent with the biosphere dataset. The comparable mean and median ratios of the biosphere and human Sr isotope datasets indicate a good degree of correspondence between them. However, the mean and median ratios of the biosphere data are lower than that of the human data (by 0.00020 and 0.00009 respectively). This pattern may be the result of differences in the representativeness of the sample populations as the biosphere samples originate from more variable sampling locations within the Caribbean and in which volcanic settings are over-represented relative to the sites from where the human samples originate.

Table 5: Statistical summary of human $^{87}Sr/^{86}Sr$ data by island

Island	**n**	**Mean**	**Median**	**Minimum**	**Maximum**	**SD**
Aruba	9	0.70900	0.70906	0.70823	0.70988	0.00045
Barbados	3	0.70913	0.70913	0.70913	0.70915	0.00001
Cuba	93	0.70842	0.70849	0.70676	0.71088	0.00052
Dominican Republic	26	0.70900	0.70904	0.70776	0.70922	0.00027
Guadeloupe	68	0.70899	0.70912	0.70749	0.70941	0.00035
Puerto Rico	29	0.70838	0.70865	0.70559	0.70890	0.00074
Saba	7	0.70834	0.70851	0.70770	0.70879	0.00042
St. Lucia	32	0.70790	0.70790	0.70723	0.70857	0.00026
St. Kitts	4	0.70754	0.70752	0.70742	0.70772	0.00013
St. Thomas	29	0.70772	0.70784	0.70628	0.70871	0.00051
St. Vincent	43	0.70762	0.70766	0.70635	0.70869	0.00036
Trinidad	16	0.71042	0.70973	0.70854	0.72179	0.00310
TOTAL	360	0.70847	0.70854	0.70559	0.72179	0.00101

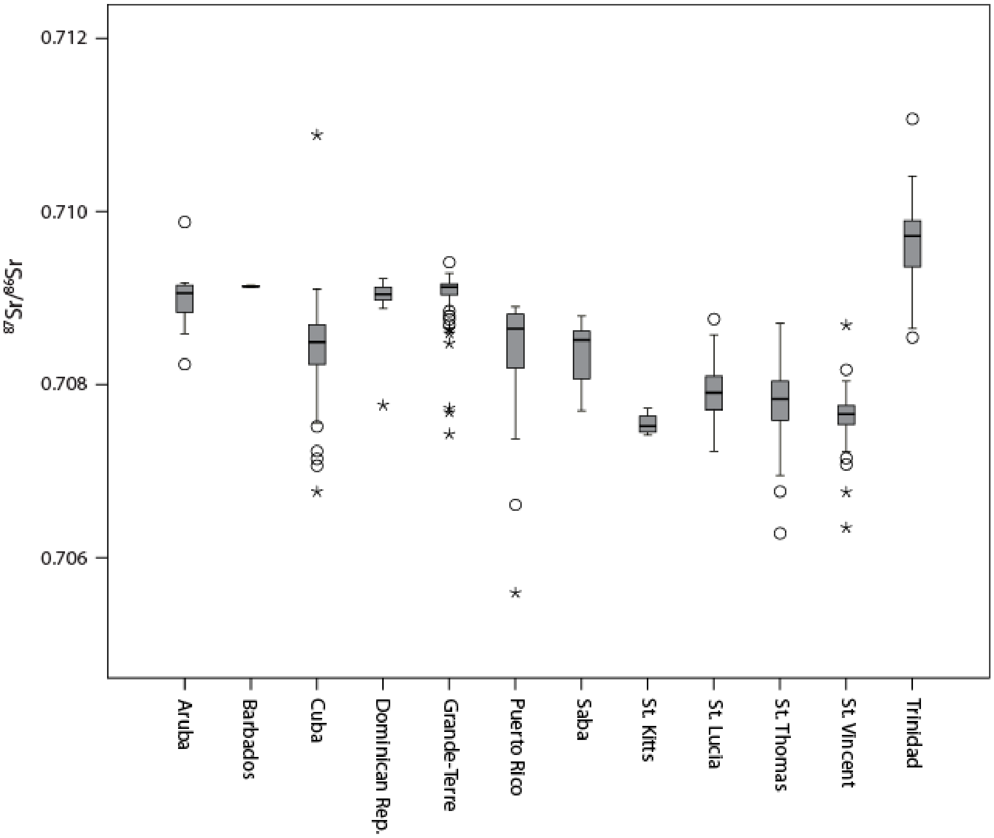


Figure 10 Boxplot of human ^{87}Sr/^{86}Sr data by island.

Key: mid-lines represent medians, shaded boxes represent lower and upper quartiles, whiskers represent 1.5 IQR, circles are outliers, and stars are extreme ratios, circles are outliers, and stars are extreme ratios. Note: One extreme (high) ^{87}Sr/^{86}Sr ratio from Manzanilla not displayed at this scale.

Table 6: Statistical summary of human $^{87}Sr/^{86}Sr$ data by site

Island	Site	N	Mean	Median	Min	Max	SD
Aruba	Malmok	4	0.70901	0.70908	0.70859	0.70918	0.00024
	Tanki Flip	2	0.70878	0.70878	0.70859	0.70897	0.00027
	Savaneta	1	0.70884	0.70884	na	na	na
	Santa Cruz	1	0.70823	0.70823	na	na	na
	Canashito	1	0.70988	0.70988	na	na	na
Barbados	Heywoods	3	0.70914	0.70913	0.70913	0.70915	0.00001
Cuba	El Chorro de Maíta	88	0.70842	0.70848	0.70676	0.71088	0.00053
	Cueva los Muertos	4	0.70868	0.70871	0.70844	0.70886	0.00018
	Potreno del Mango	1	0.70801	0.70801	na	na	na
Dom. Rep.	Bartolo	1	0.70922	0.70922	na	na	na
	El Cabo	4	0.70918	0.70918	0.70915	0.70919	0.00002
	Punta Macao	21	0.70896	0.70903	0.70776	0.70916	0.00028
Guadeloupe	Anse à la Gourde	68	0.70899	0.70912	0.70749	0.70941	0.00035
Puerto Rico	Maisabel	29	0.70838	0.70865	0.70559	0.70890	0.00074
Saba	Kelbey's Ridge	6	0.70842	0.70855	0.70770	0.70879	0.00039
	Spring Bay	1	0.70785	0.70785	na	na	na
St. Kitts	Bloody Point	4	0.70754	0.70752	0.70742	0.70772	0.00013
St. Lucia	Giraudy	1	0.70876	0.70876	na	na	na
	Lavoutte	32	0.70790	0.70790	0.70723	0.70857	0.00026
St. Thomas	Tutu	29	0.70773	0.70784	0.70628	0.70871	0.00051
St. Vincent	Escape	26	0.70755	0.70761	0.70676	0.70802	0.00026
	Argyle 1	2	0.70779	0.70779	0.70754	0.70804	0.00035
	Argyle 2	14	0.70782	0.70776	0.70734	0.70869	0.00032
	Buccament West	1	0.70635	0.70635	na	na	na
Trinidad	Manzanilla	16	0.71042	0.70973	0.70854	0.72179	0.00310

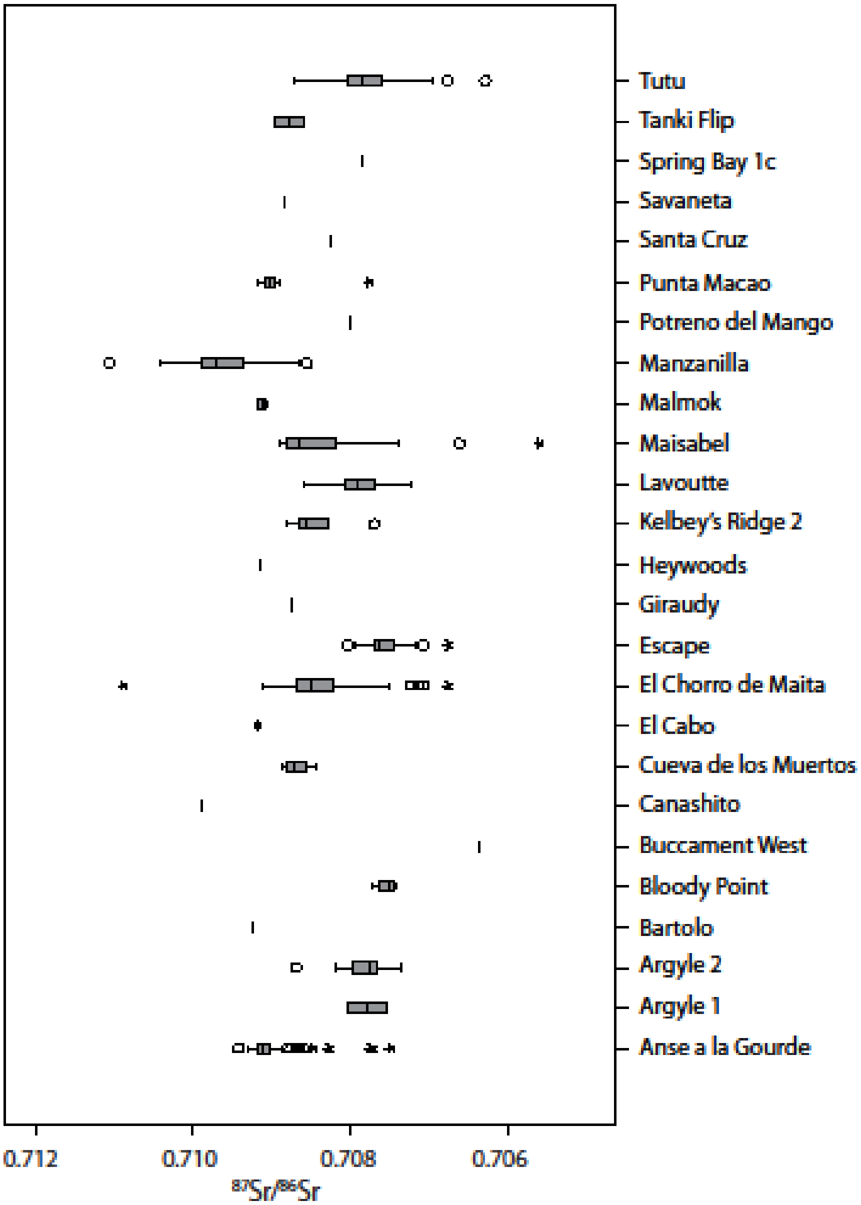


Figure 11 **Boxplot of human ^{87}Sr/^{86}Sr data by site.**
Key: mid-lines represent medians, shaded boxes represent lower and upper quartiles, whiskers represent 1.5 IQR, circles are outliers, and stars are extreme ratios. Note: One extreme (high) ^{87}Sr/^{86}Sr ratio from Manzanilla not displayed at this scale.

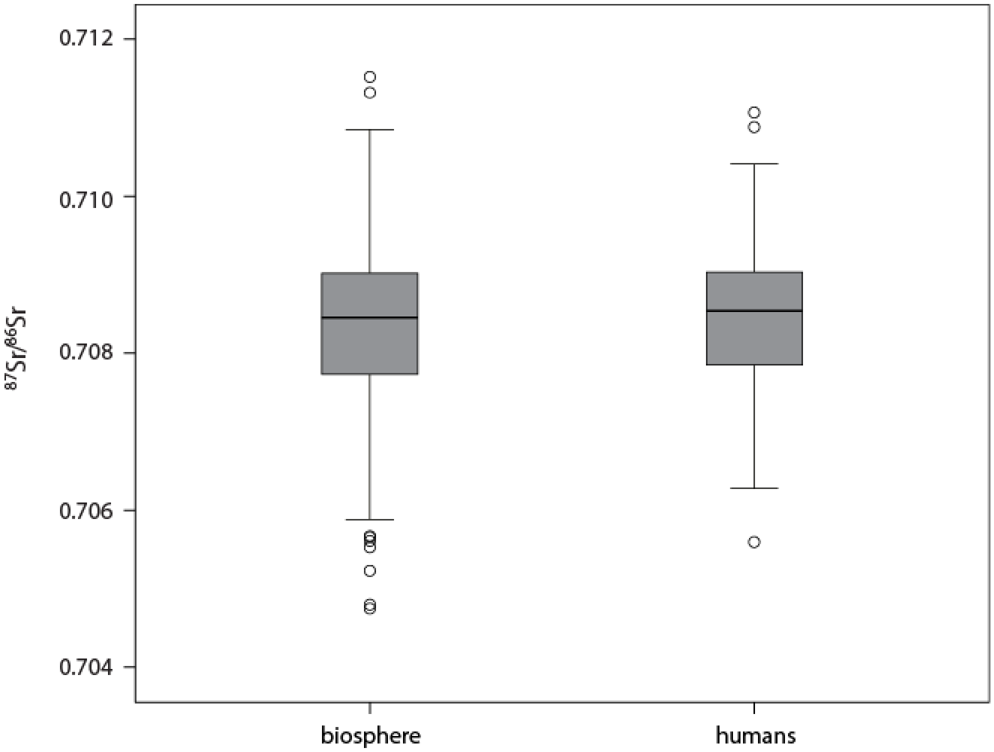


Figure 12 Boxplot comparing biosphere and human $^{87}Sr/^{86}Sr$ data.
Key: mid-lines represent medians, shaded boxes represent lower and upper quartiles, whiskers represent 1.5 IQR, circles are outliers, and stars are extreme ratios. Note: One extreme (high) human Sr isotope ratio from Manzanilla not displayed at this scale.

6.3.1 El Chorro de Maíta, Cueva de los Muertos, and Potreño del Mango- Cuba

The Sr isotope data from Cuba were obtained from three different sites although the vast majority originate from the cemetery at El Chorro de Maíta (n = 88), while a much smaller number derive from the nearby cave site of Cueva de los Muertos (n = 4), and a single specimen comes from the more distant site of Potreno del Mango near the eastern tip of the island. The $^{87}Sr/^{86}Sr$ ratios from El Chorro de Maíta (Figure 13) range from 0.70676 to 0.71088, with a mean of 0.70842 and a median of 0.70848. Analysis of this dataset reveals that it approaches a normal distribution with a nearly identical mean and median. However, the variance of the $^{87}Sr/^{86}Sr$ ratios is relatively high (sd = 0.000533) compared to the absolute variance of most of the other populations in this study. In fact, this degree of variance is surpassed only by the Maisabel and Manzanilla populations, both of which include one or more extreme ratios.

A substantial number of the human Sr isotope ratios from El Chorro de Maíta fall outside the absolute range of biosphere $^{87}Sr/^{86}Sr$ ratios obtained directly from faunal samples from the site itself, which range from 0.70796 to 0.70867 (n = 5). Nonetheless, the majority of the human $^{87}Sr/^{86}Sr$ ratios overlap with this range of biosphere $^{87}Sr/^{86}Sr$ ratios indicating a high degree of correspondence between the two datasets. Comparisons of the human samples from El Chorro de Maíta with the absolute range of biosphere $^{87}Sr/^{86}Sr$ ratios obtained from various other sampling locations across the island (n = 9) indicate a large degree of overlap in the ranges of ratios. Interestingly, despite the fact that these faunal samples were obtained from seven different sites from widely separated spatial contexts and in some cases distinct geological settings, most of them cluster with both the faunal and the local human sample populations from El Chorro de Maíta. Two faunal samples are exceptions to this general pattern. One hutía from the site of Potreno del Mango has an $^{87}Sr/^{86}Sr$ ratio of 0.70801 that is near the lower end of the nonlocal human samples from El Chorro de Maíta and another hutía from the site of La Juba along the central northern coast has a very low $^{87}Sr/^{86}Sr$ ratio of 0.70595.

The human $^{87}Sr/^{86}Sr$ ratios from Cuevas de los Muertos display reduced variance (sd = 0.00018) compared to the El Chorro de Maíta samples most likely in part owing to its small sample size (n = 4). All four samples from Cueva de los Muertos fall within the cluster of $^{87}Sr/^{86}Sr$ ratios from the local population at El Chorro de Maíta. The $^{87}Sr/^{86}Sr$ ratio from the single human sample from Potreno del Mango (0.70801) also falls within the local range of the El Chorro de Maíta population. However, the two faunal samples from this site possessed distinct $^{87}Sr/^{86}Sr$ ratios, neither of which was comparable to the human sample from this site. The cause of these disparate results is currently unknown, although they may simply be a reflection of small sample sizes that fail to reflect the full extent or range of ^{87}Sr/^{86}Sr variation at this particular site.

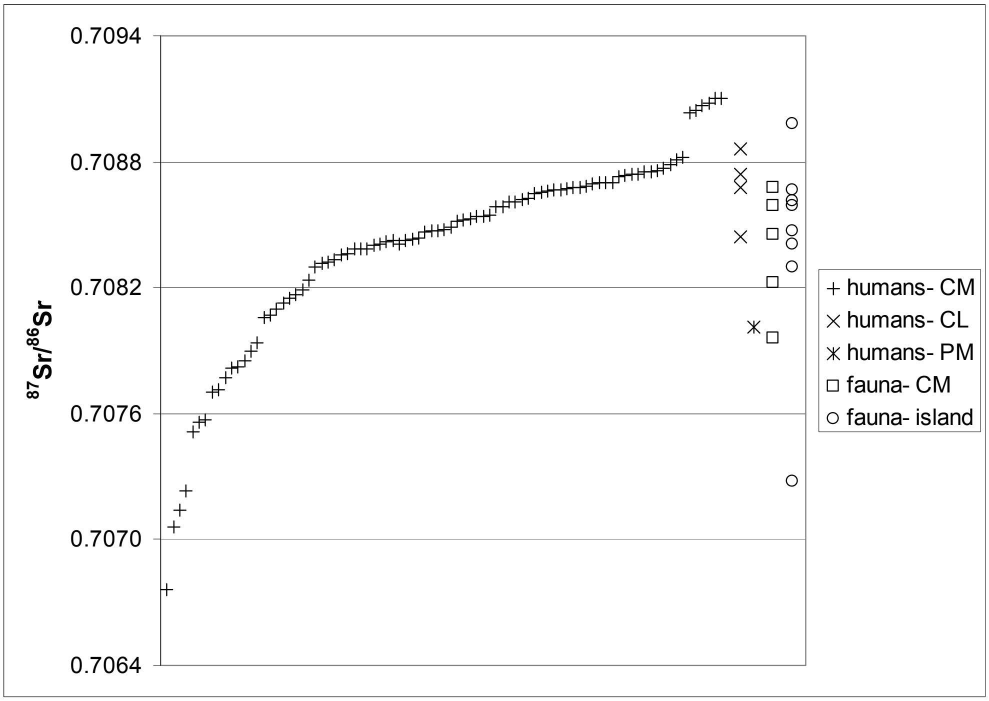


Figure 13 Strontium Isotope Ratios- Cuba.
Key: CM = El Chorro de Maíta; CL = Cueva de los Muertos; PM = Porteño del Mango.
Note: one extreme (high) outlier not displayed at this scale.

6.3.2 Punta Macao, El Cabo and Bartolo- Dominican Republic

The Sr isotope data from the Dominican Republic (Figure 14) include samples from 26 individuals; including 21 from the site of Punta Macao, four from the site of El Cabo, and one from the site of Bartolo. The ^{87}Sr/^{86}Sr ratios from all three sites range from 0.70776 to 0.70922, with a mean of 0.70896 and a median of 0.70903. There are clear differences between the means and ranges of ^{87}Sr/^{86}Sr ratios from each site. Punta Macao has the lowest mean ^{87}Sr/^{86}Sr and the largest range of ratios, although the latter is at least partially attributable to the much larger number of samples from this site and because at least one of these ratios is an extreme outlier. The dispersion of the Punta Macao results (sd = 0.000283) is intermediate relative to the other sampled populations in this study but much larger than the variance of the El Cabo data. Only one faunal sample from Punta Macao, a hutía tooth, was available for comparative analysis and it has an $^{87}Sr/^{86}Sr$ ratio of 0.70907, a result that falls near the middle of the range of human ratios from this site.

The El Cabo samples have $^{87}Sr/^{86}Sr$ ratios ranging from 0.70915 to 0.70919, a mean of 0.70918 and a median of 0.70918. The reduced variance (sd = 0.000019) at El Cabo is partly due to the small sample size but may also be influenced by the geological and subsequent Sr isotope homogeneity of the site's location. The range of El Cabo $^{87}Sr/^{86}Sr$ ratios falls at the higher end of the range for Punta Macao with considerable overlap between the two. One land snail sample from El Cabo was measured and its $^{87}Sr/^{86}Sr$ ratio corresponds well both with the human $^{87}Sr/^{86}Sr$ ratios from this site and with expectations based on associated geology.

The site of Bartolo is represented by a single individual sample with an $^{87}Sr/^{86}Sr$ ratio of 0.70922. This is the highest ratio amongst the samples from the Dominican Republic but it is not extremely elevated relative to either Punta Macao or El Cabo. Four additional faunal samples (all land snails) were analyzed from various sites located in the northern Dominican Republic. The $^{87}Sr/^{86}Sr$ ratios from these samples were moderately variable, which is to be excepted as they derive from different sites with somewhat distinct geological substrates. This range of ratios (~0.7082 to 0.7088) is lower than, and does not overlap with, the local populations from the eastern Dominican Republic.

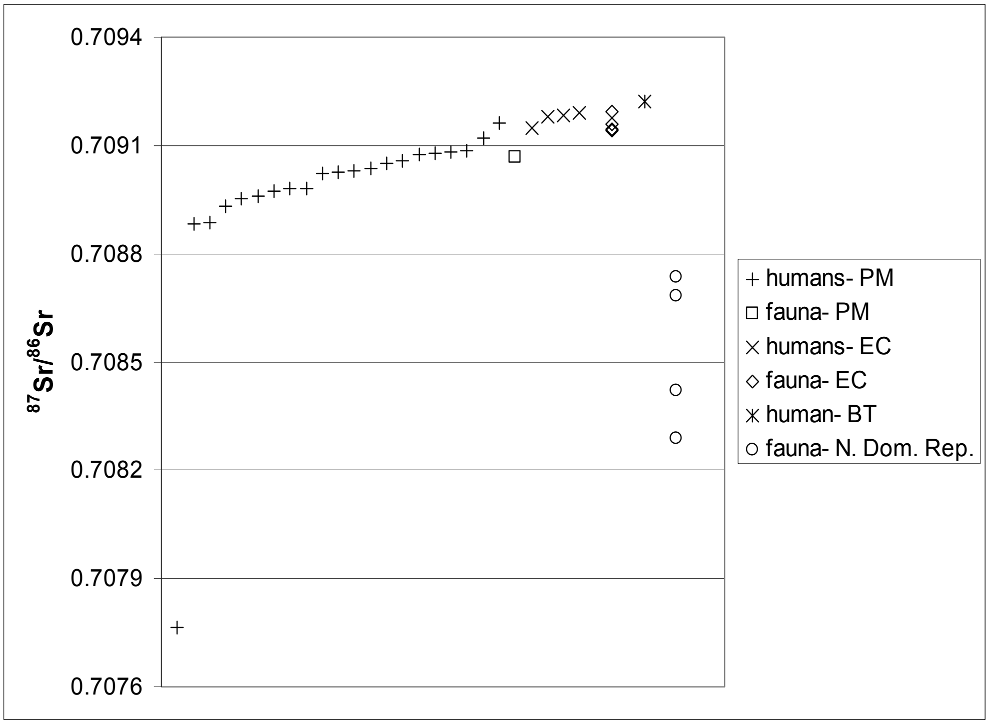


Figure 14 Strontium Isotope Ratios- Dominican Republic.
Key: PM = Punta Macao; EC = El Cabo; BT = Bartolo.

6.3.3 Maisabel- Puerto Rico

The Sr isotope ratios from Puerto Rico derive from 29 individuals (Figure 15), all of whom are from the site of Maisabel. The $^{87}Sr/^{86}Sr$ ratios from this site range from 0.70559 to 0.70890, with a mean of 0.70838 and a median of 0.70865. This range is large compared to most of the other sites in our study, as indicated by its high variance (sd = 0.00074) and is surpassed in this regard only by the extremely variable results from Manzanilla, Trinidad. The Maisabel sample population is not normally distributed and displays high skewness with a large tail on the lower side of the distribution and a significant difference between the mean and median ratios.

Faunal samples from Maisabel include five land snails and three rodent teeth, with $^{87}Sr/^{86}Sr$ ratios ranging from 0.70873 to 0.70916 (n = 8). The range of faunal $^{87}Sr/^{86}Sr$ ratios for this site overlaps only with the higher end of the range of human $^{87}Sr/^{86}Sr$ ratios. These data in conjunction with Sr isotope ratios obtained from plants sampled from diverse geological contexts display a large range (0.70523 to 0.70916) and variance (sd = 0.00133) of biosphere $^{87}Sr/^{86}Sr$ ratios for the island of Puerto Rico. This is the largest range and variance of biosphere $^{87}Sr/^{86}Sr$ ratios for a single island within this study. The range of $^{87}Sr/^{86}Sr$ ratios from Puerto Rican plant samples encompasses the range of both faunal and human Sr isotope ratios from the Maisabel site.

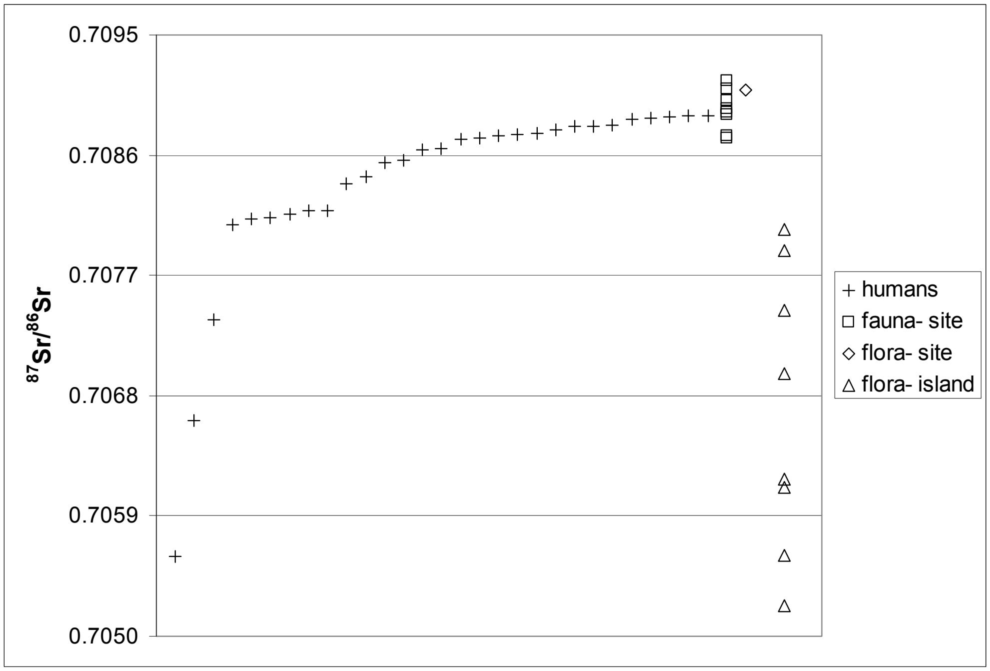


Figure 15 Strontium Isotope Ratios- Puerto Rico.
Key: human and faunal samples and one floral sample are from Maisabel.

6.3.4 Tutu- St. Thomas, U.S. Virgin Islands

The Sr isotope ratios from St. Thomas, USVI were obtained from 29 individuals (Figure 16), all of whom are from the site of Tutu. The $^{87}Sr/^{86}Sr$ ratios from this site range from 0.70628 to 0.70871 with a mean of 0.70773 and a median of 0.70784. The variance (sd = 0.00051) of the entire Tutu dataset is also somewhat large relative to other sites. The distribution of this dataset more closely approximates a normal distribution than most of the other populations in this study, displaying relatively low skewness and a similar mean and median ratio.

Although we only have a limited number of biosphere results for this site and island (one faunal sample from the site itself and five floral samples for the entire island), their $^{87}Sr/^{86}Sr$ ratios fall within the range of human $^{87}Sr/^{86}Sr$ ratios. Only one faunal sample from the site itself was analyzed, a modern land snail, which has a measured $^{87}Sr/^{86}Sr$ ratio of 0.70741 that falls near the middle of the range of human ratios for this site. Plant samples taken from diverse location around St. Thomas yielded $^{87}Sr/^{86}Sr$ ratios that display reduced variation compared to the human Sr dataset from Tutu. In fact, the faunal and floral samples from St. Thomas do not overlap with the lower end of the range of human Sr isotope ratios from the Tutu site.

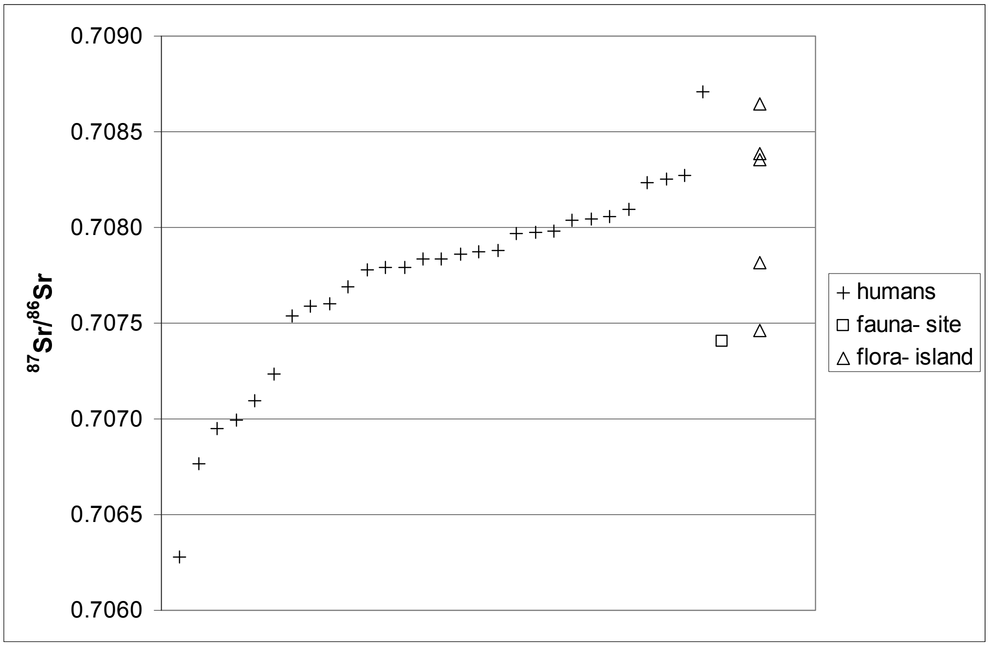


Figure 16 Strontium Isotope Ratios- St. Thomas.
Key: human samples and one faunal sample are from Tutu.

6.3.5 Kelbey's Ridge 2 and Spring Bay 1c- Saba

The Sr isotope ratios from Saba (Figure 17) represent samples from seven individuals; six from the site of Kelbey's Ridge 2 and one from the nearby site of Spring Bay 1c. The $^{87}Sr/^{86}Sr$ ratios from these two sites range from 0.70770 to 0.70879, with a mean of 0.70834 and a median of 0.70851 with a large variance (sd = 0.00042). This variance is large relative to most of the other populations in this study, relative to the small sample size, and relative to the small size of the island of Saba (~13 km^2).

A large body of comparative Sr isotope data was obtained from the island of Saba including 25 faunal and six soil samples from Kelbey's Ridge; and 25 floral samples from a large number of other locations across the island. The range of faunal $^{87}Sr/^{86}Sr$ ratios from the Kelbey's Ridge site (0.70717 to 0.70890) is larger than but completely overlaps the human Sr isotope dataset. The range of floral $^{87}Sr/^{86}Sr$ ratios from the entire island (0.70644 to 0.70920) is larger than both the faunal and human populations from Kelbey's

Ridge. The fact that the floral data display more variance than the faunal and human data are perhaps not too surprising considering that these samples were obtained from a wider variety of spatial contexts from throughout the entire island as opposed to a single location. However, the degree of variance of the biosphere ^{87}Sr/^{86}Sr ratios overall is high relative to most other islands in the Caribbean, and is surpassed in this regard only by Puerto Rico and Trinidad, both of which are much larger islands than Saba.

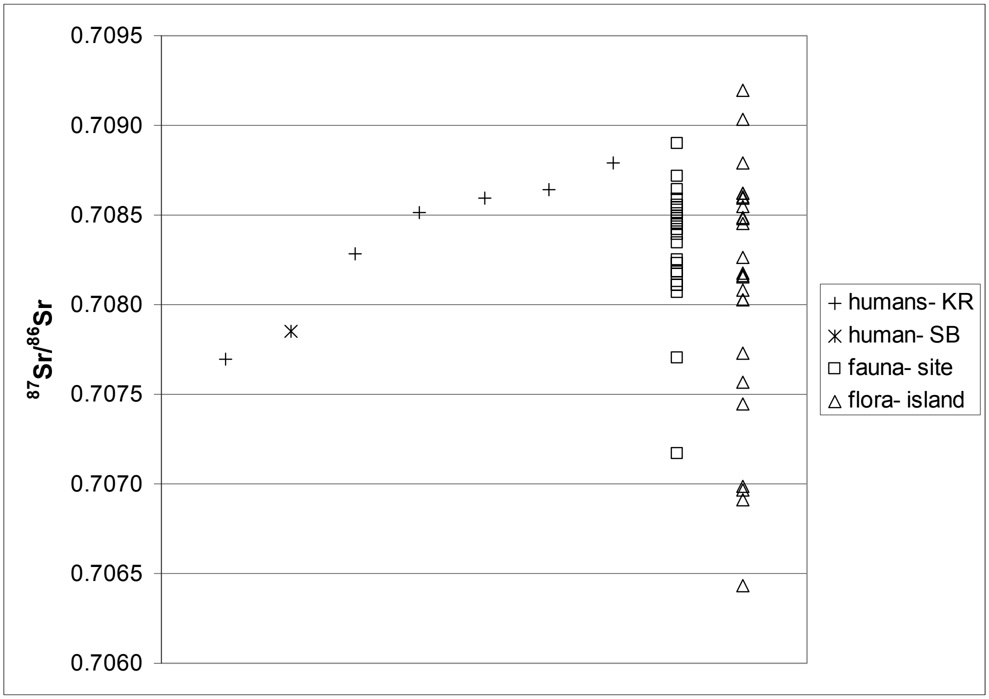


Figure 17 Strontium Isotope Ratios- Saba.
Key: KR = Kelbey's Ridge 2; SB = Spring Bay 1c.

6.3.6 Bloody Point- St. Kitts

Strontium isotope data from St. Kitts (Figure 18) were obtained from four individuals, all from the site of Bloody Point on the west-central coast. The ^{87}Sr/^{86}Sr ratios from this site range from 0.70742 to 0.70772, with a mean of 0.70754 and a median of 0.70752. This small sample set displays somewhat limited variance (sd = 0.00013), although this variance is roughly an order of magnitude larger than either the Heywoods or El Cabo sample populations that include about the same number of samples. In other words, the Bloody Point sample set is one of the least variable within this study but not quite as homogenous as similarly sized sample populations within the overall dataset.

Unfortunately, comparative faunal or floral remains from the site of Bloody Point were not available and thus could not be used to estimate the local range of biosphere Sr isotope variation. Three faunal samples obtained from the site of Sugar Factory Pier, St. Kitts near the southern end of the island, possess $^{87}Sr/^{86}Sr$ ratios ranging from 0.70744 to 0.70811. This range not only encompasses much of the variation at the Bloody Point site but is also much larger than its absolute range of $^{87}Sr/^{86}Sr$ ratios. Analyses of five plant samples taken from different locations on St. Kitts revealed $^{87}Sr/^{86}Sr$ ratios ranging from 0.70673 to 0.70862. This very wide range of ratios is larger and completely overlaps the ratios from the human samples of Bloody Point and indicates that these individuals are local to the island of St. Kitts, if not to the site itself.

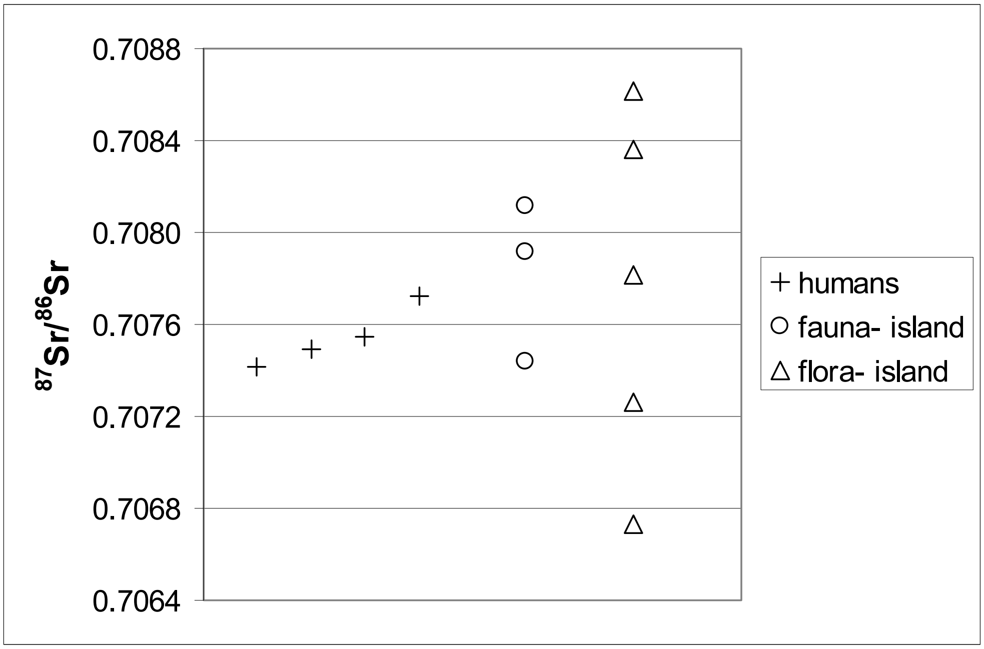


Figure 18 Strontium Isotope Ratios- St. Kitts.
Key: human samples are from Bloody Point, and faunal samples are from Sugar Factory Pier.

6.3.7 Anse à la Gourde- Guadeloupe

The Sr isotope data from Anse à la Gourde (Figure 19) include samples from 68 individuals, 18 were analyzed as part of this study and 50 were previously analyzed and published by the Caribbean Research Group at Leiden University (Booden et al. 2008). These ^{87}Sr/^{86}Sr ratios range from 0.70749 to 0.70941, with a mean of 0.708993 and a median of 0.70912. Assessment of the distribution of this dataset indicates that the data display high skewness as also indicated by the difference between the mean and median ratios, and are moderately dispersed relative to the other populations in this study (sd = 0.00035).

There was substantial overlap between the human, faunal, and soil ^{87}Sr/^{86}Sr ratios. In addition, these results agree well with geological expectations as the site lies on the coast of Grande-Terre, an island that is predominantly underlain by recent marine limestone formations. Geologically young limestone possesses ^{87}Sr/^{86}Sr ratios very similar to that of modern seawater (~0.7092). The majority of the human population at Anse à la Gourde and all of the faunal and soil samples from this site cluster together in a narrow range of ratios between roughly 0.7090 and 0.7092.

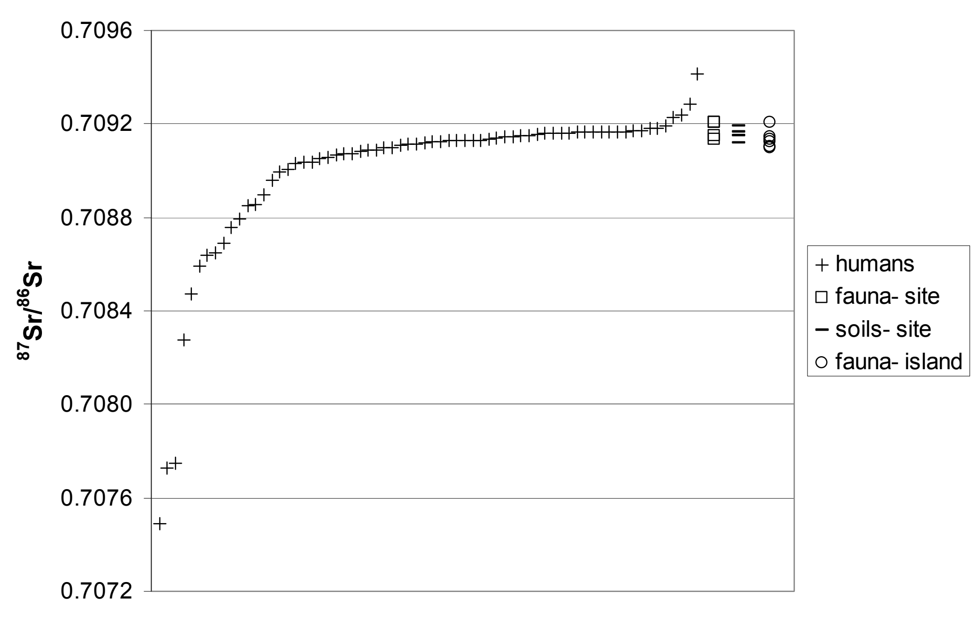


Figure 19 Strontium Isotope Ratios- Grande-Terre, Guadeloupe.
Key: human and soil samples and four faunal samples are from Anse à la Gourde.

6.3.8 Lavoutte and Giraudy- St. Lucia

The Sr isotope ratios from St. Lucia (Figure 20) derive primarily from the Lavoutte site and were obtained from 32 individuals. The $^{87}Sr/^{86}Sr$ ratios from this site range from 0.70723 to 0.70857, with a mean of 0.70790 and a median of 0.70790. Of all the sample populations in our dataset, the dispersion of the Lavoutte Sr isotope data most closely matches a normal distribution, with low skewness and kurtosis and with analytically indistinguishable mean and median values. The variance for this population (sd = 0.00026) is also low relative to the other sampled populations in our study. The majority of the human samples fall within the absolute range of the local faunal samples (n = 4) and one floral sample collected near the site at Point Hardy.

A single human enamel sample from the Giraudy site near the southeast coast possesses an $^{87}Sr/^{86}Sr$ ratio of 070876 that is much higher the Lavoutte population. Although no other samples from Giraudy are available for comparison the ratio obtained from this samples is very similar to measured values from plant remains collected in the vicinity (southern St. Lucia). There is a spatial pattern of the plant $^{87}Sr/^{86}Sr$ ratios on St. Lucia with samples from the southern half of the island possessing elevated ratios and those from northern and western St. Lucia possessing much lower ratios. This pattern is possibly a reflection of differences in underlying geology between the two halves of the island.

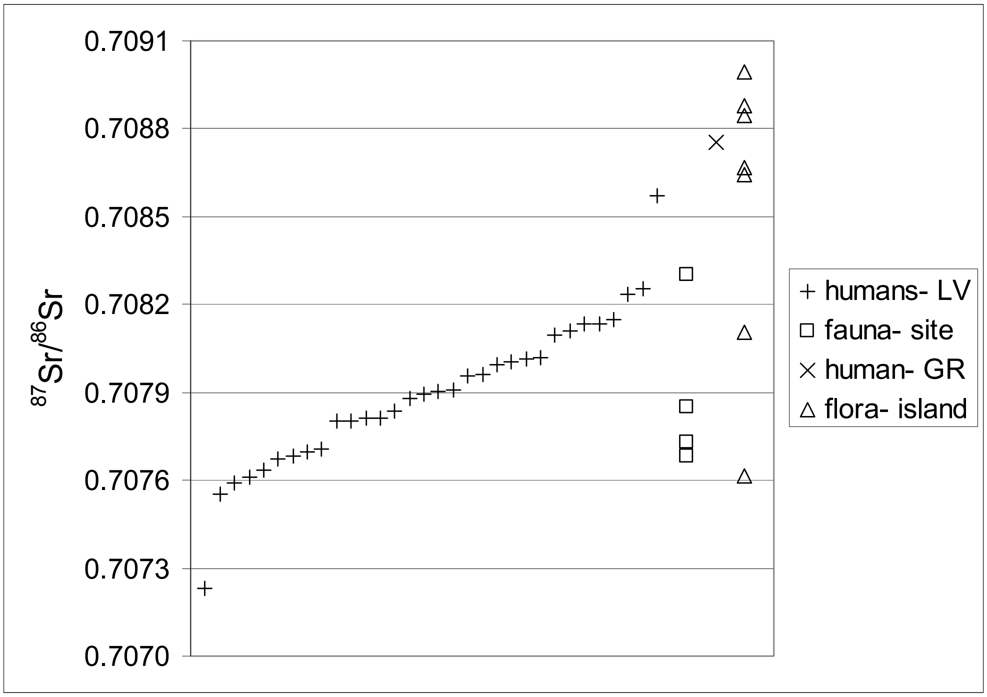


Figure 20 Strontium Isotope Ratios- St. Lucia.
Key: LV = Lavoutte; GR = Giraudy.

6.3.9 Escape, Argyle I, Argyle II, and Buccament West- St. Vincent

Strontium isotope ratios from St. Vincent (Figure 21) were obtained from four separate groups. All but one of the samples come from the adjacent sites of Escape, Argyle I and Argyle II on the east-central coast, while one sample comes from the site of Buccament West in the southwest of the island. Sr isotope results from Escape were obtained from 26 individuals and range from 0.70676 to 0.70802, with a mean of 0.70755 and a median of 0.70761. The neighboring and partially contemporaneous site of Argyle II is represented by 14 individuals with Sr isotope ratios ranging from 0.70734 to 0.70869, with a mean of 0.70782 and a median of 0.70776. The later Argyle I site is represented by only two samples with ^{87}Sr/^{86}Sr ratios of 0.70754 and 0.70804. The single sample from Buccament West has a lower ^{87}Sr/^{86}Sr ratio of 0.70635.

The structure of the Escape Sr isotope dataset displays similar characteristics as the aforementioned St. Lucian populations in terms of the size of the absolute range of ^{87}Sr/^{86}Sr ratios, the degree of variance (sd = 0.00026) and a distribution approaching normal. The St. Vincentian sample sets as a whole are generally lower than the St. Lucian sample populations but there is a considerable degree of overlap, particularly between the lower half of the Lavoutte ^{87}Sr/^{86}Sr range and the upper half of the St. Vincent ^{87}Sr/^{86}Sr range. Comparisons between the three main St. Vincent populations also display a large degree of overlap as a whole, although several of the Escape samples are lower than the absolute ranges for both of the Argyle groups.

Comparisons with ^{87}Sr/^{86}Sr ratios from St. Vincent floral and faunal samples reveal a much more complicated picture. Three rodent tooth samples from Escape/Argyle are all below the absolute range of human ratios for these sites. An agouti tooth from the Brighton site (several kilometers to the south) has a similar ratio to the lowest human ratio from Escape. Of the five floral samples from St. Vincent, two samples span the range of the human results from Escape/Argyle and the other are very similar to the Escape/Argyle rodents, and the sole Buccament West sample. In, summary, the samples from St. Vincent as a whole are highly variable and display very little clear spatial patterning. In fact, the Escape/Argyle samples represent the only population in our dataset where the majority of the 'local' faunal ^{87}Sr/^{86}Sr ratios do not overlap with the human ^{87}Sr/^{86}Sr ratios.

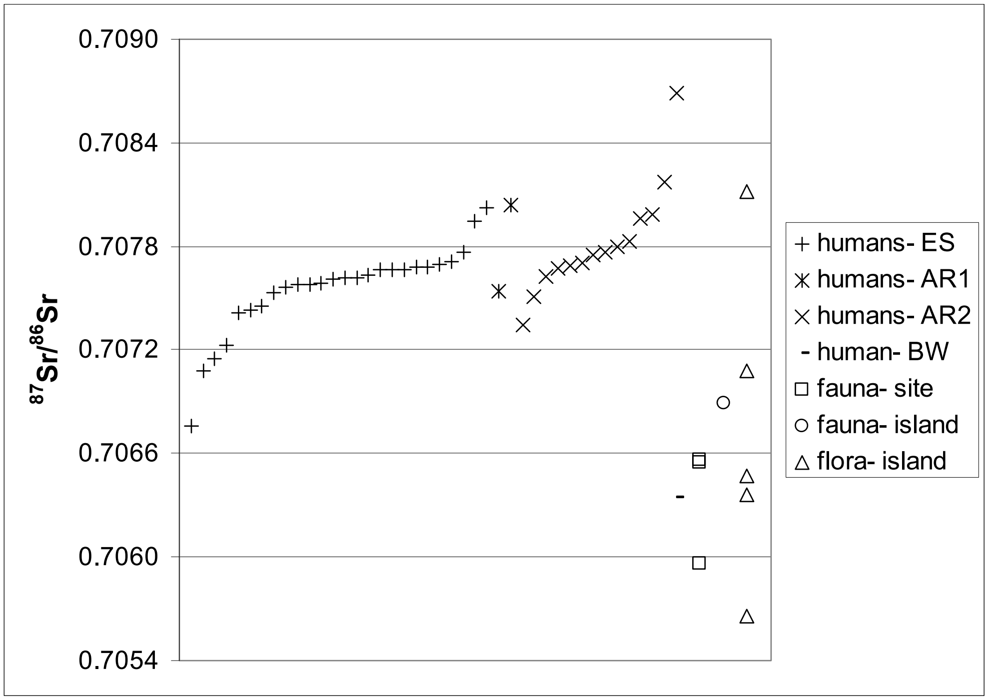


Figure 21 Strontium Isotope Ratios- St. Vincent.
Key: ES = Escape; AR1 = Argyle 1; AR2 = Argyle 2; BW = Buccament West.

6.3.10 Heywoods- Barbados

Strontium isotope data from Barbados (Figure 22) were obtained from three individuals, all from the site of Heywoods. The ^{87}Sr/^{86}Sr ratios from this site range from 0.70913 to 0.70915, with a mean of 0.70914 and a median of 0.70913. This small sample set displays very limited variance (sd = 0.00001), which is to be expected if all three individuals are local to Barbados. As discussed previously most of Barbados is dominated by geologically young limestone deposits. The human ^{87}Sr/^{86}Sr ratios from Heywoods and a single faunal sample from a similar geological context on the island (0.70918) cluster very tightly and match expectations based on geology. These ratios also overlap with $^{87}Sr/^{86}Sr$ ratios obtained from human dental enamel from the local population of the colonial era Newton Plantation site (Schroeder et al. 2009).

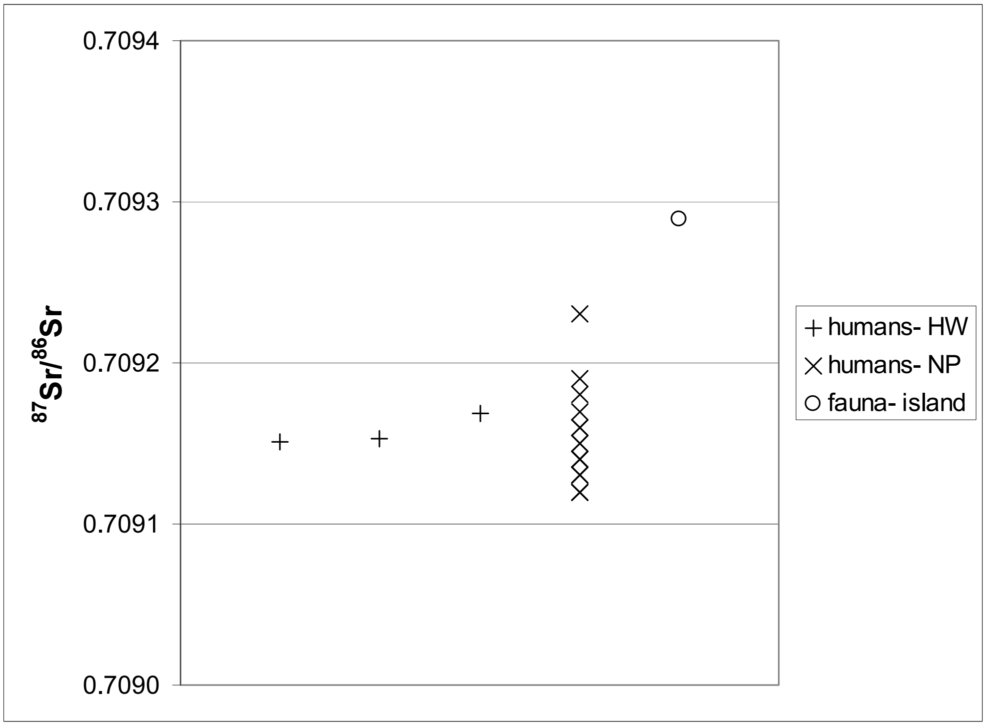


Figure 22 Strontium Isotope Ratios- Barbados.
Key: HW = Heywoods; NP = Newton Plantation. Note: $^{87}Sr/^{86}Sr$ data from NP are from (Schroeder et al. 2009) were not analyzed as part of this study but are displayed for comparison.

6.3.11 Manzanilla- Trinidad

The Sr isotope data from Trinidad were obtained from 16 individuals all of whom are from the site of Manzanilla (Figure 23). Sr isotope ratios from Manzanilla range from 0.70854 to 0.72179, with a mean of 0.71042 and a median of 0.70973. The variance of the human $^{87}Sr/^{86}Sr$ ratios from Manzanilla are by far the most variable of all the populations included in this study (sd = 0.00310). The distribution of the $^{87}Sr/^{86}Sr$ ratios is highly positively skewed with a wide tail, as seen by the large difference between the mean and median ratios. The mean ratio for human samples from Trinidad is higher than the maximum human $^{87}Sr/^{86}Sr$ ratios for the entire insular Caribbean, while the degree of variance is higher than any of the other populations (with the exception of Maisabel).

Sr isotope ratios obtained for biosphere Sr from plant and animal samples from throughout Trinidad are also highly elevated compared to all of the other Caribbean islands analyzed to date. This high degree of variance is most likely attributable to the distinct and diverse geology of this island. In fact, the mean of the biosphere $^{87}Sr/^{86}Sr$ ratios from Trinidad is higher than all other biosphere Sr isotope data obtained for the insular Caribbean with the exception of a single measurement from Tobago. Comparisons between the biosphere $^{87}Sr/^{86}Sr$ ratios from Trinidad as a whole with the human Sr isotope ratios (excluding one extreme ratio) from Manzanilla reveal a high degree of correspondence between the two datasets with broadly similar minimum, maximum and mean ratios and standard deviations.

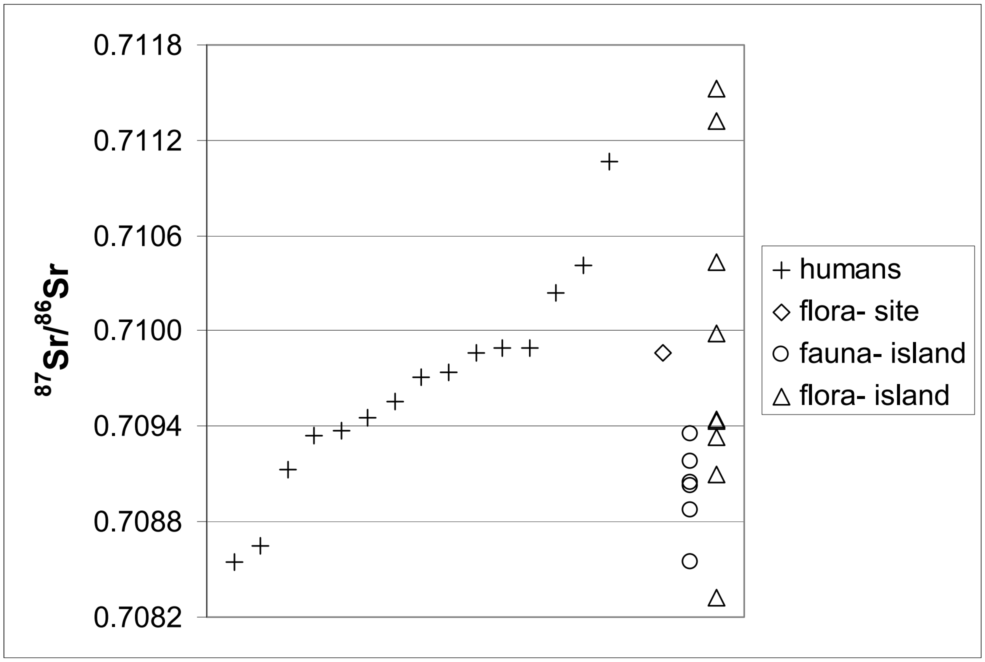


Figure 23 Strontium Isotope Ratios- Trinidad.
Key: all human and one floral sample are from Manzanilla. Note: one extreme (high) human ^{87}Sr/^{86}Sr ratio not displayed at this scale.

6.3.12 Malmok, Canashito, Santa Cruz, Savaneta, and Tanki Flip- Aruba

Strontium isotope data from Aruba were obtained from nine individuals from five different sites (Figure 24). As all of these sites are represented only by one or two individuals, these results were first pooled and treated as a single population for statistical analyses and then analyzed separately. The from Aruba range from 0.70822 to 0.70988, with a mean of 0.70900 and a median of 0.70906. This sample set displays a moderate degree of variance (sd = 0.00045) although the significance of this variance is questionable considering that the samples derive from multiple sites and that the island of Aruba is also geologically diverse.

Analyzing the ^{87}Sr/^{86}Sr ratios from each site separately, there is clearly spatial patterning of the data. The four lowest ^{87}Sr/^{86}Sr ratios were obtained from the sites of Santa Cruz, Savaneta, and Tanki Flip. The four samples from Malmok show very limited variation and cluster around the Sr isotope ratios of modern seawater (~0.7092), a not unexpected result given the recent limestone geological context of the site. Lastly, a single sample from Canashito has an elevated $^{87}Sr/^{86}Sr$ ratio that is higher than the rest of the Aruban samples. In fact, this $^{87}Sr/^{86}Sr$ ratio is highly enriched relative to the Antillean sample population as a whole and is above the range of local ratios for all other populations, with the exception of one extreme outlier from Cuba and the generally elevated population from Trinidad.

Comparison of the human $^{87}Sr/^{86}Sr$ ratios from Aruba with those obtained from five plant samples from different locations on the island indicates that these two datasets are broadly congruent. Two plant samples from Aruba possess $^{87}Sr/^{86}Sr$ ratios that are much lower than any ratios obtained from the human samples. Curiously, one of these plant samples is from the site of Tanki Flip but is distinct to the two Sr isotope ratios obtained from human samples from this same site. As the plant specimen is a modern sample there is a possibility that the local landscape has been radically modified since prehistoric times in a manner that has affected the local soil conditions. On the other hand the two human ratios from Tanki Flip have variable $^{87}Sr/^{86}Sr$ ratios. Currently the cause(s) of these differences are unknown. Three other plant samples from Aruba did, however, overlap with the range of human $^{87}Sr/^{86}Sr$ ratios. In fact, both the plant sample from Boca Grande and the one from Malmok are comparable to the human samples from Malmok, indicating a high degree of correspondence between these two separate datasets that contrasts with the low degree of correspondence amongst the Tanki Flip samples.

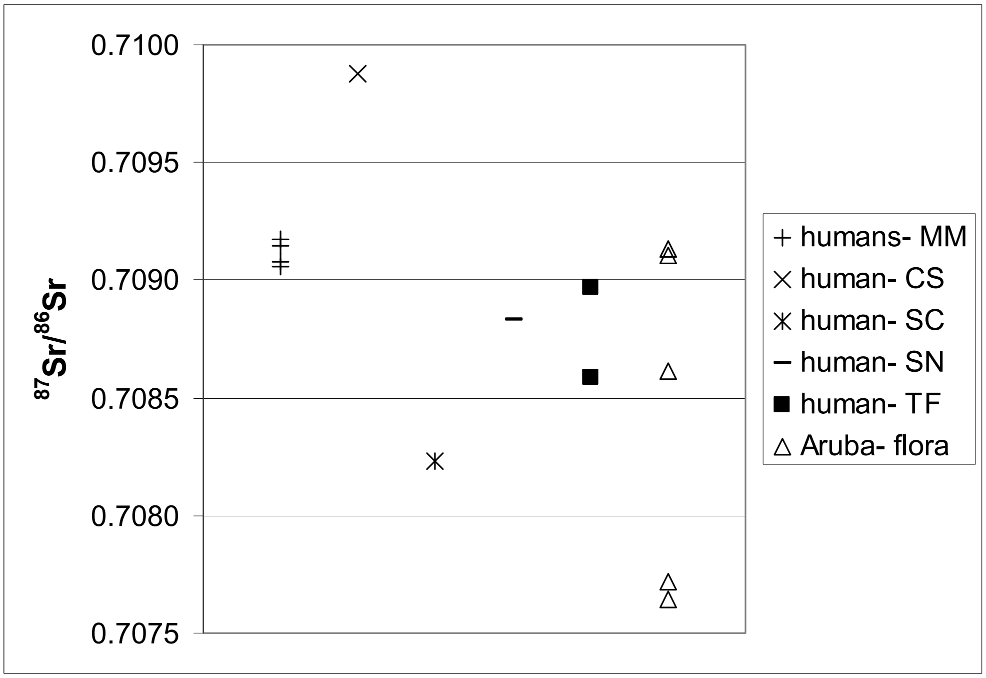


Figure 24 **Strontium Isotope Ratios- Aruba.**
Key: MM = Malmok; CS = Canashito; SC = Santa Cruz; SN = Savaneta; TF = Tanki Flip.

6.4 Human Oxygen and Carbon Isotope Results

Oxygen and carbon isotope analyses of human dental enamel were conducted on samples from fifty individuals from eight different sites spanning the length of the Caribbean archipelago and dating from the Early Ceramic Age (~500 B.C. to A.D. 500) to the early contact period (~A.D. 1492 to 1530) [see also (Laffoon et al. 2012b)]. The individual carbon and oxygen isotope results and relevant sample information are listed in Appendix C. These data are also plotted onto maps of the Caribbean (Figures 25 and 26) and displayed as scatter plot diagrams (Figures 27, 28 and 29). A statistical summary of the carbon and oxygen isotope ratios per site is presented in Table 7.

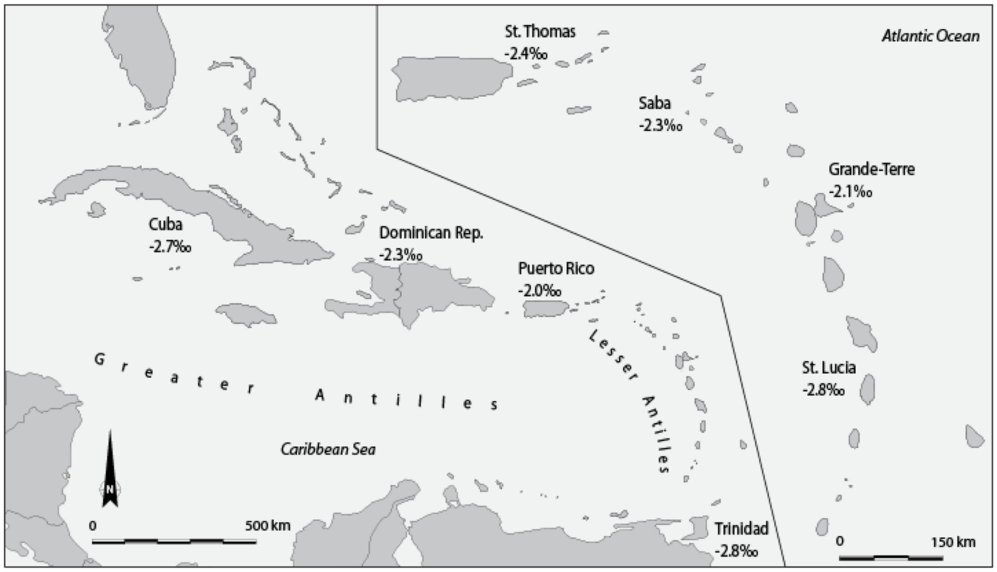


Figure 25 Map of the Caribbean displaying mean human $\delta^{18}O$ per island.
Note: mean value for El Chorro de Maíta does not include outliers.

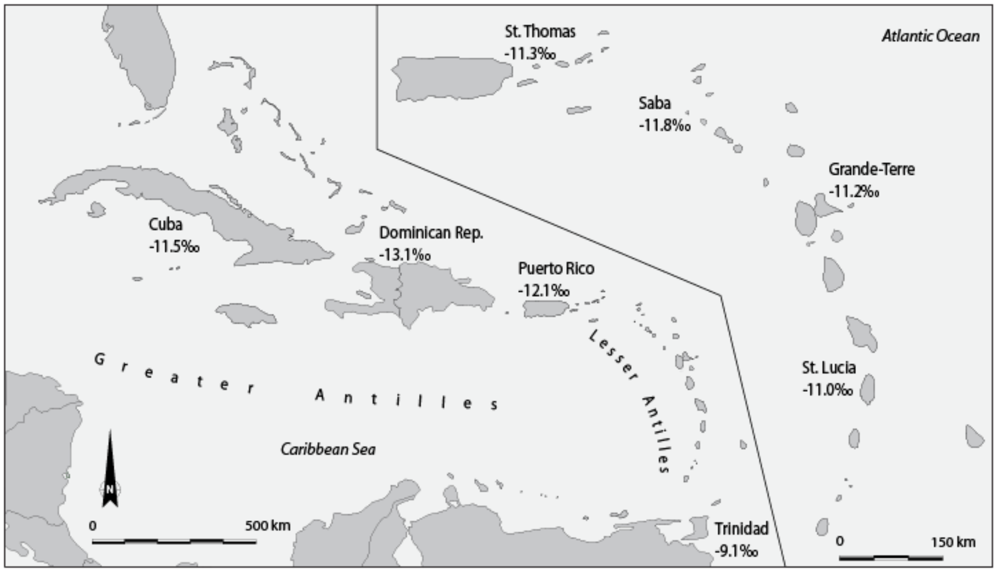


Figure 26 Map of the Caribbean displaying mean human $\delta^{13}C$ per island.
Note: mean value for El Chorro de Maíta does not include outliers.

Table 7: Statistical summary of enamel carbon and oxygen isotope data by site
Note: + indicates inclusion of one sample from nearby site of El Cabo.

SITE		**$\delta^{13}C_{ca}$**	**$\delta^{13}C_{ca}$**	**$\delta^{13}C_{ca}$**	**$\delta^{18}O_{ca}$**	**$\delta^{18}O_{ca}$**	**$\delta^{18}O_{ca}$**
	n	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**
El Chorro de Maíta	12	-10.8	-12.9	-3.7	-2.9	-5.4	-2.0
Punta Macao+	5	-13.1	-14.2	-12.4	-2.3	-2.8	-1.8
Maisabel	5	-12.1	-13.1	-11.1	-2.0	-2.9	-1.1
Tutu	5	-11.3	-12.1	-9.3	-2.4	-3.1	-1.8
Kelbey's Ridge	5	-11.7	-12.8	-9.9	-2.3	-2.7	-2.0
Anse à la Gourde	7	-11.2	-12.1	-10.8	-2.1	-2.8	-1.3
Lavoutte	5	-11.0	-12.0	-9.1	-2.8	-3.4	-2.0
Manzanilla	5	-9.1	-12.5	-7.2	-2.8	-3.3	-2.1

6.4.1 Oxygen Isotope Results

The mean $\delta^{18}O$ for human teeth samples from all sites is -2.6‰, with ratios ranging from -5.4‰ to -1.1‰ (Note: one sample had a high analytical error and is not included in the statistical assessment or discussion). This range of $\delta^{18}O$ of dental carbonate ratios is larger than the range that has been proposed as representing a local resident population in Mesoamerica: ~2‰ (White et al. 2004; White et al. 2002). This large range may reflect the presence of nonlocal individuals in our sample population and/or may be the result of pooling samples taken from multiple sites from different islands and time periods. Interestingly, the lowest $\delta^{18}O$ ratios were obtained from three individuals from the site of El Chorro de Maíta, Cuba. Removing these three results greatly reduces the range of $\delta^{18}O$ ratios (-3.4‰ to -1.1‰) to a range that more closely approximates the expectation for a local resident population (White et al. 2004; White et al. 2002).

An additional source of variation in $\delta^{18}O$ data may derive from differences in the types of teeth analyzed. Only one tooth in our sample set is a second permanent molar (M2) and thus likely formed entirely after weaning. Four sampled teeth are deciduous and were formed prior to or around birth but the vast majority of the sampled teeth (90%) are first molars (M1) and premolars and thus developed and mineralized wholly or partially prior to weaning. As breast milk is generally enriched in δ^{18}O relative to drinking water, teeth that developed prior to weaning are expected to have elevated δ^{18}O compared to teeth that develop at a later age (Roberts et al. 1988; Wright and Schwarcz 1998). However, as nearly all of the teeth in this study are pre-weaning, this effect cannot wholly account for the variation within our sample. In addition, because the exact age of weaning is unknown and may vary between individuals no attempt was made to normalize the data for this effect.

Oxygen and strontium isotope ratios are plotted in Figure 26. The two datasets are not well correlated as a whole ($r = -0.031772$), although this is not surprising as the samples derive from multiple sites on different islands each of which has a different range of local ^{87}Sr/^{86}Sr variation. As previously mentioned the δ^{18}O ratios display relatively limited variation with the exception of three individuals despite the fact that we intentionally sampled at least one or two Sr isotope outliers per site when possible (discussed in greater detail in chapter 7).

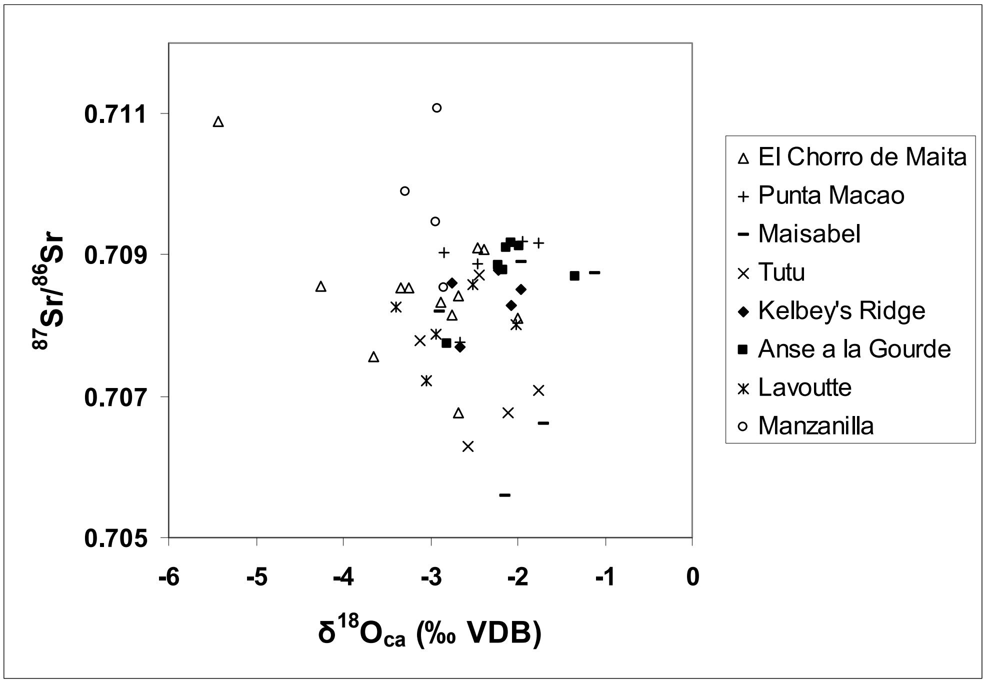


Figure 27 Diagram of human enamel $\delta^{18}O_{ca}$ and $^{87}Sr/^{86}Sr$ data from this study. Note: one extreme (high) $^{87}Sr/^{86}Sr$ ratio from Manzanilla not displayed at this scale.

6.4.2 Carbon Isotope Results

The mean $\delta^{13}C$ for human teeth samples from all sites is -11.2‰, with ratios ranging from -14.2‰ to -3.7‰. Two of the individuals from El Chorro de Maíta that possess extreme $\delta^{18}O$ are also outliers in terms of their $\delta^{13}C$ ratios. Removing these two individuals from the sample reduces the range of $\delta^{13}C$ to -14.2‰ to -7.2‰. This degree of variation is not entirely unexpected, once again owing to the different spatial and temporal contexts of the sampled populations. With the possible exception of samples from the site of Manzanilla, there does not appear to be much spatial patterning of the $\delta^{13}C$ values. The relatively elevated values from Manzanilla probably indicate somewhat greater consumption of C_4 plant resources. Although maize consumption might be considered the most likely source of elevated $\delta^{13}C$ within the prehistoric Caribbean, several other plant species, both C_4 and CAM, possessing elevated $\delta^{13}C$ may have also contributed to ancient diets, including amaranth (*Amaranthus* sp.), century plant (*Agave antillarum*), pineapple (*Ananas comosus*) and prickly pear cactus (*Opuntia* sp.) (Pestle 2010).

Carbon isotope data are plotted with strontium isotope data in Figure 27. Once again there is generally poor correlation between the two datasets as a whole (r = 0.0694730), most likely owing to the differences in the ranges of $^{87}Sr/^{86}Sr$ ratios between sites. At finer spatial resolutions there is also poor correlation between $\delta^{13}C$ and $^{87}Sr/^{86}Sr$ within individual populations, although this may also be the result of small sample sizes. However, several individuals that have been identified as nonlocal on the basis of $^{87}Sr/^{86}Sr$ also possess distinct $\delta^{13}C$ ratios compared to local populations (Laffoon and Hoogland 2012). Carbon isotope data are plotted with oxygen isotope data in Figure 27. This figure clearly shows a main cluster of individuals displaying limited isotope variation and three individuals that are clearly distinct from this main cluster in terms of possessing elevated $\delta^{13}C$ and $\delta^{18}O$ values.

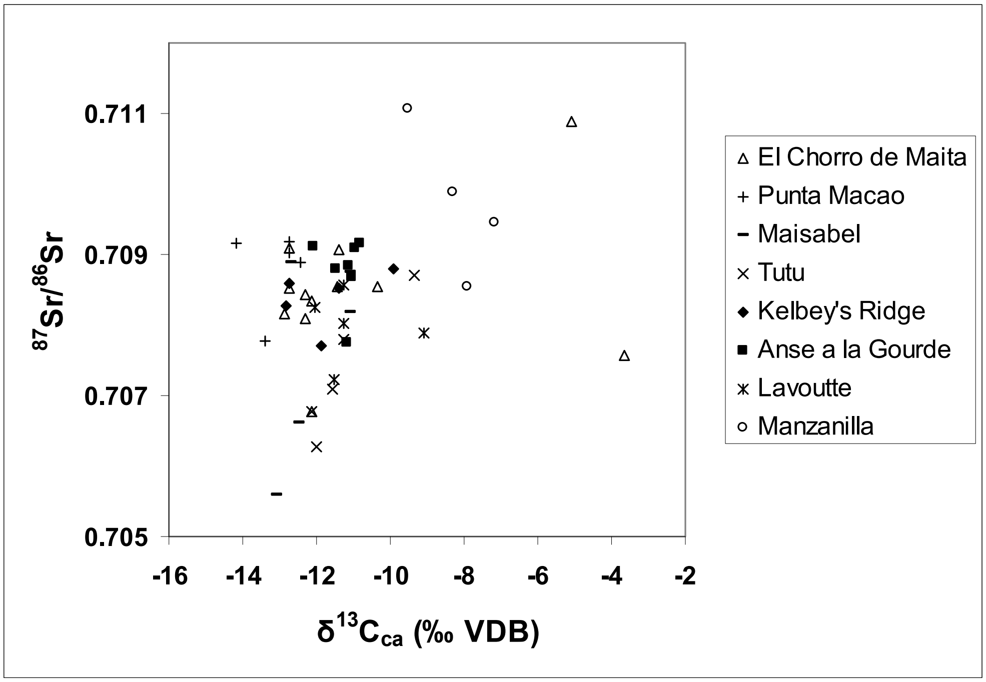


Figure 28 Diagram of human enamel $\delta^{13}C_{ca}$ and $^{87}Sr/^{86}Sr$ data from this study. Note: one extreme (high) $^{87}Sr/^{86}Sr$ ratio from Manzanilla, Trinidad is not displayed at this scale.

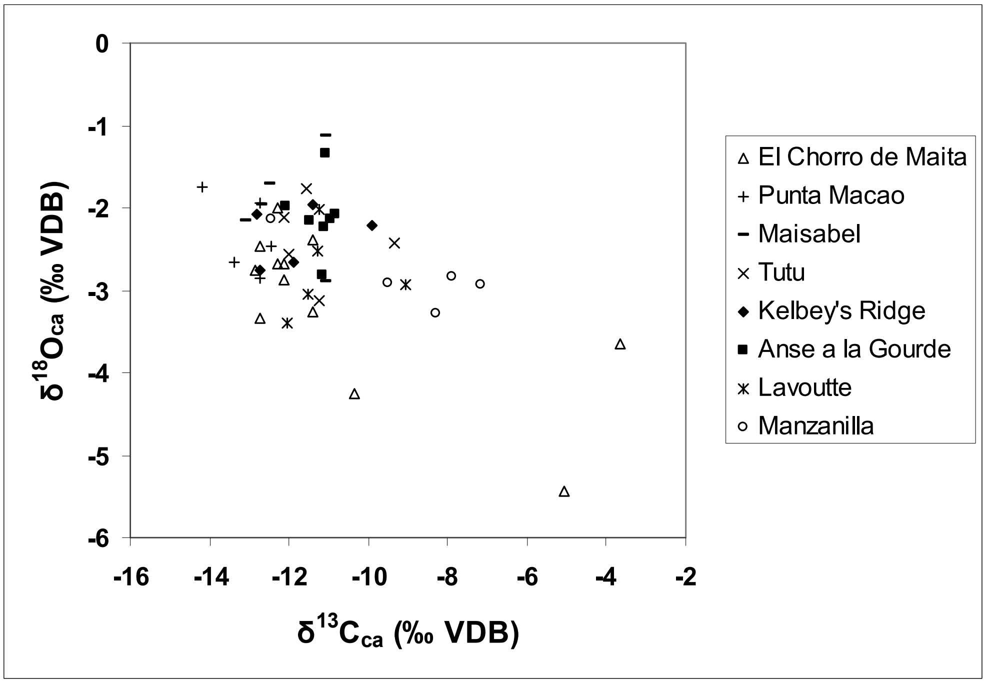


Figure 29 Diagram of human enamel $\delta^{13}C_{ca}$ and $\delta^{18}O_{ca}$ data from this study.

6.5 Summary of Results

In this chapter, I have documented the spatial variation of biosphere $^{87}Sr/^{86}Sr$ ratios in the Caribbean region at varying geographic and geological scales. I have also reported human $^{87}Sr/^{86}Sr$ ratios at multiple scales, including inter-population variation at the scale of islands and intra-population variation at the scale of sites. Lastly, I have reported the results of carbon and oxygen isotope analyses on a subset of the human sample population and have documented the variance amongst these data. In the following chapter, I discuss these results in terms of assessing local $^{87}Sr/^{86}Sr$ ranges for each site and identifying nonlocal individuals; assessing patterns in the data relative to other relevant parameters; and some archaeological implications of the inferred patterns of human migration and mobility.

CHAPTER 7 DISCUSSION

7.1 Introduction

In the previous chapter I presented the results of multiple isotope analyses of plants, animals, and human remains. In this chapter I discuss these results in terms of how they are utilized to identify and interpret patterns of human mobility in the Caribbean. This chapter begins with a discussion of the results of Sr isotope analyses of animal and plant remains to assess the spatial patterns of biosphere $^{87}Sr/^{86}Sr$ variation throughout the Caribbean region. The following section focuses on discussions of multiple isotope analyses of human remains from a number of sites throughout the Caribbean beginning with an assessment of various methods for determining local ranges of $^{87}Sr/^{86}Sr$ and the differences these methods provide in terms of the determination of locals and nonlocals. Next, I present the estimated local $^{87}Sr/^{86}Sr$ ranges and a comparison of the range of human and biosphere $^{87}Sr/^{86}Sr$ results for each site/population. In this section, I also discuss which individuals were identified as nonlocals and assessments of their possible origins. This discussion is followed by a comparative analyses of patterns of mobility vis-à-vis a number of other relevant parameters including demography, chronology, body modification practices, mortuary treatment, and dietary patterns. Finally I discuss the results of carbon and oxygen isotope analyses of a subset of the human sample population and the implications of these results for identifying nonlocals, inferring mobility, and determining the possible origins of specific nonlocal individuals.

7.2 Spatial Variability of Biosphere $^{87}Sr/^{86}Sr$ in the Caribbean

Various faunal and floral samples were collected and analyzed for Sr isotope ratios primarily to assess the range of biosphere $^{87}Sr/^{86}Sr$ variation for the site locations included in this study and to map $^{87}Sr/^{86}Sr$ variation in the Caribbean biosphere for the purpose of interpreting human Sr isotope data and investigating the geographic origins of nonlocal humans (Laffoon et al. 2012a). The animal samples comprise a mixture of modern and archaeological faunal remains, mostly land snails and rodents while the plant samples are all modern and are primarily various species of grasses. Both the animal and plant samples should reflect the local bioavailable Sr pool.

This data set establishes that there is not a simple, direct correlation between measured biosphere $^{87}Sr/^{86}Sr$ and the $^{87}Sr/^{86}Sr$ predicted based on the underlying geology. This poor correlation is likely the result of a number of factors including; multiple influxes of non-geological Sr into terrestrial Caribbean ecosystems with significant but variable contributions of marine and atmospheric Sr from marine aerosols or sea spray, and variations in the weathering and solubility of different soil components and mineralogy. We conclude that local biosphere $^{87}Sr/^{86}Sr$ cannot be directly inferred from associated geology in this region. However, our data set clearly establishes that estimations of local terrestrial biosphere $^{87}Sr/^{86}Sr$ can be derived from Sr isotope measurements of local plant and animal samples.

Despite large differences between predicted and observed *absolute* Sr isotope values, there is clear spatial patterning of biosphere $^{87}Sr/^{86}Sr$ in the Caribbean based on associated geology (Figures 30 and 31). These maps display the predicted biosphere $^{87}Sr/^{86}Sr$ for the circum-Caribbean region and eastern Caribbean respectively and are based on a multi-source predictive model that accounts for variable inputs, concentrations and compositions of Sr from bedrock weathering, precipitation, and dryfall based on the work of Bataille and colleagues (in press). This model agrees well with the empirical dataset of biosphere $^{87}Sr/^{86}Sr$ variation for the Caribbean region presented in this present study. In general, there are distinct differences in the means and ranges of $^{87}Sr/^{86}Sr$ between certain subregions with relatively little overlap in $^{87}Sr/^{86}Sr$ ranges, particularly between the two subregions from Trinidad and Venezuela and the remainder of the subregions from the Antilles proper. In contrast, substantial overlap exists between some subregions within the Antilles, in particular between areas of older limestone and those of volcanic geologies.

In terms of assessing ancient mobility within the insular Caribbean or Antilles (*sensu stricto*), despite some degree of overlap between volcanic and limestone areas, the isotopic identification of mobility is possible at certain scales. Although the Sr isotope ranges for entire archipelagos or some island groups are rather large, when broken down by associated geology there is much less overlap on a case by case basis. For example Tobago has a very large range (0.70475 to 0.71026) of biosphere $^{87}Sr/^{86}Sr$ owing to its rather complex and variable geology. This suggests that intra-island mobility between different areas of this island should be identifiable but that inter-island mobility from most areas of the Antilles to Tobago would be difficult to detect. The same overall trend holds for the Greater Antilles, where there is relatively little overlap in $^{87}Sr/^{86}Sr$ ranges between coastal alluvial deposits and limestone hills on the one hand, and the interior regions composed of mosaics of volcanic, intrusive, and metamorphic zones on the other. The implication of this pattern is that for the Greater Antilles, intra-island mobility between the interior and the coast (or *vice versa*) is potentially identifiable via Sr isotope analysis.

In terms of intra-archipelagic mobility, even within a single archipelago there are some clear distinctions in the ranges of biosphere $^{87}Sr/^{86}Sr$ between certain islands. For example, despite broad geological similarities between all of the islands of the Volcanic Caribbees, some of the islands display little or no overlap with other islands or groups of islands. Specifically, there is a general trend towards more elevated $^{87}Sr/^{86}Sr$ ratios in geological samples within the Volcanic Caribbees going from south to north, probably as the result of greater degrees of crustal contamination in the northern islands relative to the southern ones during the development of this island arc (Davidson 1983, 1987). This same general south to north trend is also apparent in the biosphere $^{87}Sr/^{86}Sr$ ranges within the Volcanic Caribbees (see Appendix A), with the exceptions of Martinique and St. Lucia. More specifically, there is little or no overlap in biosphere $^{87}Sr/^{86}Sr$ ranges between the southernmost islands of St. Vincent and Grenada and many of the volcanic islands to the north including Saba, St. Eustatius, Les Saintes, and St. Lucia. This pattern suggests that in many cases it is possible to identify inter-island mobility even between islands of broadly similar geologies. Furthermore, the lack of overlap in $^{87}Sr/^{86}Sr$ ranges between the Volcanic Caribbees and the Limestone Caribbees is a promising result for the exploration of mobility between these two archipelagos. In fact, biosphere $^{87}Sr/^{86}Sr$ results from areas dominated by marine limestone deposition most closely matched the expectations based on underlying geology. This result is not overly surprising in that the most likely cause of differences between biosphere values and geological $^{87}Sr/^{86}Sr$ ratios in coastal and island environments is the additional input of marine Sr. As geologically young limestone possesses similar ratios to that of modern seawater, little difference exists between the $^{87}Sr/^{86}Sr$ ratios of terrestrial and marine inputs in these regions.

Trinidad and Venezuela possess areas underlain by metamorphic rocks. As expected, these areas contain elevated $^{87}Sr/^{86}Sr$ relative to the overall biosphere $^{87}Sr/^{86}Sr$ range for the insular Caribbean. Sedimentary deposits of Tertiary marine strata and Quaternary alluvium from southern Trinidad and coastal Venezuela are also generally elevated in $^{87}Sr/^{86}Sr$ relative to the insular Caribbean. These patterns are of special importance for investigations of prehistoric mobility in the Caribbean, as northern mainland South America and Trinidad are widely believed to be areas of potential origin(s) for various migrations into the Antilles based on a large body of archaeological evidence (Rouse 1986, 1992). As such, migrants originating from Trinidad, Venezuela, (or from the Guiana Shield Region) should be identifiable as immigrants via Sr isotope analyses. In summary, these results indicate that baseline biosphere $^{87}Sr/^{86}Sr$ data are essential for archaeological applications of strontium isotope analysis to provenance studies in the Antilles.

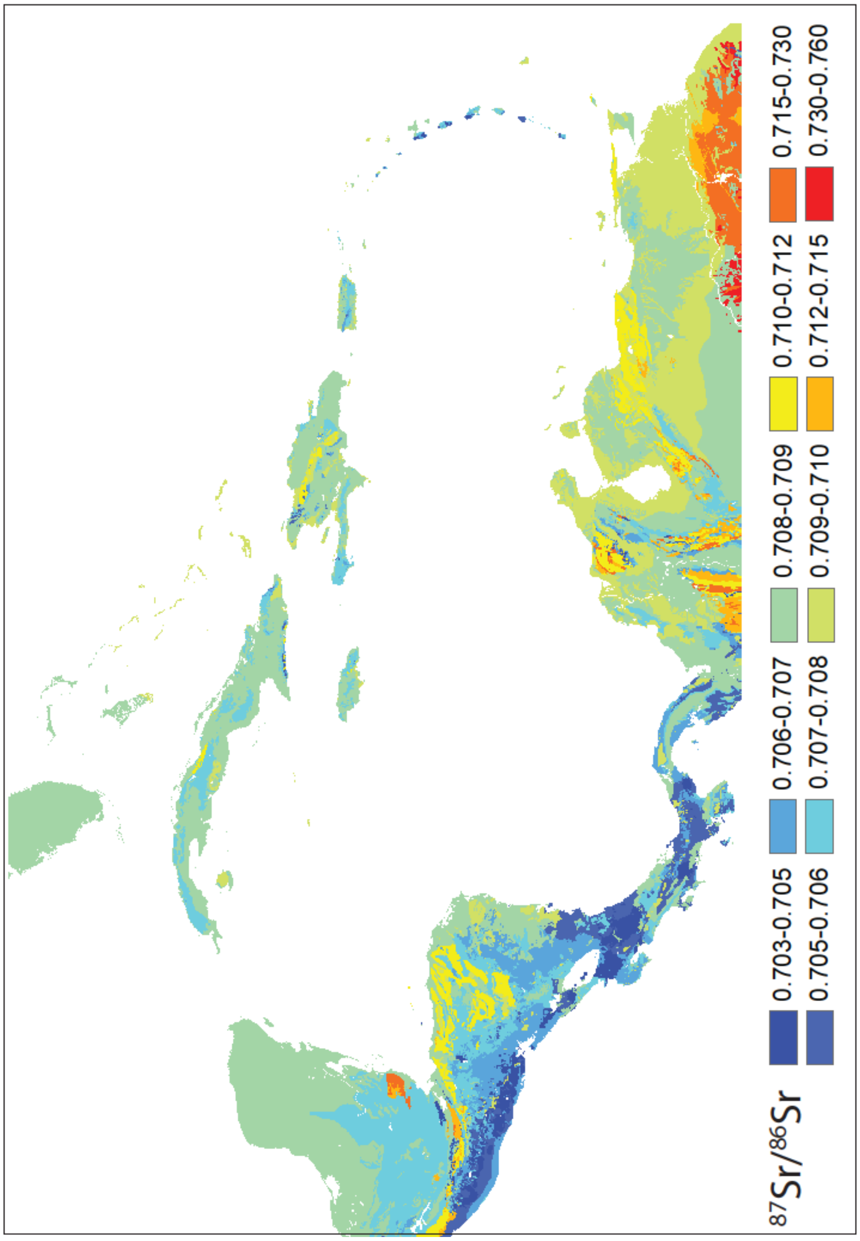


Figure 30 Map of modeled biosphere $^{87}Sr/^{86}Sr$ variation in the Circum-Caribbean.

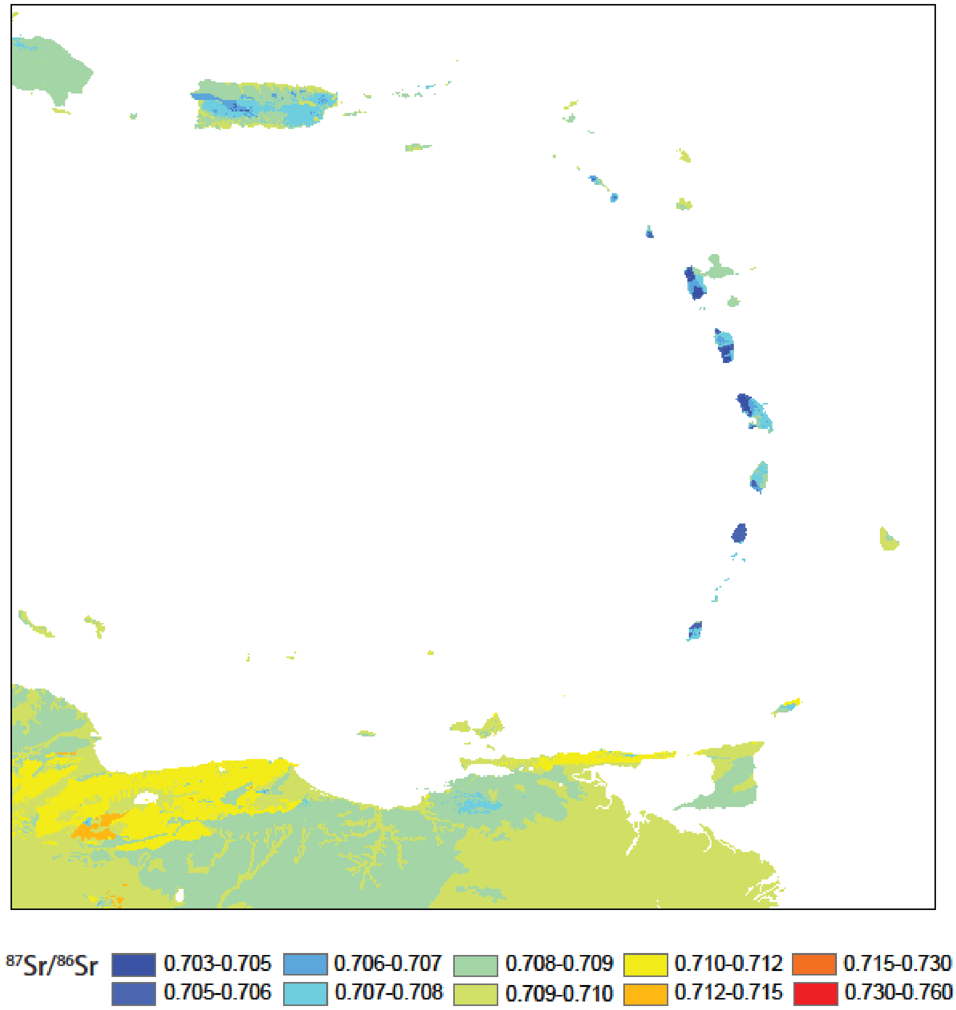


Figure 31 Map of modeled biosphere $^{87}Sr/^{86}Sr$ variation in the Eastern Caribbean.
Note: Maps adapted from figure 5B in Bataille et al. (in press).

7.2 Interpreting Human Strontium Isotope Results

In this section, I discuss the analysis of the strontium isotope data from the human sample populations in this study. I begin with a discussion of various methods for estimating local $^{87}Sr/^{86}Sr$ ranges and the potentially variable results that these produce in terms of the estimated local ranges and subsequently of the number and proportion of populations that are identified as either local or nonlocal. Next, I present the approaches that were ultimately used in this study to estimate the local Sr isotope ranges and the identification of local and nonlocal individuals. In this section I also describe the statistical measures that were employed in the analysis of the isotope data.

7.2.1 Comparison of different methods for estimating local Sr isotope ranges

Various methods have been employed to identify nonlocal individuals via strontium isotope analysis of human dental enamel. These include but are not limited to: 1) comparisons with geological expectations; 2) comparisons with bone Sr ratios from the same individual, 3) comparisons with the range of Sr isotope ratios of human teeth from the same population, 4) comparisons with the range of biosphere Sr isotope ratios (e.g., from local plants and/or animals); 5) statistical assessments of human Sr isotope data; or 6) a combination of these approaches. The choice of approach is not only dependent on the context of the archaeological assemblage but also on the availability of comparative data sets. Furthermore, and perhaps most importantly, different approaches often produce widely disparate results, not only in terms of the range of local isotope ranges but also, by consequence, in the identification of which individuals are local and which are nonlocal within a given population. In other words, certain individuals may possess Sr isotope signals that are extremes or statistical outliers relative to comparative populations and thus are identified as nonlocals regardless of which approach is utilized. On the other hand, for many populations there are often one or several individuals with $^{87}Sr/^{86}Sr$ ratios that are neither typical nor extreme relative to others (Price et al. 2002). In these cases, the choice of approach for assessing and interpreting the range and distribution of local isotope variation can greatly influence which individuals are identified as nonlocals and which as locals.

These different methods for estimating local Sr isotope ranges produced vastly different results in terms of the number and proportions of locals/nonlocals within these populations. For the sake of consistency, I would prefer to consistently apply a single system to all of the populations, unfortunately this is not possible. For example, one of the more commonly used methods, comparisons with the range of $^{87}Sr/^{86}Sr$ signals from local plants and animals (the biosphere approach), is limited in cases where these types of samples are unavailable or limited in number. Likewise, statistical assessments of Sr isotope data of human populations alone are also limited in many cases owing to very small sample sizes. Thus, no single method for assessing the range of local variation is appropriate for all of the sample populations in this study. The quantity and quality of the different data sets, the sample materials from which they derive, and the distribution of the $^{87}Sr/^{86}Sr$ ratios for different data sets are highly variable. These circumstances have forced me to use somewhat different methods for estimating the local ranges for some populations. I have tried to use methods that incorporate as much available data as possible and that are appropriate for the nature of the available data set for each population.

Ideally, the most robust approach would incorporate large sample sets of biosphere data obtained from different sample materials (plants and animals) of different species representing varying catchment areas. Additionally, biosphere data obtained directly from the site location should be complemented with similar data obtained from samples from the surrounding area to provide some indication of the spatial extent of the estimated local range. Furthermore, the integration of theoretical models of spatial variation with available empirical data sets should permit fairly robust predictions of Sr isotope variation for un-sampled areas and provide some indication of where sampling density and intensity needs to be increased (Bataille and Bowen 2012).

7.2.2 Methods applied to the identification of nonlocal humans

The primary method for identifying locals versus nonlocals that I have applied to most of the populations in this study is based on a modification of the statistical approach proposed by Booden and colleagues (2008) [see also (Wright 2005)]. For sites from which comparative biosphere samples have been analyzed for Sr isotope composition, these data have been pooled with the human $^{87}Sr/^{86}Sr$ data into a single sample population. Descriptive statistical analyses of these pooled samples were then conducted using SPSS Student Version 18.0 (Statistical Package for the Social Sciences). Outliers were identified after each iteration of the data analysis using the stem and leaf method. These outliers were subsequently removed from the sample population and the trimmed data set was reanalyzed. Outliers were removed after each subsequent iteration of this process until the distribution of the trimmed sample population possessed convergent mean and median values, low skewness relative to the standard error of skewness, and the distribution of the data approached a normal distribution (i.e., the null hypothesis of a normal distribution was not rejected via a Shapiro-Wilk test for normality).

The results of the iterative statistical analyses were then compared to the dispersion and range of $^{87}Sr/^{86}Sr$ ratios for the 'local' human population and to the absolute range of biosphere $^{87}Sr/^{86}Sr$ ratios for the site itself and the larger region or island. Descriptions of the application of this statistical method and the results thereof are presented individually for each sample population in the following sections. In some cases, variations of this approach were applied depending on the availability, quantity, and quality of comparative data and the dispersion and variance of the initial sample population.

One potential problem with this approach is that while a local population might be expected to possess normally distributed $^{87}Sr/^{86}Sr$ ratios, a normally distributed $^{87}Sr/^{86}Sr$ sample population does not necessarily indicate that a population is local. In other words, clustering of $^{87}Sr/^{86}Sr$ data could also result if the majority of sampled individuals in a given population were immigrants originating from the same (or isotopically similar) foreign location(s). That being said, this outcome is probably unlikely given the archaeological contexts of the populations in this study. Additionally, biosphere $^{87}Sr/^{86}Sr$ ratios provide an independent means of estimating and assessing local $^{87}Sr/^{86}Sr$ ranges. For most populations in this study, there is good agreement between the $^{87}Sr/^{86}Sr$ ratios of locally defined human populations and the biosphere $^{87}Sr/^{86}Sr$ data. These comparisons and exceptions to the general pattern are described in the following sections.

One caveat requires additional elaboration. While the probability of an individual possessing an extreme Sr isotope signature is theoretically quantifiable, this is not the case for local individuals. Although it may be more parsimonious to interpret a local isotopic value as resulting from local residence, this may not always be the case as natal origins from other (even distant) locations with similar baseline Sr isotope ratios are also plausible. As such, I have tended to equate local $^{87}Sr/^{86}Sr$ ratios with local residence although it is probably more appropriate to consider isotopically local individuals as possessing unknown origins. Alternatively, the nonlocal origins of certain individuals in this study are supported by independent lines of evidence including complementary carbon and oxygen isotope data and in several instances archaeological and bioarchaeological indicators of nonlocal, foreign, or exotic origins (see sections 7.4 and 7.5).

7.3 Local $^{87}Sr/^{86}Sr$ Range Estimates and Nonlocal Individuals

In this section I present and discuss the methods used to assess the local $^{87}Sr/^{86}Sr$ range for each of the populations in this study. I also present comparisons between the human $^{87}Sr/^{86}Sr$ data and biosphere $^{87}Sr/^{86}Sr$ data for each site and island. The results of descriptive statistical analyses of $^{87}Sr/^{86}Sr$ data are presented and an estimation of the number of nonlocals is given for each population. Possible geographic origins are also explored in relation to the nearest locations with similar biosphere $^{87}Sr/^{86}Sr$ ranges. The number and percentage of nonlocals amongst the different sample populations are presented in Table 8. Histograms of human $^{87}Sr/^{86}Sr$ data for the largest sample populations in this study are displayed in Figure 32. Descriptive statistics of the local trimmed populations after the removal of nonlocal outliers are presented in Table 9.

Table 8: Summary of nonlocals for the largest populations included in this study
Note: * indicates that Aruba sample population was pooled from multiple sites.

Site	**Total (n)**	**Nonlocals (n)**	**Nonlocals (%)**
Anse à la Gourde	68	17	25
Punta Macao	21	1	5
Maisabel	29	9	31
Tutu	29	7	24
Lavoutte	31	2	6
Escape/Argyle	42	12	29
Manzanilla	16	3	19
El Chorro de Maíta	88	22	25
Aruba*	9	1	11

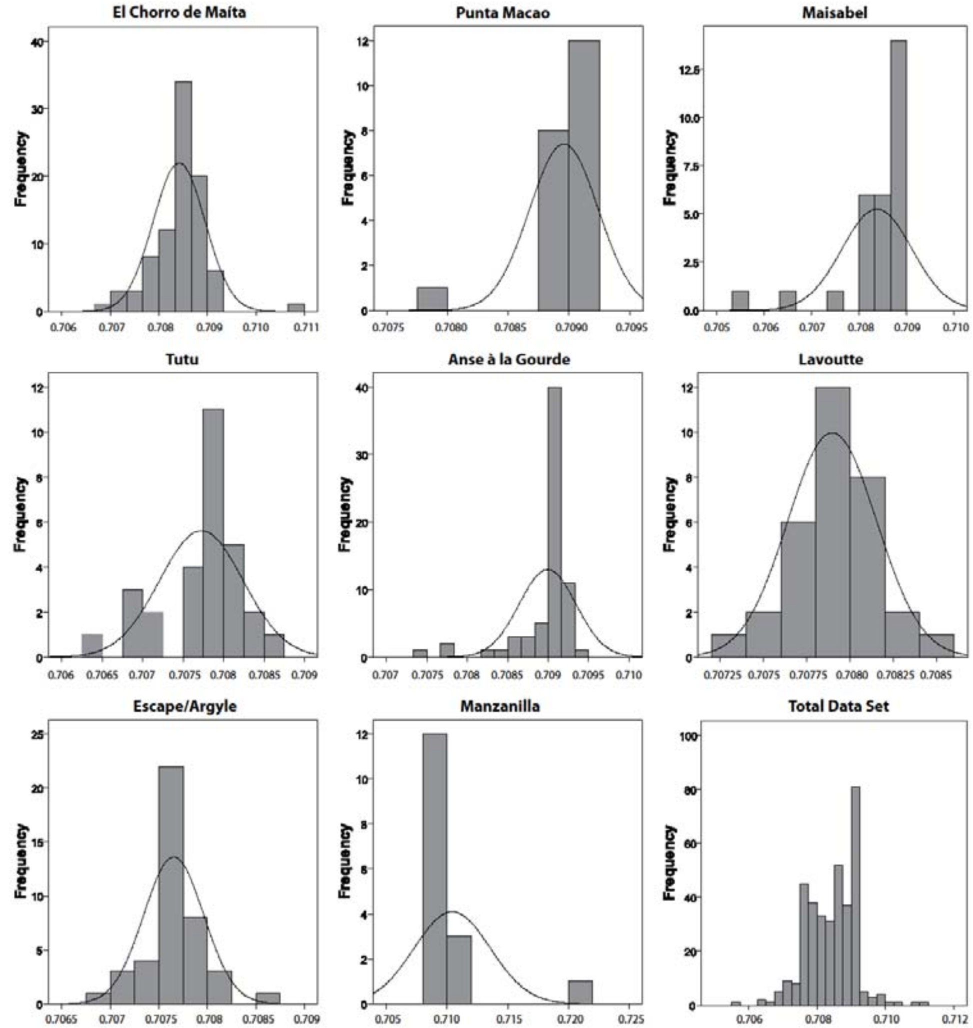


Figure 32 Histograms with normal distribution curves of human ^{87}Sr/^{86}Sr data. Note: one individual from Manzanilla not displayed in the Total Data Set histogram at this scale.

Table 9: Descriptive statistics of the 'local' human $^{87}Sr/^{86}Sr$ data for each of the largest populations in this study.
Key: CM=El Chorro de Maíta; PM=Punta Macao; MB=Maisabel; TT=Tutu; AG=Anse à la Gourde; LV=Lavoutte; E/A=Escape/Argyle; MZ=Manzanilla

Statistic	CM	PM	MB	TT	AG	LV	E/A	MZ
Mean $^{87}Sr/^{86}Sr$	0.70851	0.70902	0.70873	0.70791	0.70913	0.70790	0.70763	0.70964
Stand. Dev.	0.00020	0.00007	0.00015	0.00021	0.00005	0.00020	0.00010	0.00046
Count	66	20	20	22	51	30	30	13
Median	0.70853	0.70903	0.70876	0.70788	0.70913	0.70790	0.70765	0.70971
Minimum	0.70806	0.70888	0.70838	0.70754	0.70900	0.70755	0.70742	0.70865
Maximum	0.70882	0.70916	0.70890	0.70828	0.70924	0.70825	0.70783	0.71041
Variance	4.0E-08	5.6E-09	2.3E-08	4.3E-08	2.8E-09	3.9E-08	1.0E-08	2.2E-07
Skewness	-0.56	-0.14	-0.96	0.07	-0.53	0.02	-0.35	-0.41
Skewness- SE	0.29	0.51	0.51	0.49	0.33	0.43	0.43	0.62
Kurtosis	-0.49	-0.40	0.17	-0.51	0.09	-0.94	-0.14	0.59
Kurtosis- SE	0.58	0.99	0.99	0.95	0.66	0.83	0.83	1.19

7.3.1 El Chorro de Maíta, Cueva de los Muertos, and Porteño del Mango- Cuba

Statistical analyses of the Sr isotope results from El Chorro de Maíta were conducted on pooled sample populations. First, human and faunal samples from this site were pooled and analyzed. Outliers identified after each iteration were removed and the subsequent trimmed data set was reanalyzed until no further outliers were apparent. After several iterations the resulting data set had convergent mean and median values, low skewness relative to its standard error, and was normally distributed ($W=0.976$, $df=78$, $p=0.158$) [where W is the test statistic; df is the degrees of freedom; and p is the probability value]. Sixteen nonlocals were identified via this method. In addition to this statistical assessment, I have identified six additional possible nonlocals amongst the Chorro de Maíta population. The justification for this is that the $^{87}Sr/^{86}Sr$ ratios of these six individuals are tightly clustered, and are all outside both the absolute range of faunal values for this site and outside the local range as determined by the mean of the total sample population ± two standard deviations. There is also a gap in values between the high end of the main cluster of $^{87}Sr/^{86}Sr$ ratios and the cluster represented by these six samples. As such, I tentatively identify these six individuals as nonlocals, in addition to the sixteen identified by the iterative statistical method that was applied to the other populations in this study, for a total of 22 nonlocals for this population (25%).

The statistical approach to the assessment of the pooled $^{87}Sr/^{86}Sr$ data set from El Chorro de Maíta provides an estimate of the local $^{87}Sr/^{86}Sr$ range of approximately 0.7080 to 0.7089. All 22 of the nonlocals are outside of this range and also outside of the range of $^{87}Sr/^{86}Sr$ ratios obtained from faunal remains from this site. The $^{87}Sr/^{86}Sr$ ratios amongst the nonlocals at the site of El Chorro de Maíta seem to cluster into at least four different groups (Figure 33). The first group consists of four samples that have ratios below 0.70725. There is a small gap in the range of measured ratios with none falling between ~0.70725 and 0.7075 and then a second group consisting of eleven individuals with ratios between ~0.7075 and 0.7080 that also is below the local range. A third group is represented by a tightly clustered group of values comprised of six individuals with $^{87}Sr/^{86}Sr$ ratios above the local range and that are all very similar to the modern seawater value of 0.7092. A fourth group consists of a single individual with a highly radiogenic $^{87}Sr/^{86}Sr$ value (0.711883). This highly enriched Sr isotope signature is outside the absolute range of $^{87}Sr/^{86}Sr$ ratios for the Antilles and is matched only by a few extremely radiogenic samples from Trinidad. Estimation of this individual's potential origin and the isotopic, archaeological, bioarchaeological evidence which it is based upon are discussed in section 7.6. With the exception of this single non-Antillean individual, the other three main groups of nonlocals at El Chorro de Maíta possess $^{87}Sr/^{86}Sr$ ratios that are within the absolute range of biosphere $^{87}Sr/^{86}Sr$ both for the island of Cuba and for the Antilles more generally.

Several human and faunal samples were also analyzed from the sites of Cueva de los Muertos (four humans, one snail) and Potreno del Mango (one human, one snail, and one hutía). All five of the human samples from the sites of Cueva de los Muertos and

Potreno del Mango appear to be local both relative to faunal remains from these sites and in comparison to the Chorro de Maíta local range estimate for these sites as well.

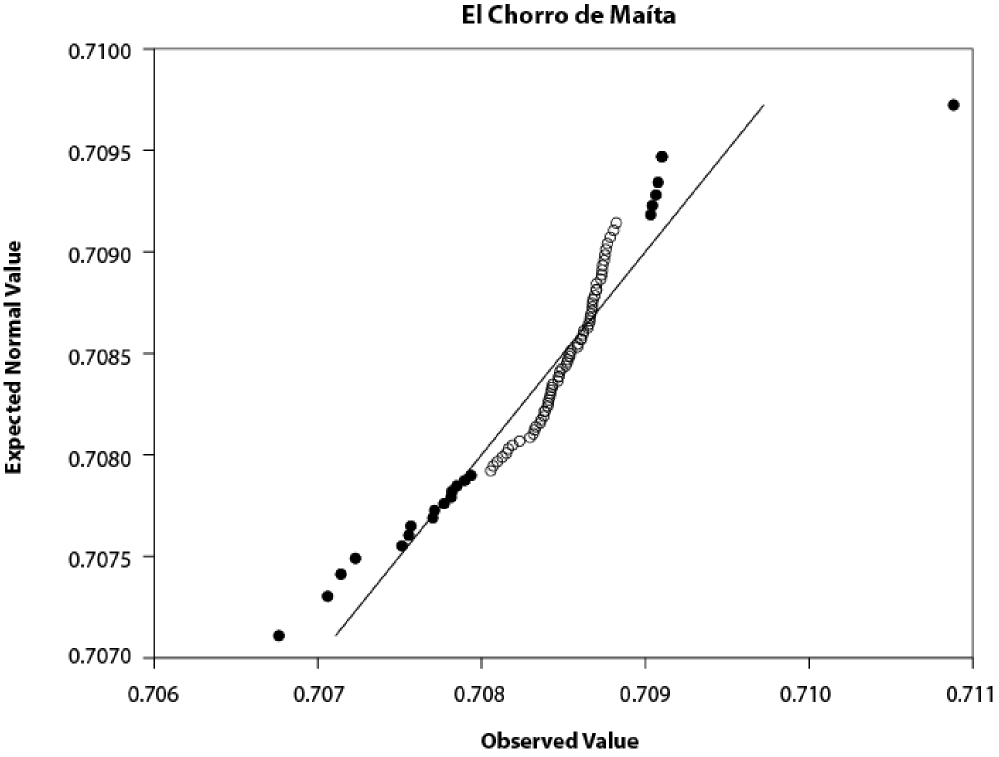


Figure 33 Normal probability Q-Q plot of human $^{87}Sr/^{86}Sr$ data from El Chorro de Maíta.
Key: filled circles indicate nonlocal (outlier and extreme) values, open circles indicate local values, line is parametric curve where y (expected normal value) = x (observed value).

7.3.2 Punta Macao and El Cabo- Dominican Republic

As is the case with several of the populations in this study, there are insufficient comparative biosphere samples with which to independently determine the local range of $^{87}Sr/^{86}Sr$ variation for the Punta Macao site. Therefore I have based the estimations of the local range and the identification of nonlocals within this population primarily on statistical analysis of the human ^{87}Sr/^{86}Sr data set. I pooled the single faunal ^{87}Sr/^{86}Sr value with those of the human population and performed basic statistical analyses on the pooled data set. This analysis identified one individual sample as an outlier which confirmed the assessment based on simple observation of the data. Removal of this single sample and reanalysis of the trimmed data set greatly reduced the dispersion of the data and produced similar mean and median values. The skewness of the sample was also greatly reduced to less than that of its standard error and results of a Shapiro-Wilk test (W=0.972, df=21, p=0.785) indicates that the trimmed sample has a normal distribution.

Using this statistical approach to the assessment of the pooled ^{87}Sr/^{86}Sr data set from Punta Macao provides an estimate of the local ^{87}Sr/^{86}Sr range of approximately 0.7088 to 0.7092. Despite the aforementioned danger of circularity when using human ^{87}Sr/^{86}Sr data to estimate the local range, there is some evidence, albeit limited in this case, to suggest that the normally distributed ^{87}Sr/^{86}Sr ratios at Punta Macao represents the local population. The single faunal ^{87}Sr/^{86}Sr value from this site is within the range of human values and the local range is in general agreement with geological expectations as the underlying bedrock is primarily Pliocene-Pleistocene reef limestone. Furthermore, the range of the local population at Punta Macao overlaps substantially with the values obtained from both human and faunal samples from the nearby site of El Cabo, which has a similar geological setting (see below).

Only one individual from the site of Punta Macao was identified as a nonlocal (~5%). This nonlocal has a depleted ^{87}Sr/^{86}Sr value (0.70776) relative to the local population at this site (Figure 34). Similar to the situation for Cuba, there are very few biosphere data for the Dominican Republic (or the island of Hispaniola), especially relative to the size of this island. In addition to the small number of samples from the far eastern peninsula of the Dominican Republic (Municipio Altagracia), four additional biosphere samples from different sites in the northeast coastal regions. Despite these limitations, the preliminary data permits an initial exploration of the potential geographic origin of the nonlocal individual from Punta Macao. Specifically, this individual's ^{87}Sr/^{86}Sr ratio is outside of the range of biosphere ^{87}Sr/^{86}Sr ratios obtained to date for the

Dominican Republic (~0.7082-.7092). The nearest location with similar, measured biosphere $^{87}Sr/^{86}Sr$ ratios in this study is Puerto Rico.

All four human samples and all four faunal samples from El Cabo possess comparable $^{87}Sr/^{86}Sr$ ratios that are tightly clustered around the value of seawater and match the associated geology (Pleistocene marine limestone). Thus all four humans at this site are considered local. Much of the far eastern peninsula of Hispaniola is underlain by a similar karstic terrain and so much of this region probably shares broadly similar baseline $^{87}Sr/^{86}Sr$ signals. As such, these four individuals could be nonlocal to the site but local to the region. The sole sample from the site of Bartolo is difficult to interpret owing to a lack of comparative data but the $^{87}Sr/^{86}Sr$ value (0.70922) of this individual is nearly identical to that of modern seawater (~0.7092) and very similar to the results from El Cabo and many of the local individuals from Punta Macao.

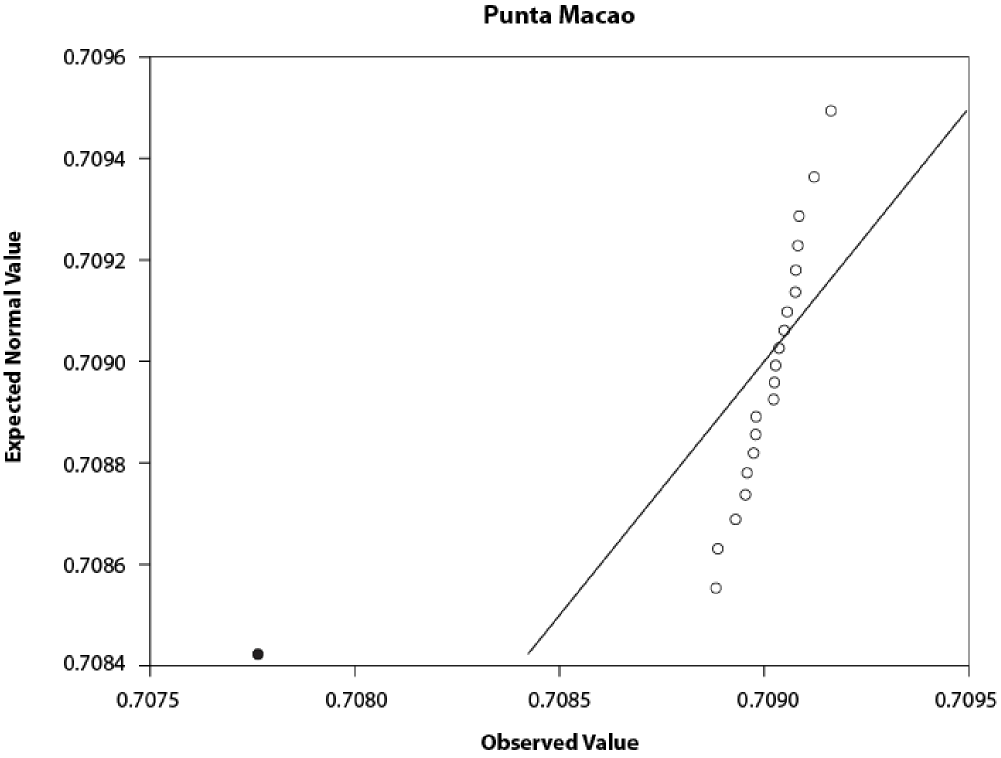


Figure 34 Normal probability Q-Q plot of human $^{87}Sr/^{86}Sr$ data from Punta Macao.
Key: symbols are the same as Figure 31.

7.3.3 Maisabel- Puerto Rico

The number of biosphere samples from Maisabel is larger than for most other sites in this study and should help to provide a better estimate of the local range of $^{87}Sr/^{86}Sr$ for this site. I have pooled both data sets into a single sample population for statistical analysis. The initial analysis indicated the presence of three outliers. These three individuals were removed from the sample population and the data was reanalyzed. Analysis of the trimmed data set did not identify outliers but the distribution was non-normal and bimodal with a skewness that was nearly double its standard error. The smaller mode included six samples with the lowest $^{87}Sr/^{86}Sr$ ratios which also fell outside the absolute range of biosphere values for this site. These six ratios were removed and another iteration of this process was conducted on the trimmed data set. This iteration revealed no more outliers and this trimmed data set possessed a convergent mean and median with a reduced skewness that was less than its standard error. The results of a Shapiro-Wilk test of this trimmed sample indicated a normal distribution (W=0.977, df=29, p=0.750).

Using this statistical approach to the assessment of the pooled $^{87}Sr/^{86}Sr$ data set from Maisabel provides an estimate of the local $^{87}Sr/^{86}Sr$ range of approximately 0.7083 to 0.7092. There is only a limited degree of overlap between the human and faunal data sets for this site with nearly half of the human values falling outside of the range of faunal $^{87}Sr/^{86}Sr$ ratios from Maisabel (~0.7087 to 0.7092) and a third falling outside this range if a single snail sample from a nearby location in Vega Baja is included in the biosphere range (0.7084). In total, nine nonlocals were identified amongst the human population from Maisabel (~31%) all of whom possess $^{87}Sr/^{86}Sr$ ratios that are outside of the range of faunal values from this site and are lower than the local population (Figure 35). The nonlocal $^{87}Sr/^{86}Sr$ ratios from Maisabel fall into two groups. The first consists of three individuals with highly variable but relatively low $^{87}Sr/^{86}Sr$ ratios that range between approximately 0.7056 and 0.7074. The second group is comprised of six individuals with $^{87}Sr/^{86}Sr$ ratios that cluster tightly between 0.70808 and 0.70819. Both groups of nonlocals are within the absolute range of biosphere $^{87}Sr/^{86}Sr$ for the island of Puerto Rico. Therefore, these individuals are nonlocal to the site of Maisabel but not necessarily to the entire island. In fact, Puerto Rico has one of the largest ranges of biosphere $^{87}Sr/^{86}Sr$ in this study, probably owing in part to the large differences in underlying geology between the interior and the coastal areas of the island.

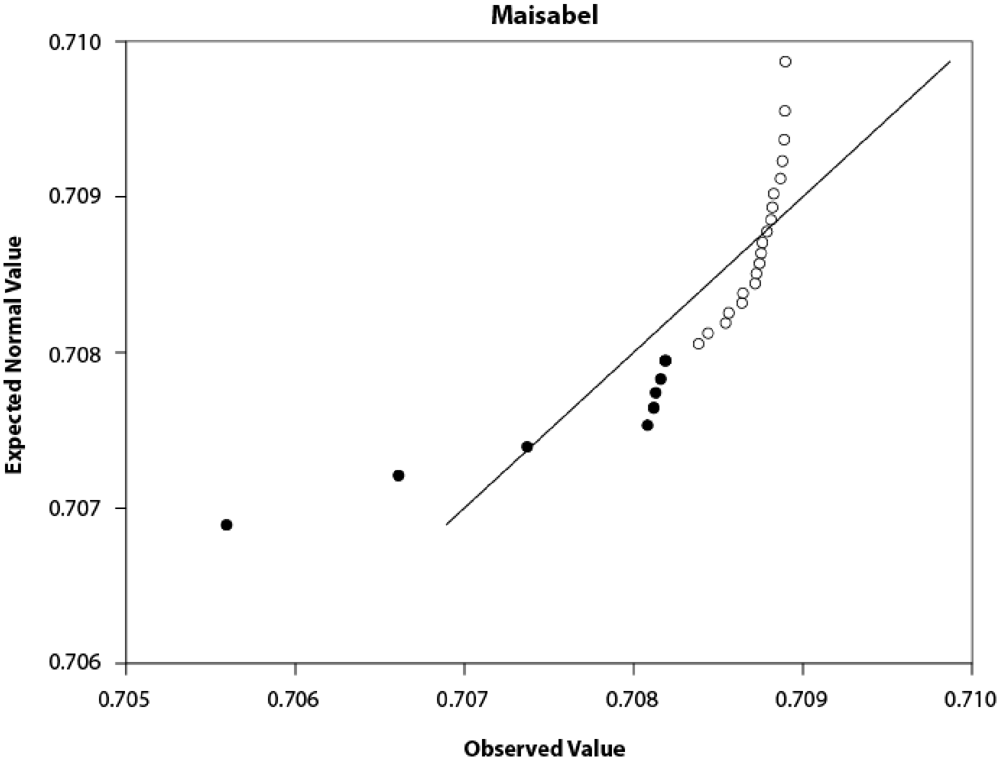


Figure 35 Normal probability Q-Q plot of human $^{87}Sr/^{86}Sr$ data from Maisabel. Key: symbols are the same as Figure 31.

7.3.4 Tutu- St. Thomas, U.S. Virgin Islands

Two biosphere samples were available from the Tutu site to assess the local $^{87}Sr/^{86}Sr$ range (one snail and one grass sample). These data were pooled with the human data and the pooled data set was subjected to statistical analysis. The first iteration identified three outliers and the distribution of the data set was non-normal and highly skewed. These three outliers were removed and the trimmed data set was reanalyzed. The second iteration identified another outlier but did not substantially reduce the skewness or produce a normally distributed population so this outlier was removed and the process was repeated. The third iteration revealed two additional outliers and produced a distribution that approached normal but with a skewness that was more than double its standard error so these two outliers were removed and a further iteration was conducted. One additional outlier was identified in this last iteration of the trimmed sample population, which had a convergent mean and median, a skewness that was similar to its standard error, and was normally distributed (W=0.968, df=25, p=0.583).

Using this statistical approach to the assessment of the pooled $^{87}Sr/^{86}Sr$ data set from Tutu provides an estimate of the local $^{87}Sr/^{86}Sr$ range of approximately 0.7074 to 0.7083. In total, seven nonlocals were identified from the Tutu population (~24%). The $^{87}Sr/^{86}Sr$ ratios of nonlocals from Tutu fall into two broad groupings (Figure 36). The first is composed of a single individual with a $^{87}Sr/^{86}Sr$ ratio (0.70871) that is elevated relative to the local population at Tutu but only slightly higher than the absolute range of biosphere (floral) $^{87}Sr/^{86}Sr$ ratios for the island of St. Thomas (0.70746-0.70864. The second group consists of six individuals with somewhat variable $^{87}Sr/^{86}Sr$ ratios (~0.7063 to 0.7073) that are all low relative to the local range at Tutu. Interestingly, these six nonlocals are outside of the absolute range of biosphere $^{87}Sr/^{86}Sr$ ratios for the island of St. Thomas. Based on the available evidence, these six individuals may be nonlocal not only to the Tutu site but to the island of St. Thomas. The $^{87}Sr/^{86}Sr$ ratios of all the nonlocals at Tutu are within the range(s) of biosphere $^{87}Sr/^{86}Sr$ for Puerto Rico and many of the islands of the northern Lesser Antilles and thus it is not possible to narrow down their possible origins more precisely using only Sr isotope data. However, additional lines of evidence including data from other isotope measurements permit us to propose more refined investigations of the natal origins of these nonlocals (see section 7.4.6).

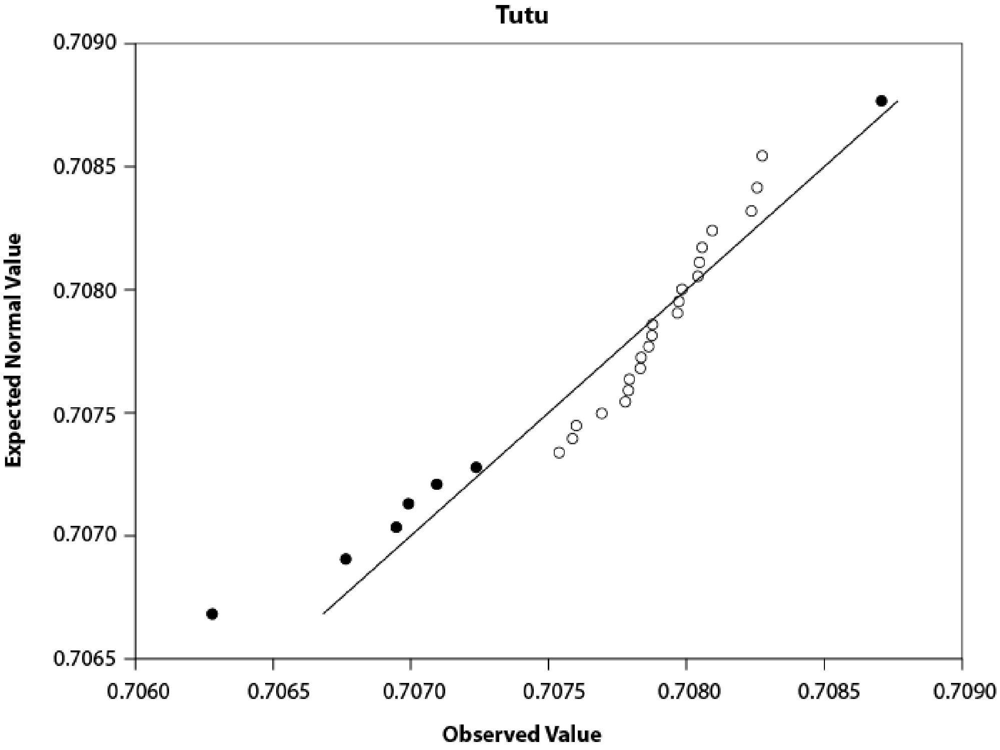


Figure 36 Normal probability Q-Q plot of human $^{87}Sr/^{86}Sr$ data from Tutu. Key: symbols are the same as Figure 31.

7.3.5 Kelbey's Ridge 2 and Spring Bay- Saba

All human $^{87}Sr/^{86}Sr$ ratios from Kelbey's Ridge are within the absolute range of local biosphere Sr isotope variation, at the scale of both the site and the island. One modern land snail shell sample was an extreme outlier relative to the rest of the sample population from Kelbey's Ridge, including all of the archaeological snails from this site. Owing to the possibility that the Sr isotope ratio from this sample reflects the incorporation of Sr from modern pollutants or fertilizers, this sample was excluded from the pooled sample population. Exploratory data analysis of the pooled human and biosphere sample population from Kelbey's Ridge was conducted to assess structure and pattern within this data. The analysis identified one outlier that fell just outside the lower quartile minus

1.5*IQR. The population displayed a similar mean and median, a skewness that was similar to its standard error, and a normal distribution (W=0.946, df=31, p=0.121).

The statistical approach to the assessment of the pooled $^{87}Sr/^{86}Sr$ data set from Kelbey's Ridge provides an estimate of the local $^{87}Sr/^{86}Sr$ range for this site of approximately 0.7078 to 0.7089. Within this study, Saba, is the most extensively and intensely mapped islands in terms of biosphere $^{87}Sr/^{86}Sr$ (n=50). The range of biosphere $^{87}Sr/^{86}Sr$ for the entire island of Saba (~0.7064 to 0.7092) is large relative to the size of this island. Based on the statistical analysis, there are no individuals from Kelbey's Ridge that are outliers. One individual has a 'borderline' $^{87}Sr/^{86}Sr$ signal (0.7077) that falls at the low end of the local biosphere range for Kelbey's Ridge and may represent a nonlocal at the site level. However, even if this individual was interpreted as a nonlocal at the scale of this site, the $^{87}Sr/^{86}Sr$ value is within the absolute range of biosphere $^{87}Sr/^{86}Sr$ for the island of Saba.

The single human sample from the neighboring site of Spring Bay 1c has an $^{87}Sr/^{86}Sr$ ratio of 0.70785 that is within the range of biosphere samples from Kelbey's Ridge. Although it is not possible to independently assess the $^{87}Sr/^{86}Sr$ range for the site of Spring Bay itself, owing to a lack of comparative samples, I consider it appropriate to use the Kelbey's Ridge Sr isotope range as the two sites are only separated by a few hundred meters. This individual's $^{87}Sr/^{86}Sr$ ratio is within the range of biosphere $^{87}Sr/^{86}Sr$ for the island of Saba indicating a probable local origin at the scale of the island.

7.3.6 Bloody Point- St. Kitts

The four human samples from the site of Bloody Point have heterogeneous Sr isotope ratios ranging from ~0.7074 to 0.7077. Unfortunately, there are no biosphere data from this site with which to compare and assess these results or to independently estimate the local range for this population. Three faunal samples were measured from the Sugar Factory Pier site on St. Kitts located approximately 15 km southeast from Bloody Point on the western coast. Nonetheless, the human $^{87}Sr/^{86}Sr$ ratios from Bloody Point show a high degree of overlap with, and primarily fall within, the range of values from the Sugar

Factory Pier faunal samples (~0.7074 to 0.7081). Five biosphere samples, all from grasses, collected from various locations across St. Kitts display a wide range of $^{87}Sr/^{86}Sr$ ratios (~0.7067 to 0.7086) that entirely encompasses both the faunal samples from Sugar Factory Pier and the human samples from Bloody Point. Thus, although it is not possible at this time to determine if the human samples from Bloody Point are local to this site their $^{87}Sr/^{86}Sr$ ratios are consistent with a local origin on the island of St. Kitts.

7.3.7 Anse à la Gourde- Guadeloupe

Human and faunal $^{87}Sr/^{86}Sr$ ratios from Anse à la Gourde were pooled into a single population and the resulting data set was statistically analyzed. Initial analysis of the pooled data set indicated that the sample population was negatively skewed and not normally distributed. The first iteration identified twelve outliers and the population was reanalyzed after their removal. The second iteration revealed that the removal of these outliers reduced the dispersion of the data and produced mean and median values that were more comparable but that the trimmed data set was still skewed with a skewness that was much greater than its standard error indicating a non-normal distribution. Reanalysis of the trimmed data set identified five additional outliers that were also removed and the iteration was repeated. The resulting trimmed data set produced by this second iteration possesses a reduced skewness that is similar to its standard error. A Shapiro-Wilk test for normality of this trimmed data set does not reject the null hypothesis that the sample is normally distributed (W=0.965, df=55, p=0.107).

Using this statistical approach to the assessment of the pooled $^{87}Sr/^{86}Sr$ data set from Anse à la Gourde provides an estimate of the local $^{87}Sr/^{86}Sr$ range of approximately 0.70898 to 0.70926. This indicates that as many as seventeen individuals from the human population at this site are nonlocal (25%). Based on assessment of the data, the individuals identified as nonlocals at Anse à la Gourde fall into at least three groupings (Figure 37). The first group is represented by three individuals with $^{87}Sr/^{86}Sr$ ratios below 0.7078. These ratios are very low relative to both the local population and expectations based on associated geology. In the Lesser Antilles, biosphere $^{87}Sr/^{86}Sr$ ranges similar to these values are common in most of the islands of the Volcanic Caribbees. The second group is the largest and includes twelve individuals with $^{87}Sr/^{86}Sr$ ratios ranging from roughly 0.70826 to 0.70896. These values are also lower than the local population at this site but less so than the first cluster and fall within the range of biosphere $^{87}Sr/^{86}Sr$ for several islands of the Volcanic Caribbees and many of the composite islands of the Limestone Caribbees. The third group is represented by two individuals with $^{87}Sr/^{86}Sr$ ratios that are elevated relative to the local population. These $^{87}Sr/^{86}Sr$ ratios exceed 0.70928 and thus are higher than seawater, the highest expected Sr isotope end member for this geographic setting. These two ratios are also higher than nearly all human or biosphere $^{87}Sr/^{86}Sr$ measurements for the Antilles (*sensu stricto*). The nearest location with measured $^{87}Sr/^{86}Sr$ ratios similar to these signals is the island of Trinidad.

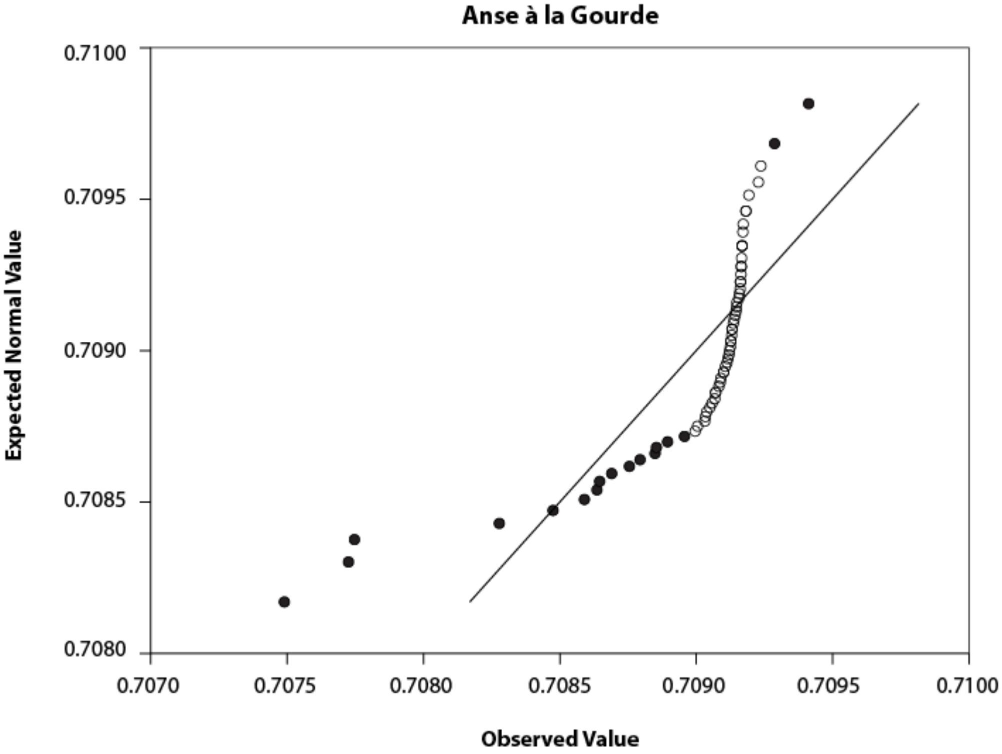


Figure 37 Normal probability Q-Q plot of human $^{87}Sr/^{86}Sr$ data from Anse à la Gourde.
Key: symbols are the same as Figure 31.

7.3.8 Lavoutte and Giraudy- St. Lucia

The Lavoutte population is one of the only samples in this study that is normally distributed before the removal of outliers and thus did not require measures that are used for non-normally distributed data (e.g., stem and leaf methods). Therefore, an estimation of the local range for this population was based on a more traditional method using the mean of all human $^{87}Sr/^{86}Sr$ ratios ± two standard deviations. This method indicates the presence of two nonlocal outliers. Recalculating the local range using a pooled sample that includes both human and biosphere $^{87}Sr/^{86}Sr$ data produces a similar local range estimate and identifies the same two individuals as outliers. Re-analysis of the trimmed sample population, after the removal of these two outliers, indicates that it has a similar mean and median, low skewness and a normal distribution (W=0.970, df=34, p=0.463).

The statistical approach to the assessment of the pooled $^{87}Sr/^{86}Sr$ data set from Lavoutte provides an estimate of the local $^{87}Sr/^{86}Sr$ range of approximately 0.7075 to 0.7083. Two individuals from Lavoutte were identified as nonlocal (~6%) and both of these have $^{87}Sr/^{86}Sr$ ratios that are outside of the absolute range of biosphere values for this site. Of these two nonlocals one possesses a high $^{87}Sr/^{86}Sr$ ratio (0.7086) relative to the local population and the other a lower value (0.7072). In both cases there is a considerable gap between their $^{87}Sr/^{86}Sr$ ratios and the minimum and maximum $^{87}Sr/^{86}Sr$ ratios of the local population, respectively (Figure 38). The nonlocal with an elevated $^{87}Sr/^{86}Sr$ signal relative to the local population is within the absolute range of biosphere $^{87}Sr/^{86}Sr$ for the island of St. Lucia as a whole. Therefore, although this individual appears nonlocal to the site of Lavoutte, he/she could have originated from another site within St. Lucia, for example from areas in the southern part of the island which is characterized by higher $^{87}Sr/^{86}Sr$ ratios. The other nonlocal possesses a lower $^{87}Sr/^{86}Sr$ signal that is outside the absolute range of biosphere $^{87}Sr/^{86}Sr$ for St. Lucia suggesting an extra-insular origin for this individual. The nearest location with similar biosphere $^{87}Sr/^{86}Sr$ ratios is the island of St. Vincent, although other islands in the Lesser Antilles also possess similar biosphere $^{87}Sr/^{86}Sr$ ratios such as Basse-Terre, Grenada, Martinique, Nevis, and Tobago.

One human sample was analyzed from the site of Giraudy in southern St. Lucia. This individual has an $^{87}Sr/^{86}Sr$ ratio of 0.70876 that is within the range of biosphere $^{87}Sr/^{86}Sr$ ratios from St. Lucia and is particularly similar to other ratios obtained from plant samples from the southern part of the island. Although there are insufficient independent data to assess the local biosphere range for this site, the single human $^{87}Sr/^{86}Sr$ value from Giraudy is consistent with an origin in southern St. Lucia.

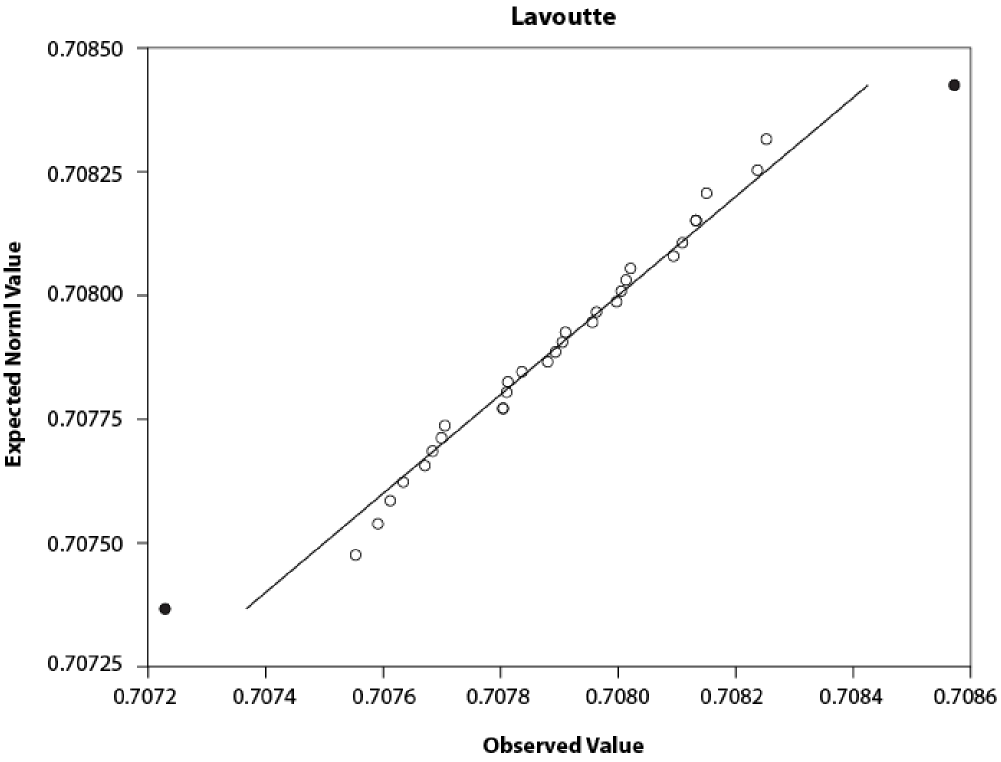


Figure 38 Normal probability Q-Q plot of human $^{87}Sr/^{86}Sr$ data from Lavoutte. Key: symbols are the same as Figure 31.

7.3.9 Escape, Argyle I and II, and Buccament West- St. Vincent

For the sake of statistical analyses, samples from the three adjacent sites of Escape, Argyle I and Argyle II were pooled into a single sample population. This is considered appropriate considering the fact that these three sites are adjacent (within ~200 meters of each other) and thus their inhabitants probably shared similar catchment areas. Furthermore, there is a high degree of overlap between the $^{87}Sr/^{86}Sr$ ratios of the three populations. The three rodent samples from Escape possessed very low $^{87}Sr/^{86}Sr$ ratios relative to all of the human $^{87}Sr/^{86}Sr$ ratios from these three sites with no overlap in $^{87}Sr/^{86}Sr$ ratios. The causes for these discrepancies are unknown but indicate that caution is required in the interpretation of the $^{87}Sr/^{86}Sr$ results from these sites. Owing to this lack of congruence, I have tentatively rejected the hypothesis that all of the humans from this site are nonlocal (i.e., if the biosphere $^{87}Sr/^{86}Sr$ ratios alone were used to estimate the local range) and instead I have not included the biosphere (faunal) samples in the pooled sample population from this site(s). Initial statistical analyses of the human data identified five outliers. These five individuals were removed from the pooled data set and a basic statistical analysis of the trimmed sample was conducted. This process was repeated until no further outliers were identified. The fourth iteration revealed no further outliers and the resulting data set has low skewness relative to its standard error, a coinciding mean and median, and is normally distributed (W=0.977, df=30, p=0.727).

The statistical approach to the assessment of the pooled $^{87}Sr/^{86}Sr$ data set from the Escape/Argyle population(s) provides an estimate of the local $^{87}Sr/^{86}Sr$ range of approximately 0.7074 to 0.7079. In total, twelve nonlocals were identified amongst the pooled Escape/Argyle populations (29%). These nonlocals include six from the Escape site (~23%), one from Argyle I (50%), and five from Argyle II (~36%). These nonlocals fall into three broad groups (Figure 39). The first group is represented by five individuals (four from Escape and one from Argyle II) with relatively low $^{87}Sr/^{86}Sr$ ratios (~0.7067 to 0.70734) that are below the local range for this site. The second group is represented by six individuals (two from Escape, one from Argyle I, and three from Argyle II) with relatively elevated $^{87}Sr/^{86}Sr$ ratios (~0.70794 to 0.70817) that are above the local range for this site. Individuals from these two groups appear to be nonlocal relative to the local population at this site(s) but as their ratios are within the absolute range of biosphere $^{87}Sr/^{86}Sr$ at the scale of the island of St. Vincent (~0.7057 to 0.7081), they are considered local at the scale of this island. A third group is comprised of a single individual with an elevated $^{87}Sr/^{86}Sr$ value (0.7087) that is outside of the absolute range of biosphere $^{87}Sr/^{86}Sr$ for St. Vincent possibly indicating an extra-insular origin for this individual. The nearest location with measured biosphere $^{87}Sr/^{86}Sr$ ratios that are similar to this nonlocal is St. Lucia, while other locations in the Lesser Antilles include Saba, St. Eustatius and much of the Limestone Caribbees.

A single human sample from the Buccament West site was also analyzed. No comparative samples are available with which to assess the local range at this site. This single sample has an $^{87}Sr/^{86}Sr$ value that is substantially lower than all of the human samples from the Escape and Argyle sites. Interestingly, the value from this individual more closely matches the values of faunal remains from the Escape site and the values of floral samples from southern St. Vincent. Thus, although it is not possible to directly assess whether this individual is local to the site of Buccament West, this $^{87}Sr/^{86}Sr$ ratio is consistent with an origin on St. Vincent.

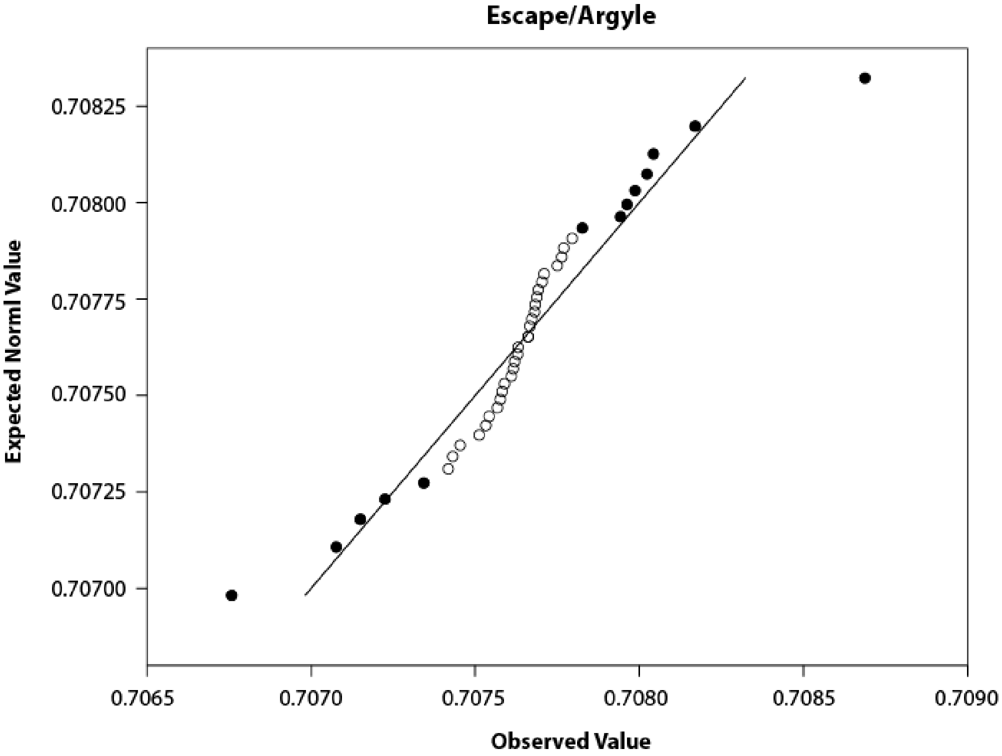


Figure 39 Normal probability Q-Q plot of human $^{87}Sr/^{86}Sr$ data from Escape/Argyle.
Key: symbols are the same as Figure 31.

7.3.10 Heywoods- Barbados

The small number of analyzed human samples (n=3) from the Heywoods site prohibits statistical assessment of this data set but all three samples have nearly identical $^{87}Sr/^{86}Sr$ ratios. No biosphere $^{87}Sr/^{86}Sr$ data are available from this site with which to assess the local range of $^{87}Sr/^{86}Sr$ ratios but one snail sample from the same general area has an $^{87}Sr/^{86}Sr$ ratio that is very similar to the three humans from Heywoods. These values are also consistent with measured $^{87}Sr/^{86}Sr$ ratios of local individuals from the colonial period Newton Plantation site (Schroeder et al. 2009). Furthermore, all of these values are in good agreement with expected $^{87}Sr/^{86}Sr$ ratios (0.7092) based on the underlying geology of most of Barbados, which is primarily composed of late Tertiary and Quaternary marine sedimentary deposits. Therefore, the three individuals from Heywoods appear to be local at least to the island of Barbados.

7.3.11 Manzanilla- Trinidad

The human sample population from Manzanilla was pooled with a single floral sample from this site and the pooled data set was subjected to statistical analysis. The analysis revealed the presence of three outliers, including one extremely elevated $^{87}Sr/^{86}Sr$ ratio. These three outliers were removed and a second iteration was run. The trimmed data set has somewhat similar mean and median values, a skewness that is lower than its standard error, and a normal distribution (W=0.966, df=14, p=0.820). However, it should be noted that although analysis of the trimmed data set did not indicate the presence of any additional outliers, it is possible that other nonlocals exist within this population that remain unidentified. The possibility of unidentified nonlocals in this population is deemed somewhat more likely for this population relative to others, owing to the relative paucity of biosphere samples (n=1); and the relatively high dispersion, variance, and range of the trimmed data set.

The statistical approach to the assessment of the pooled data set from Manzanilla provides an estimate of the local $^{87}Sr/^{86}Sr$ range of approximately 0.7086 to 0.7104. In total, three nonlocals (Figure 40) were identified amongst the Manzanilla population (~19%). Of these three nonlocals, one possesses an $^{87}Sr/^{86}Sr$ ratio that is low relative to the local Manzanilla population but is within the range of biosphere $^{87}Sr/^{86}Sr$ ratios for the island of Trinidad. The second nonlocal has an $^{87}Sr/^{86}Sr$ ratio that is higher than the range of biosphere $^{87}Sr/^{86}Sr$ ratios for the Antilles (excepting a small number of extreme values). This individual's Sr isotope signal is possibly indicative of an origin in mainland South America as the nearest location with measured biosphere $^{87}Sr/^{86}Sr$ ratios is northern coastal Venezuela. The third nonlocal from Manzanilla has by far the highest $^{87}Sr/^{86}Sr$ ratio in our study (n>640). This $^{87}Sr/^{86}Sr$ ratio is higher than unexpected for any Antillean context and furthermore is also higher than any published $^{87}Sr/^{86}Sr$ ratio from Mesoamerica (n>600) with the exception of a single peccary sample from the site of Tipu, Belize (Thornton, 2011). Such an elevated Sr isotope ratio is considered to be relatively rare in the insular Caribbean and would only be expected from regions dominated by very old geological formations. The closest region to Trinidad possessing such older geological formations is the Guiana Shield Region of northeastern South America. A possible origin from this region would not be entirely unexpected given the proposed connection between the Guianas and Trinidad in prehistoric times (Boomert 2000).

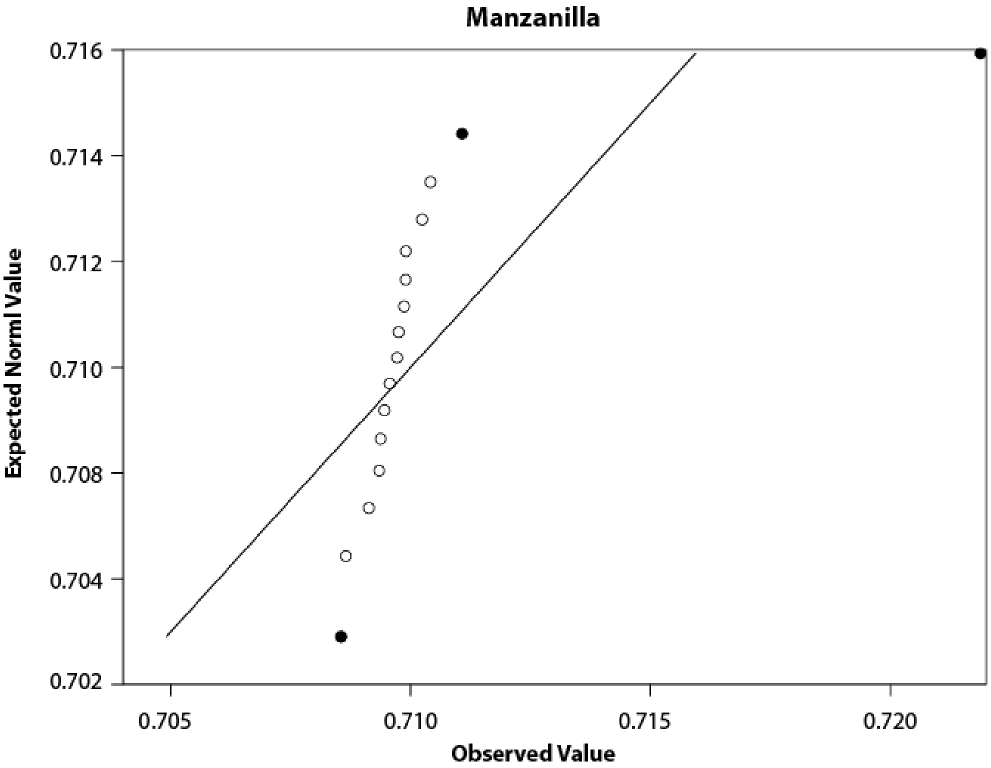


Figure 40 Normal probability Q-Q plot of human $^{87}Sr/^{86}Sr$ data from Manzanilla.
Key: symbols are the same as Figure 31.

<u>7.3.12 Malmok, Canashito, Santa Cruz, Savaneta, and Tanki Flip- Aruba</u>

Human samples from Aruba and derive from several different sites and only five biosphere samples were collected for the entire island of Aruba. As such, it is not possible to conduct statistical analyses separately on each sample population. For a few sites, it is possible to directly compare human and biosphere $^{87}Sr/^{86}Sr$ data. In the case of Malmok, the $^{87}Sr/^{86}Sr$ ratios of the four human samples are very similar (~0.70906 to 0.70918) and to a single grass sample collected at this site (0.70913). In contrast the $^{87}Sr/^{86}Sr$ ratio from a single human sample from Santa Cruz (0.70823) was distinct from the $^{87}Sr/^{86}Sr$ ratio obtained from a grass sample from this site (0.70772). Similarly, $^{87}Sr/^{86}Sr$ ratios from two humans from Tanki Flip (~0.70859 to 0.70897) were somewhat divergent not only from each other but also relative to a grass sample from this site (0.70764). It is possible that the plant samples are reflecting the incorporation of modern Sr derived from pollution or fertilizers and thus do not accurately reflect the range of biosphere $^{87}Sr/^{86}Sr$ in the distant past. Alternatively, the limited data set may simply not reflect the degree of $^{87}Sr/^{86}Sr$ variation that is present at these sites. In the absence of additional relevant data it is difficult to assess the implications of these differences at this time. For Malmok, the preliminary evidence suggests that all four individuals are local to this site. For the other sites, there is simply insufficient data to determine locality at the scale of individual populations or sites.

There is, however, a high degree of overlap between the ranges of $^{87}Sr/^{86}Sr$ values from human and floral samples from the island of Aruba. Additionally, most of the human $^{87}Sr/^{86}Sr$ values from Aruba are within the absolute range of floral values from this island. A single human sample from the pre-ceramic site of Canashito has an $^{87}Sr/^{86}Sr$ value (0.70988) that is notably elevated relative to both the human and floral data sets from Aruba (~0.7076 to 0.7092) and relative to the absolute range of biosphere $^{87}Sr/^{86}Sr$ for the Antilles in general. Thus, this individual is considered to be a nonlocal at the scale of the island of Aruba and owing to the high $^{87}Sr/^{86}Sr$ ratio also nonlocal to the Antilles (*sensu stricto*). Although several equally high $^{87}Sr/^{86}Sr$ values were obtained from Trinidad, the nearest location with similar measured $^{87}Sr/^{86}Sr$ values is the northern coast of mainland South America. Specifically, this individual's $^{87}Sr/^{86}Sr$ signature is nearly identical to a number of plant samples from the Falcón Basin region of coastal Venezuela. Such an origin would fit with current hypotheses concerning human migrations from western Venezuela into Aruba (Versteeg 1991a). However, this $^{87}Sr/^{86}Sr$ value is also within the range of expected $^{87}Sr/^{86}Sr$ values for many areas of mainland South America, more generally.

7.4 Patterns of Paleomobility

In the following sections I will discuss patterns of paleomobility, including explicit comparisons of locals versus nonlocals in terms of sex, age, chronology, mortuary treatment, and diet. The aim of these comparative analyses is to assess patterns within and between locals and nonlocals for each of the populations in this study. The identification of patterning in these data is important in order to investigate similarities and differences between locals and nonlocals in terms of: 1) biological sex; 2) age at death; 3) chronology; 4) grave goods; and 5) dietary practices. These comparisons are generally limited to the larger populations within this study and to those for which relevant data are available concerning these various parameters. The results of the statistical analyses (using SPSS) are presented separately for each set of comparisons, first by sample population and then for all data pooled together.

7.4.1 Patterns of Paleomobility: biological sex

For the sake of making comparisons between locals and nonlocals in terms of demography (sex and age) these skeletal populations are treated as single populations despite the fact that many of them span several centuries and certain individuals are clearly not contemporaneous with others. This analysis was conducted to determine if there are any distinct correlations between origins and biological sex or age at death independent of chronology [Assessment of locality in relation to chronology is discussed in section 7.4.3]. The populations for which sufficient demographic data are available and that are large enough for statistical analyses are El Chorro de Maíta, Maisabel, Tutu, Anse à la Gourde, and Lavoutte (Table 10 and Figure 41). For these populations individuals that were identified as possible male or possible female based on osteological analyses of skeletal traits were treated as males and females, respectively. Subadults and adults of indeterminate sex were not included in this analysis. Most demographic data described herein are based upon the results of recent osteological analyses (and subsequent skeletal reports) conducted by Darlene Weston, with the exception of the Tutu data which can be found in (Sandford et al. 2002).

Of the 88 individuals from the Chorro de Maíta population that were analyzed for Sr isotope composition, 64 adults were sexed (33 females and 31 males). Of the 33 females, eight are nonlocal (24.2%) and of the 31 males, 13 are nonlocal (41.9%). There are clearly more nonlocal males than nonlocal females both in terms of absolute numbers and proportionally. Although, the difference between these proportions seems large upon initial observation, they are not statistically significant based on a Fisher's exact test (p=0.184). Nonetheless, the proportion of nonlocal males relative to the total male population from El Chorro is the highest of all of the populations in this study. Furthermore, the Chorro de Maíta population is one of only two populations in this study (the other being Manzanilla, Trinidad), where the percentage of nonlocal males exceeds that of nonlocal females.

Of the 29 individuals from Maisabel that were analyzed for Sr isotope composition, 20 adults were sexed (seven females and 13 males). Of the seven females, three are nonlocal (42.9%) and of the 13 males, five are nonlocal (38.5%). In absolute terms, there are more nonlocal males than nonlocal females but proportionally there are slightly more nonlocal females. The observed difference between these two groups is not statistically significant (Fisher's exact test, p=1.000). Interestingly, the Maisabel sample population not only has the largest proportion of nonlocals (~31%) in this study but also by far the highest proportion of nonlocal females and the second highest proportion of nonlocal males.

Of the 29 individuals from Tutu that were analyzed for Sr isotope composition, 19 adults were sexed (13 females and six males). Of the 13 females, five are nonlocal (38.5%) and of the six males, two are nonlocal (33.3%). There are more nonlocal females than nonlocal males both in absolute numbers and proportionally. The observed difference between these two groups is not statistically significant (Fisher's exact test, p=1.000). The Tutu sample population has the second highest proportion of nonlocal females and the third highest proportion of nonlocal males in this study. This is partly a reflection of the fact that most of the nonlocal individuals could be sexed and that nearly all of the juveniles and individuals of indeterminate sex are local.

Of the 68 individuals from Anse à la Gourde analyzed for Sr isotope composition, the biological sex of 57 adults was determined (34 females and 23 males). Of the 34 females, nine are nonlocal (26.5%) and of the 23 males, five are nonlocal (21.7%). In both absolute terms and proportionally, there are more nonlocal females than nonlocal males. The observed difference between these two groups is not statistically significant (Fisher's exact test, p=0.762). The Anse à la Gourde sample population has the third highest proportion of nonlocal females but the fifth highest proportion of nonlocal males in this study.

Of the 32 individuals from Lavoutte that were analyzed for Sr isotope composition, 23 adults were sexed (12 females and 11 males). Of the 12 females, one is nonlocal (8.3%) and of the 11 males, none is nonlocal (0%). The observed difference between these two groups is not statistically significant (Fisher's exact test, p=1.000). The Lavoutte sample population has one of the lowest proportions of nonlocals (~6%) relative to the overall size of the sample population, which is one of the largest in this study. Since only one of the two nonlocals from Lavoutte could be sexed it is not possible to assess any potential differences in mobility between males and females for this population.

For all of the other sample populations in this study, there were an insufficient number of samples, too few nonlocals, and/or a lack of reliable osteological data to assess patterns of mobility relative to biological sex. Therefore, I have pooled all sexed individuals in this study into a single sample population to assess broader patterns of mobility within the entire region. The pooled sample population includes results from the five populations discussed above in addition to the results from Punta Macao and Manzanilla. In total, the pooled sample population includes 207 individuals, almost equally represented by females (n=106) and males (n=101). Interestingly, there is an equal number of nonlocal females and nonlocal males (n=27) and the proportions of each are nearly identical (~25.5% and 26.7%, respectively).

In summary, there is substantial variation between populations in the proportion of nonlocals of each sex, ranging from 0% as some sites to over 40% at others. However, most of this variation can be accounted for by differences in the proportions of nonlocals generally (of both sexes) between different populations. In terms of intra-population variation, the observed differences between nonlocal females and nonlocal males are not statistically significant for any of the populations in this study. Observed differences in the proportions of nonlocals relative to sex are the largest for the Chorro de Maíta population, with a 17% higher proportion of nonlocals amongst males than amongst females.

Table 10: Comparisons between locality and biological sex

Site	**Female**	**Female**	**Female**	**Male**	**Male**	**Male**
	total	nonlocal	%	total	nonlocal	%
Chorro de Maíta	33	8	24.2	31	13	41.9
Punta Macao	5	1	20.0	8	0	0.0
Maisabel	7	3	42.9	13	5	38.5
Tutu	13	5	38.5	6	2	33.3
Anse à la Gourde	34	9	26.5	23	5	21.7
Lavoutte	12	1	8.3	11	0	0.0
Manzanilla	2	0	0.0	9	2	22.2
Total	106	27	25.5	101	27	26.7

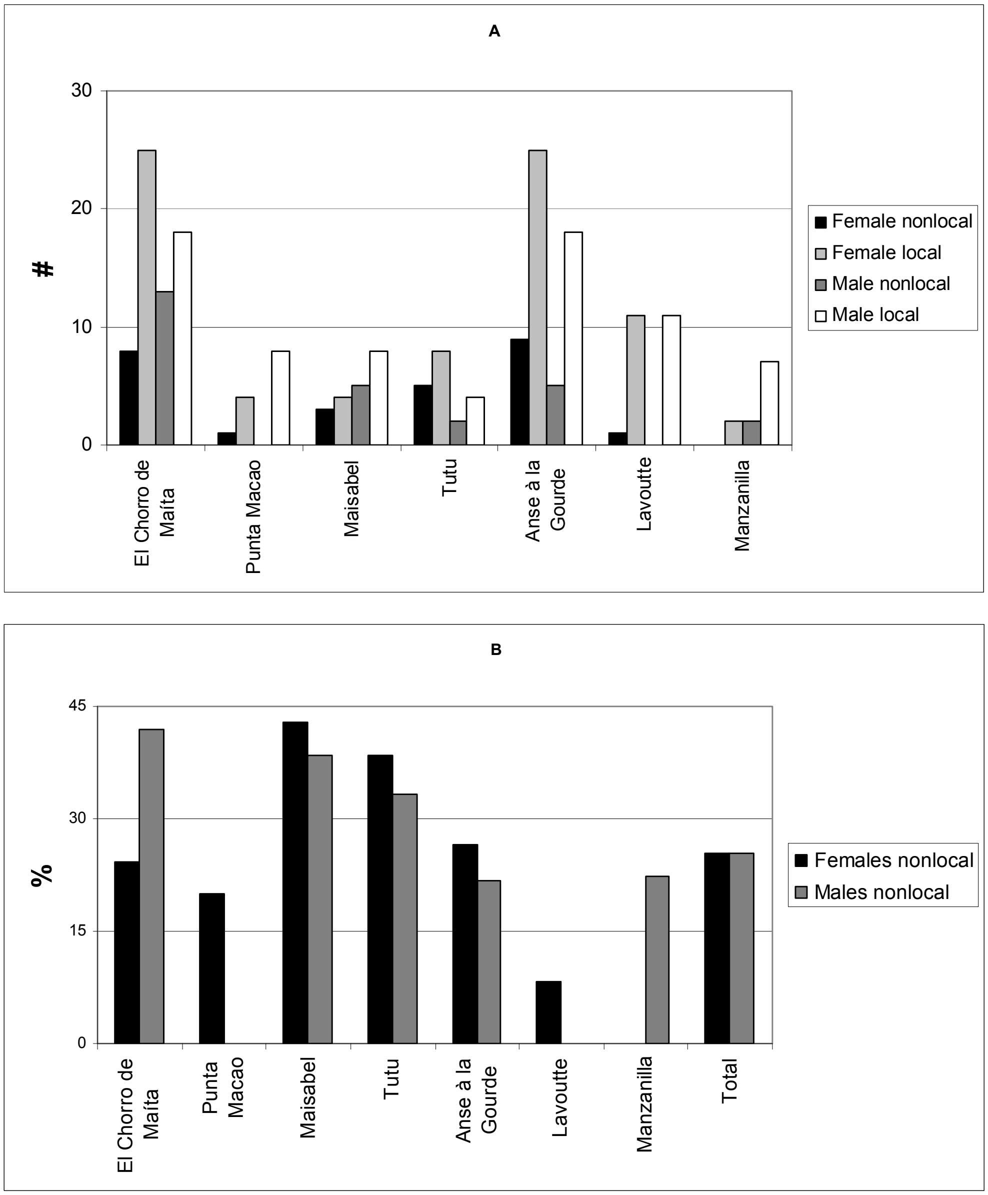


Figure 41 Charts of patterns between locality and biological sex: A) absolute numbers of female locals/nonlocals and male locals/nonlocals per population; and B) percentage of females and males that are nonlocal per population.

7.4.2 Patterns of Paleomobility: age at death

Analyses of locality relative to skeletal age were conducted on the same populations as the analyses for biological sex using the same statistical methods (Table 11 and Figure 42). The available data does not permit the use of more refined age categories and so comparisons are only made between the broad age categories of adults and subadults (defined here as individuals older and younger than 18 years of age at death, respectively). Aging of skeletal remains are based on available physical anthropological reports and publications of the studied populations (Sandford et al. 2002; Weston and Schats 2010; Weston 2011a; Weston 2010b). Individuals that could not be properly aged, for example owing to very poor condition of the skeletal remains, were not included in this analysis.

For the Chorro de Maíta population, there are 63 adults and 25 subadults. Amongst the adults, 20 (31.7%) are nonlocal and amongst the subadults two (8%) are nonlocal. The difference between these groups is statistically significant (Fisher's exact test, p=0.028). The observed pattern matches the expected pattern in that subadults are expected to be relatively less mobile than adults. This does not imply that subadults did not migrate, only that there should be some correlation between age and the likelihood of migration based on a life history model.

For the Maisabel population, there are 23 adults and six subadults. Amongst the adults, eight (34.8%) are nonlocal and amongst the subadults, one (16.7%) is nonlocal. Although the percentage of nonlocals amongst the adults is more than double the percentage of nonlocals amongst the subadults, the difference between these groups is not statistically significant (Fisher's exact test, p=0.633). Small populations such as this are extremely sensitive to small fluctuations as the presence of a single datum (the sole nonlocal subadult) makes a substantial difference in terms of the significance of the difference between these two groups.

For the Tutu population, there are 20 adults and nine subadults. Amongst the adults, seven (35.0%) are nonlocal and amongst the subadults none (0%) are nonlocal. Despite the apparently large difference between these groups, this difference is not quite statistically significant (Fisher's exact test, p=0.066). Nonetheless, the p value is just outside of the range of significance and is probably an artifact of very small sample sizes. Once again, the high proportion of nonlocals amongst the adults and the absence of nonlocals amongst the subadults match expectations.

For the Anse à al Gourde population, there are 59 adults and nine subadults. Amongst the adults, 14 (23.7%) are nonlocal and amongst the subadults three (33.3%) are nonlocal. The difference between these groups is not statistically significant (Fisher's exact test, p=0.762). However, contrary both to expectations and the results from the other populations in this study, there are proportionally more nonlocals amongst the subadults than adults, even though the absolute number of nonlocal adults is larger. Although the absolute number of nonlocal juveniles at this site is small, these results are somewhat peculiar considering that the $^{87}Sr/^{86}Sr$ ratios of two of these nonlocal juveniles are the two highest values amongst this population and are also elevated relative to the absolute range for the Antilles (*sensu stricto*). The nearest location with similar, measured $^{87}Sr/^{86}Sr$ ratios is Trinidad, indicating that these two juveniles possibly migrated from a distant origin (> 500 km) at relatively young ages (~2 and ~5-7 years of age at death, respectively). It is also somewhat peculiar that none of the other nonlocal adults from this population possess similarly elevated $^{87}Sr/^{86}Sr$ values, although this may simply be the result of differential burial treatment or sampling bias.

For the Lavoutte population, there are 27 adults and five subadults. Amongst the adults, two (7.4%) are nonlocal and amongst the subadults none (0%) are nonlocal. The difference between these groups is not statistically significant (Fisher's exact test, p=1.000). The small difference between these groups reflects the fact that a very small percentage of individuals (~6%) from Lavoutte have been identified as nonlocal. This percentage is also relatively small relative to the overall size of this sample population compared to other populations in this study of similar size. However, as with Tutu, none of the subadults from Lavoutte are nonlocal.

Similar to the situation for biological sex, there are insufficient numbers of samples or relevant data to conduct statistical analyses individually for the other populations in this study. Therefore, I have pooled all individuals for which we have an osteological identification of skeletal age into a single sample population for the sake of comparative analysis. The pooled sample population includes results from the five populations discussed above in addition to the results from Punta Macao, Manzanilla, Heywoods, and the composite Escape/Argyle assemblage. In total, the pooled sample population includes 310 individuals, 248 adults and 62 subadults. Statistical analysis of this pooled data set indicates that there is a statistically significant difference between nonlocal adults and nonlocal subadults (Fisher's exact test, p=0.031). Thus despite the high degree of variation between the contexts of the sample populations, the general trend is that adults are far more likely to be nonlocal than subadults.

Table 11: Comparisons between locality and age at death

Site	**Adult**	**Adult**	**Adult**	**Subadult**	**Subadult**	**Subadult**
	total	nonlocal	%	total	nonlocal	%
El Chorro de Maíta	63	20	31.7	25	2	8.0
Punta Macao	16	1	6.3	2	0	0.0
Maisabel	23	8	34.8	6	1	16.7
Tutu	20	7	35.0	9	0	0.0
Anse à la Gourde	59	14	23.7	9	3	33.3
Lavoutte	27	2	7.4	5	0	0.0
Escape/Argyle	26	7	26.9	1	1	100
Heywoods	3	0	0.0	0	0	0.0
Manzanilla	11	2	18.2	5	1	20.0
Total	248	61	24.6	62	8	12.9

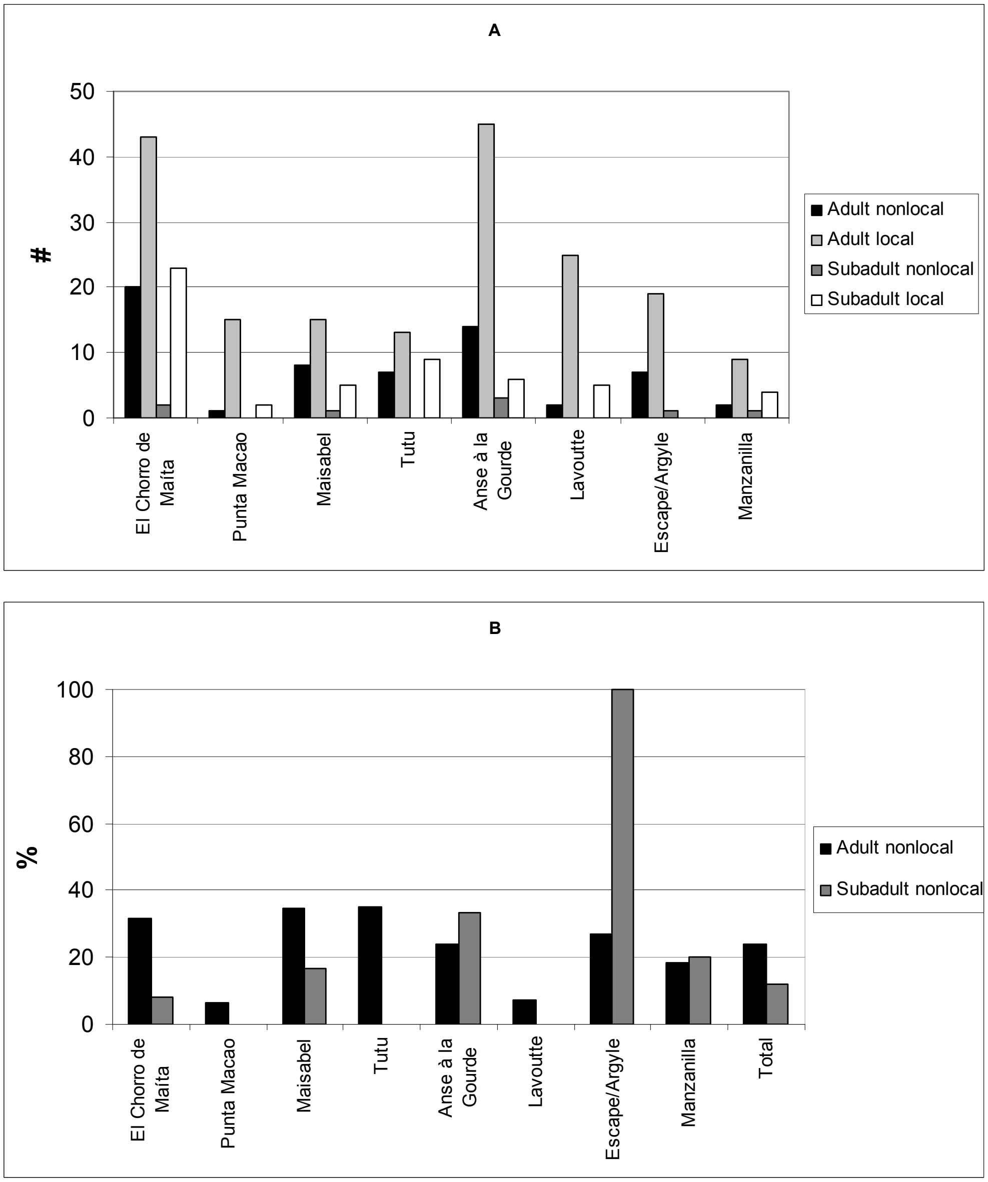


Figure 42 Chart of patterns between locality and age at death.
A) Numbers of adult locals/nonlocals and subadult locals/nonlocals per population; and B) Percentages of adults and subadults that are nonlocal per population.

7.4.3 Patterns of Paleomobility: chronology

Sufficient data on the chronology and dating of individual burials are only available for a few of the populations studied herein, namely Maisabel, Tutu, and Anse à la Gourde. Unfortunately, radiocarbon dates are only available for a limited number of individuals from each of these populations. In most cases there is a strong degree of overlap between the 2-sigma radiocarbon dates for different individuals from the same population and in some cases the dispersion of the median probability dates indicates that some burial population represent the long term accumulation of individual over several centuries. Owing to these limitations, the individual skeletal remains have been simply clustered into two or more categories (e.g., early/late) based on direct radiocarbon dating of skeletal remains. These categories have been supplemented, for example in cases where associated material remains or burial practices could be clearly attributed to one or the other of these temporal categories. Statistical analyses was then conducted to determine if there were significant differences in the presence of nonlocals between earlier and later time periods for each of these populations.

For Maisabel, of the 29 individuals analyzed for Sr isotopes, radiocarbon dates (obtained directly from the skeletal material) are available for the vast majority (n=24, ~83%). The five individuals for whom no radiocarbon dates are available could be assigned to an early or later component based on associated material remains, namely ceramic materials. Thus compared to most of the other populations in this study we have good chronological control of the individual burials at least in reference to their derivation from an earlier or later Ceramic Age context. In total, 13 individuals could be assigned to an earlier context dating from roughly A.D 500-1000, and 16 individuals could be assigned to a later group dating from roughly AD 950-1450. The early group is comprised of seven locals and six nonlocals (~46%) and the later group is comprised of 13 locals and three nonlocals (~19%). Despite the fact that there are twice as many nonlocals in the early group compared to the later group and that proportionally the difference is quite large, it is not statistically significant (Fisher's exact test, p=0.226).

For Tutu, of the 29 individuals analyzed for Sr isotopes, radiocarbon dates are available for 24 of them. In total, nine individuals fall into an earlier group dating from roughly A.D. 450-950 and 15 fall into a later group dating from roughly A.D. 1150-1450. The early group is comprised of six locals and three nonlocals (~33%) and the later group is comprised of 11 locals and four nonlocals (~27%). The observed difference between these groups is not statistically significant (Fisher's exact test, p=1.000).

For Anse à la Gourde, of the 68 individuals analyzed for Sr isotopes, radiocarbon dates are available for 24 of them. The dispersion of these radiocarbon dates is somewhat continuous over approximately 500 years of occupation with little clear clustering of the median probability dates. The dated individuals from this site can be divided into three roughly defined groups; 1) an early group dating from roughly A.D. 980-1150; 2) an intermediate group dating from roughly A.D. 1150-1270; and 3) a later group dating from roughly A.D. 1270-1430. The earlier group consists of five individuals, two locals and three nonlocals (60%). The intermediate group consists of 13 individuals, five locals and eight nonlocals (~62%). The later group consists of six individuals, five locals and one nonlocal (~17%). The proportions of nonlocals amongst the dated individuals is somewhat inflated owing to the fact that Sr isotope results guided the sampling strategy for radiocarbon dating analysis. Proportionally, there are clearly many more nonlocals in the early and intermediate groups relative to the later group. These observed differences are, however, not statistically significant (Pearson Chi-Square, 2-sided, p=0.169).

I also conducted a comparison of the number and proportion of nonlocals dating to the Early versus those dating to the Late Ceramic Ages from the sites where secure chronological data was available (for the sake of this analysis, a cutoff of ~A.D. 700 was used). For this comparison I included individuals from the larger sample populations who could be clearly assigned to one of these two groups based on direct radiocarbon dates and/or associated material remains. This pooled dataset includes individuals from the populations of Punta Macao, Maisabel, Tutu, Anse à la Gourde, Lavoutte, Escape/Argyle 1. Other populations were not included if they dated to the Archaic Age (Malmok) or contact period (El Chorro de Maíta and Argyle 2), if there was ambiguity in terms of assigning a particular burial to one of these two time periods (e.g., undated individuals from Tutu), or if local Sr isotope range estimates could not be done at the site level (e.g., Ceramic Age sites on Aruba). In total, 224 individuals were included in this analysis. Amongst 62 individuals dating to the Early Ceramic Age there are 20 nonlocals (32.3%)

and amongst the 162 individuals dating to the Late Ceramic Age there are 27 nonlocals (16.7%). Thus proportionally, the percentage of nonlocals from the earlier period is twice that of the later period and this difference is statistically significant (Fisher's exact test, p=0.016). Therefore, in general there are proportionally many more nonlocals in the Early Ceramic Age compared to the Late Ceramic Age. This pattern is consistent with current models of human migration patterns for the Early Ceramic Age, during which population densities were much lower and social relationships (including possible marriage exchange) were frequently maintained over long distances.

7.4.4 Patterns of Paleomobility: grave goods

To assess possible patterns or associations between mobility and mortuary treatment, I compiled available mortuary data for several of the populations included in this study. Unfortunately, for several burial populations details of mortuary treatment are poorly documented or simply not available. For other populations, the quality of the available data is highly variable thereby limiting comparative analyses. Therefore, comparative analysis between mobility and mortuary treatment are restricted to direct assessments of locals and nonlocals relative to the presence or absence of grave goods and in a limited number of cases to the types of grave goods. These analyses have been conducted for the El Chorro de Maíta, Tutu, and Anse à la Gourde burial populations. Substantial mortuary data are also available for the Maisabel population but nearly all of the individuals that were analyzed for Sr isotopes have cultural materials associated with the burials pits. Thus no comparison could be made based on the presence/absence of grave inclusions and no pattern was found between natal residence and the type of grave goods for this site.

At El Chorro de Maíta, of the 88 individuals analyzed for Sr isotope composition, 71 individuals were not interred with grave goods and 17 individuals were interred with grave goods (Valcárcel Rojas 2012). Of the 71 individuals that were not interred with grave goods, 53 are local and 18 are nonlocal (~25%). Of the17 that were interred with grave goods, 13 are local and four are nonlocal (~24%). These observed differences are not statistically significant (Fisher's exact test, p=1.000). All four of the nonlocals with grave goods were found with aglets, or brass tubes, presumably of European origin, 3 adult males and a juvenile age 10-11 years at death. However, most of the individuals that were interred with aglets are local.

At Tutu, of the 29 individuals analyzed for Sr isotope composition, 19 individuals were not interred with grave goods and 10 individuals were interred with grave goods, primarily pottery (Righter 2002; Sandford et al. 2002). Individuals buried in or with ceramic vessels are mostly represented by subadults and adults dating to the earlier component of the site. Of the 19 individuals that were not interred with grave goods, 15 are local and four are nonlocal (~21%). Of the 10 that were interred with grave goods, seven are local and three are nonlocal (30%). These observed differences are not statistically significant (Fisher's exact test, p=0.665).

At Anse à la Gourde, of the 68 individuals analyzed for Sr isotope composition, 37 individuals were not interred with grave goods and 31 individuals were interred with grave goods. Grave goods consist of a wide variety of materials and objects of both local and exotic origins including for example lithic tools, whole or fragmentary ceramic vessels, and various beads and ornaments of bone, teeth, shell and stone. Of the 37 individuals that were not interred with grave goods, 28 are local and nine are nonlocal (~24%). Of the 31 that were interred with grave goods, 23 are local and eight are nonlocal (~26%). These observed differences are not statistically significant (Fisher's exact test, p=1.000). One interesting pattern that was observed for this site is that grave inclusions of exotic origin, including a flake of Long Island flint, an adze of St. Martin greenstone, and an apron consisting of over 1000 shell beads, primarily composed of *Strombus gigas* (Lammers-Keijsers 2007) are exclusively associated with nonlocal females (Hoogland et al. 2010).

Some assessment of associations between mortuary treatment and locality is possible for the site of Manzanilla, Trinidad. One burial contains the remains of a nonlocal adult male as a secondary deposit of a bone bundle (Dorst 2008). Another burial contains a nonlocal adult male in a composite burial of four individuals in total, including both primary and secondary burials. This individual's extremely radiogenic $^{87}Sr/^{86}Sr$ signature (0.7219) is by far the highest in this study and suggests a possible origin in

Guiana Shield region of South America based on comparison with the high $^{87}Sr/^{86}Sr$ of this geologically old region. Interestingly, two other individuals in this composite burial possess apparently local $^{87}Sr/^{86}Sr$ values, indicating the inclusion of both locals and a nonlocal in the same burial deposit. Lastly, another nonlocal is an adolescent aged 14-16 years interred in a single, primary flexed burial, possibly dating to the Araquinoid period occupation (Dorst 2008). This individual exhibits the second highest $^{87}Sr/^{86}Sr$ ratio (0.7111) recorded to date amongst prehistoric Antillean skeletal collections. A frog-shaped ornament, possibly made of chlorite, found in association with burial F291 may have an exotic (Amazonian) origin (Boomert 1987) although the provenance of this specimen has yet to be determined with certainty.

7.4.5 Patterns of Paleomobility: dietary patterns

For a large number of individuals in this study carbon and nitrogen isotope data are available with which to compare the strontium isotope data. Bone isotope data are available for populations from the sites of Maisabel, Tutu, and Anse à la Gourde (Table 12 and Figure 43). In this section I will make direct comparisons between local and nonlocal groups from these sites based on the available bone isotope data and also assess these in terms of the overall variation in dietary isotope patterns throughout the Caribbean region (Figure 44). The purpose is not so much to attempt to reconstruct patterns of paleo-diet but to assess similarities and differences between locals and nonlocals in terms of general dietary patterns and the potential of dietary isotope data for exploring the potential natal origins of nonlocal individuals.

One possible complication of comparing dietary patterns to patterns of migration as inferred from strontium isotope data are the direct consumption of marine resources. In principle, this could substantially contribute to the overall dietary Sr budget and thus alter the $^{87}Sr/^{86}Sr$ ratios of biogenic tissues shifting them towards a seawater signal. Abundant evidence indicates that most, if not all, indigenous populations of the Antilles consumed marine resources but that there was considerable inter- and intra-societal variation in this regard (deFrance et al. 1996; Keegan and DeNiro 1988; Newsom and Wing 2004; Pestle

2010; Stokes 1998). There is also evidence that salt was an economically, socially, and symbolically important commodity in the ancient Antilles and may have been widely used as a food preservative (Morsink 2012). Sea salt consumption has been identified as a possible source of altered (elevated) $^{87}Sr/^{86}Sr$ ratios amongst prehistoric Maya populations (Wright 2005).

Nonetheless, the Sr isotope results from this study do not support a scenario in which marine strontium (obtained directly from the consumption of marine resources) is a primary or dominant source of dietary strontium. For almost all of the populations studied herein (with the exception of the St. Vincent sites), the $^{87}Sr/^{86}Sr$ ratios of the locally defined population closely match not only those of small terrestrial animals but in many cases also those of plants collected from the site or in the surrounding vicinity. Furthermore, for several populations the $^{87}Sr/^{86}Sr$ ratios of nonlocal individuals fall significantly below both the main cluster of (local) human values but also local biosphere samples. Thus the direct consumption of marine Sr can be ruled out as a cause for these lower $^{87}Sr/^{86}Sr$ ratios as the consumption of marine Sr would elevate $^{87}Sr/^{86}Sr$ ratios in most Antillean contexts. Lastly, as discussed in section 7.2, inputs of marine Sr into local terrestrial ecosystems in the Antilles via rainfall, sea spray, or dry fall are substantial and produce a noticeable effect on the $^{87}Sr/^{86}Sr$ ratios of the Caribbean biosphere at all levels of the local food chains. As previously mentioned, another caveat of this approach is that isotopes in bone generally reflect the last years or decades of life, while dental enamel (the material that was analyzed for Sr isotopes) reflects the early years of life, i.e., childhood. As such a degree of caution is required in the direct comparisons of these different data sets. Dietary information derived from carbon isotope analyses of dental enamel, reflecting dietary intake during childhood is discussed in section 7.6.

For the site of Maisabel, Stokes (1998) has reported carbon and nitrogen isotope results from the analysis of bone collagen and carbon isotope results from the analysis of bone apatite (n=18). Sixteen of these have also been analyzed for Sr isotopes, nine of whom are local and seven are nonlocal. Comparison of the bone collagen data between the locals and nonlocals indicates broadly similar trends for $\delta^{13}C_{co}$ but clear differences in $\delta^{15}N$. The mean $\delta^{13}C_{co}$ for locals and nonlocals is identical (-18.1‰). The mean $\delta^{15}N$ for locals (10.1‰) is enriched by about 1‰ relative to nonlocals (9.2‰) [errors for $\delta^{13}C$ and

$\delta^{15}N$ are typically in the range of ± 0.1‰]. Although this difference seems modest, the difference is significant using Student's t-test ($p=0.014$). This pattern is interesting in regard to the possible origins of the nonlocals at this site and requires further examination at the scale of specific individuals.

The five most depleted $\delta^{15}N$ values from Maisabel all derive from nonlocals. Of these, B23 (an adult female) possesses the most depleted $\delta^{13}C_{co}$ of this population, and B2 (an adult male) possesses the most enriched $\delta^{13}C_{co}$ of this population. Interestingly, these values are also at the far extremes of measured $\delta^{13}C_{co}$ values from Puerto Rico (Pestle 2010). B23's combined $\delta^{13}C_{co}$ and $\delta^{15}N$ values are generally more comparable to those obtained from the site of Paso del Indio. Of the more than two hundred measurements from prehistoric Puerto Rican sites, B2's $\delta^{13}C_{co}$ value is exceeded only by one sample from the site of Punta Candelero (Pestle 2010) and is actually more comparable to values obtained from sites in the northern Lesser Antilles (Norr 2002; Stokes 1998). Two other nonlocal individuals have depleted $\delta^{15}N$ values, B7 and B21, but possess $\delta^{13}C_{co}$ and $\delta^{13}C_{ca}$ bone values that are within the range of local variation.

Interestingly, the dental enamel carbon isotope values of both of these individuals are also extremely depleted in $\delta^{13}C_{ca}$. The degree of offset between their enamel and bone $\delta^{13}C_{ca}$ values (~2.8‰ and 3.7‰, respectively) far exceeds what would be expected based on trophic level effects related to weaning and suggests possible mobility-related changes in diet between childhood and adulthood. In fact, the enamel $\delta^{13}C_{ca}$ value from B21 (-13.1‰) is one of the most depleted measurements ever obtained for the ancient Antilles and suggests relatively minimal contributions of C_4 resources to this individual's childhood dietary energy. This is particularly interesting considering B21's extremely low $^{87}Sr/^{86}Sr$ value (0.7056) which is the lowest value amongst the entire human data set in this study ($n>360$). Another nonlocal, B14 possesses a very low $\delta^{13}C_{ca}$ bone values (-11.7‰), not only relative to Maisabel but to ancient Puerto Rico populations more generally. Compared to the total Puerto Rican data set ($n>200$), B14's $\delta^{13}C_{ca}$ value (and $\delta^{13}C_{ap\text{-}co}$ value) is exceeded only by a few measurements from Paso del Indio, and compared to the overall Antillean data set is more similar to measured values from the Dominican Republic (Stokes 1998).

If we assume that the nearest possible origins are the most likely, then inland or central Puerto Rico may be the natal origin(s) of several of the nonlocals at Maisabel, especially those with relatively depleted $^{87}Sr/^{86}Sr$ values which match biosphere $^{87}Sr/^{86}Sr$ values from the central and southern regions of the island. Nonlocals with inland origins might be expected to consume less marine protein relative to coastal populations such as the local population at Maisabel. If so, this might explain the observed pattern of somewhat depleted $\delta^{15}N$ values amongst certain nonlocals (the possible inland migrants) at Maisabel relative to the local group at this site. However, it should be noted that other factors might be affecting this particular pattern, for example this may also reflect temporal variation in dietary patterns as the majority of the nonlocals at Maisabel date to the earlier period. The mean $\delta^{13}C_{ap}$ for locals (-10.0‰) and nonlocals (-9.7‰) are within analytical error, indicating relatively little difference between these groups in terms of the average carbon isotope compositions of whole diets. Additionally, comparisons with the range and variance of measured $\delta^{13}C_{co}$, $\delta^{13}C_{ap}$, and $\delta^{15}N$ in the Caribbean indicate that some of the nonlocals at Maisabel may have non-Puerto Rican origins.

For the site of Tutu, Norr (2002) reported carbon and nitrogen isotope results from the analysis of bone collagen and carbon isotope results from the analysis of bone apatite (n=25). Twenty of these individuals have also been analyzed for Sr isotopes, including 14 locals and six nonlocals. Comparisons of these stable isotope values indicate very similar patterns for locals and nonlocals at this site. The mean $\delta^{13}C_{co}$ for locals is -15.4‰ and for nonlocals -15.7‰. The mean $\delta^{15}N$ for locals is 12.4‰ and for nonlocals is 11.5‰. The mean $\delta^{13}C_{ap}$ for locals is (-10.4‰) and nonlocals (-10.7‰). Student t-tests of these results indicate no significant differences between locals and nonlocals for any of these three data sets: $\delta^{13}C_{co}$ (p=0.684); $\delta^{15}N$ (p=0.121); $\delta^{13}C_{ap}$ (p=0.359).

Exploring the relationships between nonlocals and dietary practices at the scale of individuals highlights some interesting patterns. Two nonlocal individuals, T4 and T31 (both adult females) have the most depleted $\delta^{15}N$ values and also two of the most depleted $\delta^{13}C_{co}$ values amongst this population. Of these, T4's combined $\delta^{15}N$ and $\delta^{13}C_{co}$ values fall in between the main clusters of values from the Lesser and Greater Antilles. T31's $\delta^{15}N$ and $\delta^{13}C_{co}$ values clearly are outside the absolute range of values for the Lesser Antilles and are most similar to those obtained from Puerto Rican populations. Another individual from Tutu, T26 (also an adult female) has a similarly depleted $\delta^{13}C_{co}$ value but a $\delta^{15}N$ that is similar to the local population at this site. All three of these individuals also have relatively low $^{87}Sr/^{86}Sr$ ratios that are very similar to biosphere $^{87}Sr/^{86}Sr$ ranges from Puerto Rico, indicating that this island could be the origin of one or all of them. A fourth nonlocal from Tutu, T38 (an adult male) has the most enriched $\delta^{13}C_{co}$ value from Tutu (-12.9‰) and one of the most enriched $\delta^{13}C_{co}$ values in the entire Caribbean and also an extremely low $\delta^{13}C_{ap-co}$ value. T38's combined $\delta^{13}C_{co}$, $\delta^{13}C_{ap}$, and $\delta^{15}N$ values are distinct from the rest of the Tutu population (both locals and other nonlocals) and are most similar to those obtained reported for the Bahamas, Anguilla, and Grande-Terre (Guadeloupe). However, T38's $^{87}Sr/^{86}Sr$ value (0.7087) is probably too low for an origin in any of these places which generally possess higher biosphere $^{87}Sr/^{86}Sr$ ranges (~0.7090-0.7092). It is possible that T38's natal origin is in an area with similar dietary (but unreported) dietary isotope patterns as these islands but somewhat lower biosphere $^{87}Sr/^{86}Sr$ ranges, for example possibly some of the composite islands of the northern Lesser Antilles.

For the site of Anse à la Gourde, Stokes (1998) and de Vos (2010) [see also (Laffoon and de Vos 2011)] reported carbon and nitrogen isotope results from the analysis of bone collagen (n=58) and carbon isotope results from the analysis of bone apatite (n=21). Of the bone collagen samples, 49 have also been analyzed for Sr isotopes, including 36 locals and 13 nonlocals. Analyses of the stable isotope data indicate very similar dietary patterns between locals and nonlocals for this population. The mean $\delta^{13}C_{co}$ for locals is -14.7‰ and for nonlocals -14.9‰. The mean $\delta^{15}N$ for locals is 11.0‰ and for nonlocals is 10.9‰. Of the bone apatite samples, 17 have also been analyzed for Sr isotopes, including 11 locals and six nonlocals. The mean $\delta^{13}C_{ap}$ for locals is (-8.5‰) and nonlocals (-8.2‰). Student t-tests of these results indicate no significant differences between locals and nonlocals for any of these three data sets: $\delta^{13}C_{co}$ (p=0.561); $\delta^{15}N$ (p=0.732); $\delta^{13}C_{ap}$ (p=0.687).

There are, however, some correlations between diet and locality as certain nonlocals at Anse à la Gourde also possess distinct carbon and nitrogen isotope values. For example, individual F2215 (an adult female), has the most depleted $\delta^{13}C_{co}$ value and the second most depleted $\delta^{15}N$ value amongst this population. F2215's $\delta^{13}C_{co}$ value is at the extreme of the range of variation for the Lesser Antilles and is in fact more comparable to values obtained from the Greater Antilles, especially Puerto Rico. A Puerto Rican origin is also possible for this individual based on her $^{87}Sr/^{86}Sr$. No $\delta^{13}C_{ap}$ bone measurement is available for this individual, although her $\delta^{13}C_{ap}$ enamel value is similar to the local population.

Another nonlocal individual, F311 (also an adult female), has the most enriched $\delta^{13}C_{ap}$ value and highest $\delta^{13}C_{ap-co}$ value amongst this population. In fact, F311's $\delta^{13}C_{ap}$ value is one of the highest values recorded to date in the Antilles. Although a few similarly enriched values have been obtained from Puerto Rican individuals, F311's $\delta^{13}C_{co}$ value is outside of the range of variation for Puerto Rico. Significantly, F311's enamel $\delta^{13}C_{ap}$ value (-11.1‰) is substantially more depleted than her bone value (-6.0‰) and is quite similar to the local population at Anse à la Gourde. This pattern suggests not only a profound change in dietary practices between childhood and adulthood but also that during childhood her diet was more similar to the local population than during adulthood. Another interesting fact to note about individual F311 is that she was interred with a bead apron consisting of over 1000 drilled shell beads and is the only individual from this burial assemblage (or from anywhere in the Antilles) that has been discovered with such a grave inclusion. Since there is no evidence for local production of these types of beads at this site, this apron has been interpreted as a foreign import (Lammers-Keijsers 2007).

Table 12: Comparisons between locality and diet for three prehistoric Caribbean populations

Note: data sources are- 1) Stokes 1998; 2) Norr 2002; 3) Laffoon and de Vos 2011; 4) Pestle 2010; 5) Antón 2008; 6) Krigbaum et al. in press; 7) St. Christopher's National Trust- unpublished archival data

Island	Site	Group	$\delta^{15}N_{co}$	$\delta^{13}C_{co}$	$\delta^{13}C_{ap}$	$\Delta^{13}C_{ap-co}$	source
			mean	mean	mean	mean	
Puerto Rico	Maisabel	All	9.7	-18.1	-9.9	8.2	1
		locals	*10.1*	*-18.1*	*-10.0*	*8.0*	1
		nonlocals	*9.2*	*-18.1*	*-9.7*	*8.4*	1
St. Thomas (USVI)	Tutu	All	12.2	-15.5	-10.5	5.0	2
		locals	*12.4*	*-15.4*	*-10.4*	*5.0*	2
		nonlocals	*11.5*	*-15.7*	*-10.7*	*5.0*	2
Grande-Terre (Guad.)	Anse à la Gourde	All	10.9	-14.8	-8.4	6.4	1,3
		locals	*11.0*	*-14.7*	*-8.5*	*6.3*	1,3
		nonlocals	*10.9*	*-14.9*	*-8.2*	*6.7*	1,3
Bahamas	multiple	All	9.8	-13.4	-10.8	2.6	1
La Tortue (Haiti)	Manigat Cave	All	8.7	-16.5	-9.9	6.6	1
Dominican Republic	Juan Dolio	All	11.9	-17.1	-12.5	4.6	1
	Boca del Socco	All	11.9	-18.0	-11.9	6.2	1
Puerto Rico	Punta Candelero	All	9.9	-17.5	-8.3	9.2	4
	Paso del Indio	All	9.8	-19.1	-9.4	9.7	4
	Tibes	All	9.5	-17.6	-8.6	9.0	4
	Rio Tanamá	All	9.1	-19.6	-10.5	9.1	5
Anguilla	multiple	All	10.1	-14.4	-10.7	3.7	1
Saba	multiple	All	10.8	-15.7	-11.0	4.7	1
St. Martin	Hope Estate	All	10.4	-15.7	-10.8	4.9	1
La Desirade (Guad.)	Petite Riviere	All	10.3	-14.1	-8.2	5.9	1
St. Lucia	Grande Anse	All	12.4	-16.3	-8.1	8.3	1
Carriacou	Grand Bay	All	11.1	-12.8	-8.6	4.1	6
Grenada	Pearls	All	12.6	-17.0	-13.0	4.0	1
St. Kitts	Bloody Point	All	11.0	-15.3	-9.9	5.4	7

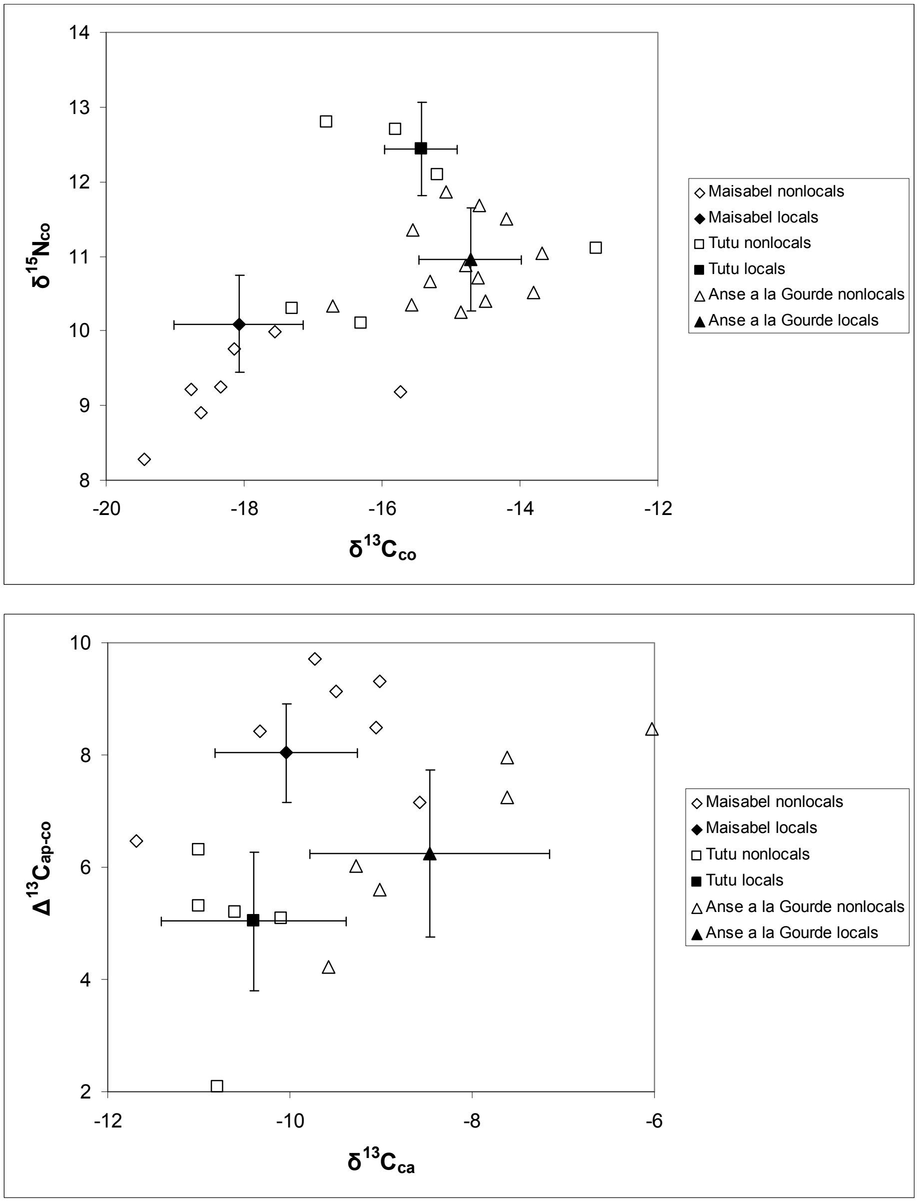


Figure 43 Diagrams of bone $\delta^{13}C$ and $\delta^{15}N$ data from 3 populations included in this study.

A) $\delta^{13}C_{co}$ and $\delta^{15}N_{co}$; B) $\delta^{13}C_{ap}$ and $\Delta^{13}C_{ap-co}$. Note: The symbols for nonlocals represent isotope values of individual samples and the symbols for locals represent the mean ± standard deviation (1σ) of the local samples. Carbon and nitrogen isotope data are from Laffoon and de Vos 2011; Norr 2002; Stokes 1998.

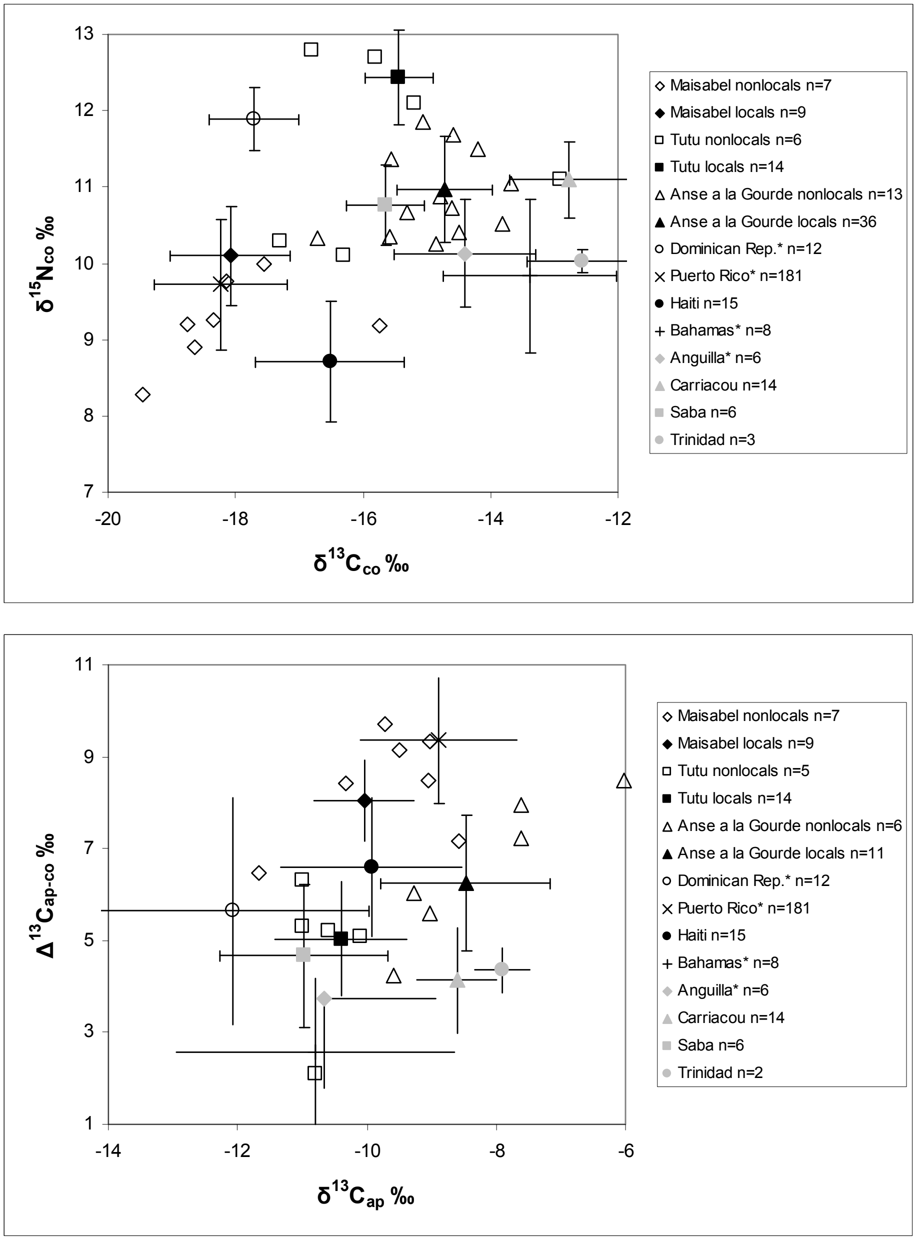


Figure 44 Diagrams of bone $\delta^{13}C$ and $\delta^{15}N$ data from prehistoric Caribbean populations.

A) $\delta^{13}C_{co}$ and $\delta^{15}N_{co}$; and B) $\delta^{13}C_{ap}$ and $\Delta^{13}C_{ap\text{-}co}$. The symbols for nonlocals = isotope values of individual samples and the symbols for locals = the mean ± standard deviation (1σ) of the local samples; * = samples pooled from multiple sites. isotope data are from- Krigbaum et al. in press; Laffoon and de Vos 2011; Norr 2002; Pestle 2010; Stokes 1998.

7.5 Assessing Human Dental Enamel Carbon and Oxygen Isotope Results

As previously mentioned, the promising provenance results obtained from strontium isotope analyses of human dental enamel from the Caribbean led to the exploration of the utility of other isotopes for the study of paleomobility in the Caribbean (Laffoon et al. 2012b). A subset of our total human sample population was analyzed for carbon and oxygen isotopes with the aim of assessing whether sufficient spatial variation of ^{18}O exists within this region to infer ancient migrations and to explore the usefulness of both ^{18}O and ^{13}C for investigating the nonlocal origins of several specific individuals that were determined to be nonlocal based on Sr their isotope values and other evidence for foreign origins.

The oxygen isotope results from archaeological human dental enamel in the Caribbean display relatively little variation as a whole. In general, despite minor differences in δ^{18}O between different islands, the intra-population variance is nearly as large as the inter-population variance and is not substantial relative to other potential sources of error (e.g., temporal variation in climatic and hydrological conditions, weaning effects, and various other cultural practices) influencing the δ^{18}O of consumed water (Knudson 2009). Overall, these patterns suggest that the analysis of δ^{18}O in archaeological teeth from the Antilles may be potentially more useful for the identification of individuals immigrating from outside of the Antilles (and assessments of their possible origins) than as a tool for tracking intra-Caribbean mobility.

Published δ^{18}O data from the Caribbean (both local and African born) and Mesoamerica were compiled to compare with our Antillean data set and to assess intra- and inter-regional variation (Table 13, Figures 45 and 46). Published δ^{18}O results from archaeological human dental remains from Caribbean contexts are limited to one study of the slave cemetery of Newton Plantation, Barbados (Schroeder et al. 2009). These results are of particular interest to our research in that they provide a baseline of δ^{18}O ranges in the Antilles although comparisons between the data sets must be done with caution owing to several caveats concerning temporal, spatial and cultural sources of δ^{18}O variation. The Newton Plantation population dates to a later time period (ca. 17th to 19th centuries) than our sample set (ca. 6th to 16th centuries). Barbados is also a geographic outlier relative to the rest of the Antilles as it is not actually in the Caribbean Sea but in the Atlantic Ocean approximately 100 kilometers east of the southern Lesser Antilles. Additionally, large cultural differences may be expected between a British-controlled sugar plantation population and pre- and proto-historic Amerindian communities in terms of weaning ages and/or the storage, processing, and consumption of imbibed water sources.

Table 13: Summary of human enamel $\delta^{18}O$ and $\delta^{13}C$ data from Caribbean archaeological populations

Note: * does not include outliers; † indicates data from Schroeder et al. (2009).

Site	**Region**	**Population**	**n**	**$\delta^{18}O_{ca}$ ‰**	**$\delta^{13}C_{ca}$ ‰**
				Mean (range)	*Mean (range)*
Chorro de Maíta*	Cuba	Antillean	9	-2.7 (-3.3 to -2.0)	-12.2 (-12.9 to -11.4)
Punta Macao	Dom. Rep.	Antillean	5	-2.3 (-2.8 to -1.8)	-13.1 (-14.2 to -12.4)
Maisabel	Puerto Rico	Antillean	5	-2.0 (-2.9 to -1.1)	-12.1 (-13.1 to -11.10
Tutu	St. Thomas	Antillean	5	-2.4 (-3.1 to -1.8)	-11.3 (-12.1 to -9.3)
Kelbey's Ridge 2	Saba	Antillean	5	-2.3 (-2.7 to -2.0)	-11.7 (-12.8 to -9.9)
Anse à la Gourde	Guadeloupe	Antillean	7	-2.1 (-2.8 to -1.3)	-11.2 (-12.1 to -10.8)
Lavoutte	St. Lucia	Antillean	5	-2.8 (-3.4 to -2.0)	-11.0 (-12.0 to -9.1)
Manzanilla	Trinidad	Antillean	5	-2.8 (-3.3 to -2.1)	-9.1 (-12.5 to -7.2)
All sites (pooled)	Antilles	Antillean	46	-2.5 (-3.4 to -1.1)	-11.5 (-14.2 to -7.2)
Newton Plantation	Barbados †	Barbadian	18	-4.3 (-5.5 to -3.5)	-10.5 (-12.4 to -8.8)
Newton Plantation	Barbados †	African	7	-5.8 (-6.2 to -5.4)	-16.0 (-19.9 to -10.6)
El Chorro de Maíta	Cuba	CM45	1	-5.4	-5.1
El Chorro de Maíta	Cuba	CM72B	1	-3.7	-3.7

Based on the results of multiple isotope analyses and skeletal indicators of foreign cultural practices (African-style dental modification) the Newton Plantation population has been divided into first and later generation groups (Schroeder et al. 2009). The mean $\delta^{18}O_{ca}$ from the Barbadian born group is -4.3‰ and ranges from -5.5‰ to -3.5‰ (n=18). The mean $\delta^{18}O_{ca}$ of the proposed African-born group is -5.8‰ and ranges from -5.4‰ to -6.2‰ (n=7). Clearly, the Barbadian born individuals are less depleted in $\delta^{18}O$ relative to the African born individuals with almost no overlap in $\delta^{18}O$ values.

Despite their broadly similar $\delta^{18}O$ values, Schroeder and colleagues (2009) have proposed that the first-generation, forced migrants interred at Newton Plantation originated from several different regions within Africa, based primarily on their highly variable $^{87}Sr/^{86}Sr$ signatures.

In comparison with our $\delta^{18}O_{ca}$ data set, the Barbadian-born population at Newton Plantation is relatively depleted in $\delta^{18}O_{ca}$ (Schroeder et al. 2009). The cause of these differences is unknown but may be related to differences in precipitation patterns between Barbados and the rest of the Antilles. The mean $\delta^{18}O_{ca}$ of the trimmed data set from this study (minus three outliers) is -2.4‰, which is a difference of -1.9‰ compared to the locally born population at Newton Plantation, with no overlap in the ranges of values. Nonetheless, the $\delta^{18}O_{ca}$ values of the African born immigrants at Newton Plantation are potentially useful for assessments of the natal origins of the African individual from El Chorro de Maíta, Cuba (CM45). The $\delta^{18}O_{ca}$ value of CM45 is -5.4‰, falling within the range of values amongst the African-born individuals from Newton Plantation.

Large data sets of $\delta^{18}O$ results from the analyses of archaeological human teeth and bone from Mesoamerica have been published in recent years (Price et al. 2007b; Price et al. 2010; Schwarcz et al. 2010; White et al. 1998; White et al. 2002; White et al. 2007; Wright and Schwarcz 1998, 1999; Wright 2004; Wright et al. 2010). Available $\delta^{18}O$ data from Mesoamerica have been derived from the analyses of bone and enamel phosphate. Here we report enamel carbonate values and approximate carbonate equivalents of phosphate oxygen values as reported by Price and colleagues (Price et al. 2010) and Wright and colleagues (Wright et al. 2010). In Mesoamerican skeletal remains, $\delta^{18}O_{ca}$ values vary from roughly -10‰ to >0‰ (relative to PDB) with lower values found amongst populations from the Pacific coast and Central Highlands of Mexico and higher values from lowland Mesoamerica, such as northern Guatemala and Belize. This range of $\delta^{18}O_{ca}$ values (>10‰) is substantially larger than, and entirely encompasses, the relatively small range of (local) Antillean $\delta^{18}O$ data (~2.3‰) from this study (excluding three outliers). At finer spatial scales, the Antillean $\delta^{18}O$ data more closely match the values obtained from lowland Mesoamerica. The nearest match with the Antillean $\delta^{18}O$ data set in terms of mean and ranges is lowland Belize, although considerable overlap also exists with many populations from lowland areas and the Gulf Coast.

The available $\delta^{18}O$ data sets from Mesoamerica can be used to explore the possible Mesoamerican origin of individual CM72B from El Chorro de Maíta, Cuba. Comparison of CM72B's $\delta^{18}O$ value of -3.7‰ with reported $\delta^{18}O$ ranges from various regions of Mesoamerica further constrains the possible natal origins for this individual. Published $\delta^{18}O_{ca}$ (and $^{87}Sr/^{86}Sr$ isotope) data from several major sites in ancient Mesoamerica illustrate some of the broad spatial patterns of isotopic variation in this region (Price et al. 2007b; Price et al. 2010; Wright 2004; Wright et al. 2010). Central Highland sites in the relatively higher and drier areas of Mexico such as Teotihuacán possess more negative $\delta^{18}O_{ca}$ (<-6‰) while Southern Highland sites such as Kaminaljuyú and Copán possess more intermediate $\delta^{18}O_{ca}$ (roughly -3.5‰ to -6‰). Lowland sites like Tikal possess less negative $\delta^{18}O_{ca}$ (>-4‰) relative to sites in the highlands. On the one extreme, there is no overlap between CM72B's $\delta^{18}O$ value and the $\delta^{18}O$ ranges of any populations from the Central Highlands or Pacific Coast regions, which are all relatively depleted in ^{18}O. On the other extreme, $\delta^{18}O$ ranges in the lowland areas such as Belize and the Petén are relatively more enriched in ^{18}O and similar to the Antillean range, which is not surprising given their overall similarities in latitude, altitude, and temperature and rainfall regimes. However, on the basis of $\delta^{18}O$ values alone many other sites and regions within Mesoamerica cannot be eliminated as a potential origin(s) for individual CM72B.

The consideration of $^{87}Sr/^{86}Sr$ data can further constrain the potential origins of individual CM72B, as Mesoamerica is one of the more extensively mapped regions of the world in terms of both human and biosphere $^{87}Sr/^{86}Sr$ variation (Buikstra et al. 2004; Hodell et al. 2004; Price et al. 2000; Price et al. 2006; Price et al. 2008; Thornton 2011; White et al. 2007; White et al. 2009; Wright 2005; Wright et al. 2010). While the $\delta^{18}O$ data permits the elimination of most of western and southern Mesoamerica as potential areas of origin, the $^{87}Sr/^{86}Sr$ value from CM72B (~0.7075) is also too elevated for an origin in the Central or Southern Highlands, which generally possess much lower $^{87}Sr/^{86}Sr$ (<0.706). On the other hand, the $^{87}Sr/^{86}Sr$ value from CM72B is too low for an origin in the Northern Lowlands, which generally possesses more elevated $^{87}Sr/^{86}Sr$ (>0.708) (Hodell et al. 2004; Price et al. 2010). The combination of these two independent sets of isotope data (^{18}O and $^{87}Sr/^{86}Sr$) narrow down the possible origins of

CM72B to a smaller portion of Mesoamerica, roughly representing the Southern Maya Lowlands, a conclusion that is also consistent with comparisons of her style of dental modification to documented patterns amongst the ancient Maya (Romero Molina 1986) [see also discussion in (Valcárcel Rojas et al. 2011)].

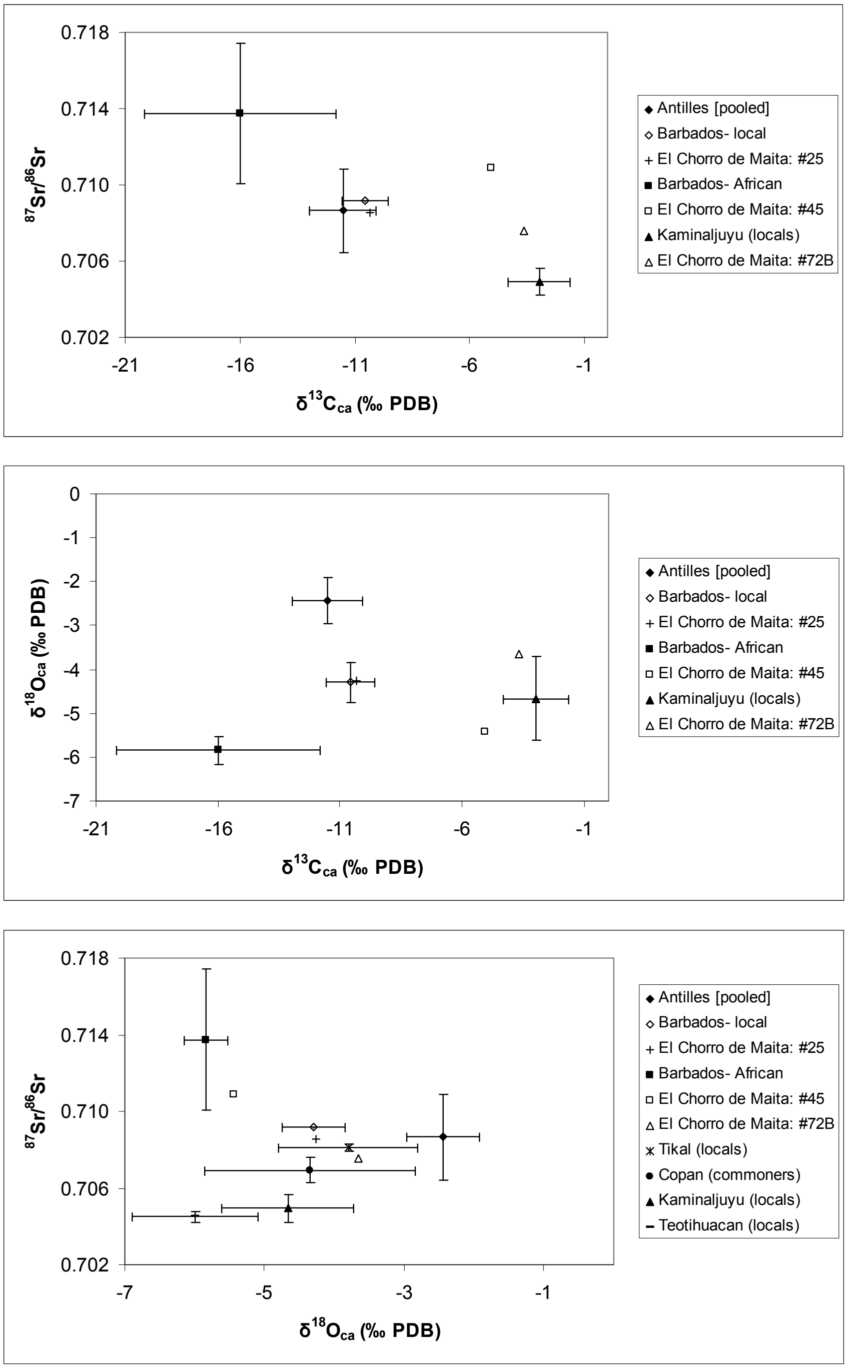


Figure 45 Diagrams of enamel $^{87}Sr/^{86}Sr$, $\delta^{13}C_{ca}$ and $\delta^{18}O_{ca}$ data from this study compared with other archaeological populations from Barbados and Mesoamerica.

A) $\delta^{13}C_{ca}$ and $^{87}Sr/^{86}Sr$; B) $\delta^{13}C_{ca}$ and $\delta^{18}O_{ca}$; C) $\delta^{18}O_{ca}$ and $^{87}Sr/^{86}Sr$. Note: Barbadian isotope data are from (Schroeder et al. 2009) and Mesoamerican isotope data are from (Buikstra et al. 2004; Hodell et al. 2004; Price et al. 2000; Price et al. 2006; Price et al. 2008; Thornton 2011; White et al. 1998; White et al. 2007; White et al. 2009; Wright and Schwarcz 1998; Wright 2005; Wright et al. 2010).

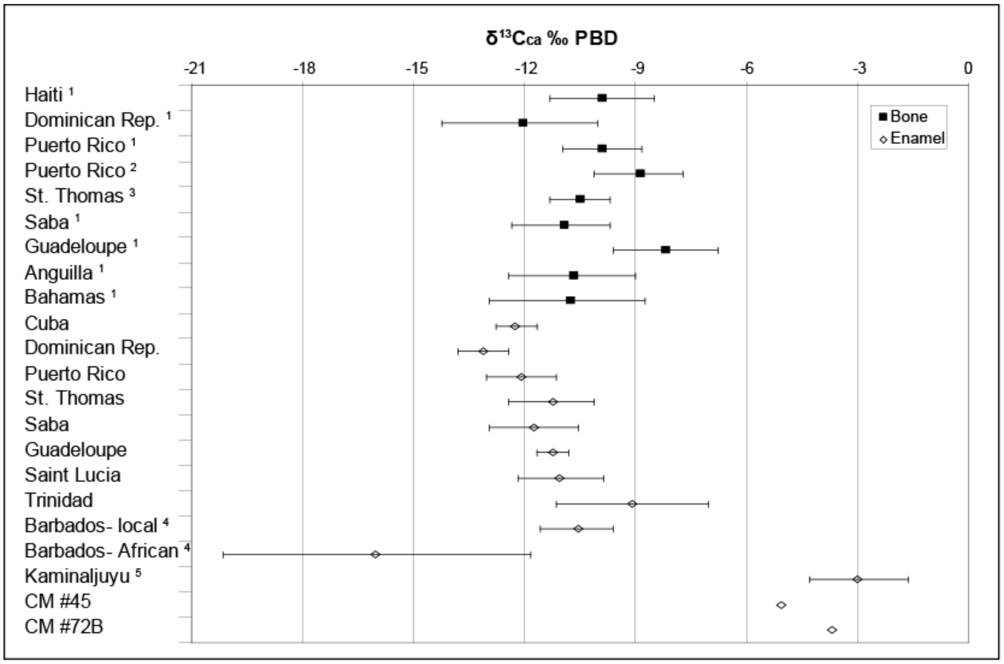


Figure 46 Diagram of enamel $\delta^{13}C_{ca}$ data from this study compared with bone and enamel $\delta^{13}C_{ca}$ data from other archaeological populations in the Caribbean and Mesoamerica.

Note: Isotope data are from [1]Stokes 1998; [2]Pestle 2010; [3]Norr 2002; [4]Schroeder et al. 2009; [5]Wright and Schwarcz 1998; and this study.

To provide a regional comparison, I also compiled published $\delta^{13}C$ from various sites in the Caribbean and Mesoamerica (Figures 45 and 46). Most prehistoric $\delta^{13}C$ data from the Caribbean are derived from the analysis of bone. Owing to the trophic level effect of breastfeeding on $\delta^{13}C$ values from human enamel, caution is required in the comparison of results. The estimated offset in $\delta^{13}C$ (~1‰) from breastfeeding (Richards et al. 2002; Wright and Schwarcz 1998, 1999) is relatively small compared to the overall extent of δ^{13}C variation both within the Antilles, and between the Antilles and Mesoamerica. Antillean bone $\delta^{13}C_{ap}$ values range from approximately -17‰ to -5‰ indicating a relatively high degree of individual variation in the consumption of C_4 resources. However, mean values per population are much more restricted ranging from -12.1‰ to -8.2‰, possibly indicating that the presence of a few individuals with atypical dietary practices are somewhat inflating the general pattern of variation both at individual sites and within the Antilles more generally.

Enamel $\delta^{13}C_{ca}$ results from this study are broadly similar to published bone $\delta^{13}C_{ap}$ results but display reduced intra-population variance possibly owing to much smaller sample sizes. Comparisons amongst populations indicate that bone $\delta^{13}C_{ap}$ values are generally higher than enamel $\delta^{13}C_{ca}$ values from the same site. Direct bone-enamel comparisons could be made for specific individuals and these indicate distinct differences between tissue types (mean absolute pair-wise difference is 2.4‰, n=12). Ten of these individuals have bone $\delta^{13}C_{ca}$ that are higher than their enamel $\delta^{13}C_{ca}$, in some cases the degree of offset is substantial (>3‰). This trend may result from large differences in dietary consumption patterns between adults and children within a local population. Another possibility is that age-related differences in dietary practices are attributable to migration between areas with different dietary practices (Müldner et al. 2011; Schroeder et al. 2009). Nonetheless, the overall pattern for both enamel and bone carbonate δ^{13}C indicates limited C_4 consumption amongst most prehistoric Caribbean populations. In other words, there is little isotopic evidence to indicate that C_4 plants in general, or maize in particular, were primary staple crops in the prehistoric Antilles [see also(Mickleburgh and Pagán Jiménez 2012)].

Mesoamerica is the origin of the domestication of maize and it is in this region that maize was first adopted as a staple crop and the area where intensive maize agriculture has its longest history (Johannessen and Hasdorf 1994; White et al. 200). Mean δ^{13}C values from Mesoamerican populations are consistently higher than Caribbean populations. Various lines of archaeological, iconographic, ethno-historic, and isotopic evidence indicate that maize was clearly a staple crop in this region (Johannessen and Hasdorf 1994). Comparing δ^{13}C results from the Caribbean with the large body of published $\delta^{13}C$ results from Mesoamerica (Price et al. 2010; Tykot 2002; White et al. 200; Wright and Schwarcz 1998, 1999; Wright et al. 2010) highlights several interesting patterns. Despite considerable variation in $\delta^{13}C$ within and between different Mesoamerican populations, and some degree of overlap on an individual basis, most Mesoamerican populations consumed greater amounts of C_4 resources than their contemporary Caribbean counterparts.

Two of the foreign migrants at El Chorro de Maíta, CM45 and CM72B, possess two of the highest enamel $\delta^{13}C_{ca}$ values ever measured amongst Caribbean populations. Individual 72B's $\delta^{13}C_{ca}$ value is -3.7‰, and more comparable to most Mesoamerican populations than to any Caribbean population. Contextualizing this value in reference to $\delta^{13}C$ values obtained directly from dental carbonate from the Maya region permits direct comparisons between data sets without the potential complications of comparing bone versus enamel values. For example, published enamel $\delta^{13}C_{ca}$ from the local population at the site of Kaminaljuyú, Guatemala range from approximately -0.6‰ to -6.9‰ (Wright and Schwarcz 1998; Wright et al. 2010). This does not indicate that CM72B originated from this site or even from Guatemala, but clearly her $\delta^{13}C_{ca}$ value is in much closer agreement to this population than it is to the local population at the site of El Chorro de Maíta, Cuba, or to any other population in the insular Caribbean. As such this result provides further support for the interpretation of this individual as a migrant from the Maya region.

Individual CM45, the proposed African immigrant at El Chorro de Maíta, is not only an outlier in terms of his $\delta^{18}O$ (-5.4‰) but also in terms of his $\delta^{13}C_{ca}$ (-5.1‰). The carbon isotope ratio is extreme not only relative to the rest of the population from this site but also relative to Caribbean populations generally and indicates substantial consumption of C_4 plant resources during childhood. CM45 also possesses $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ values that are comparable to several African immigrants amongst the Newton Plantation slave population (Schroeder et al. 2009). However, his $\delta^{13}C_{ca}$ value is highly enriched relative to the Africans from Newton Plantation (ranging from -19.9‰ to -10.6‰). Despite similarities in $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ ratios between CM45 and many of these African born individuals, their $\delta^{13}C$ values are different and do not support a shared origin. A distinct origin for CM45, relative to the African-born individuals at Newton

Plantation, would not be surprising given the known regional, historical, and cultural differences in their burial contexts. In other words, an African arriving in the early decades of the Spanish colonization of Cuba (ca. 16th century) may be expected to have arrived in the Americas by rather different mechanisms than African slaves brought to an English colonial sugar plantation in Barbados (ca. 17th-19th centuries).

Given the other lines of evidence pointing to an African origin for CM45, I propose millet or sorghum (as opposed to maize) as the most likely C_4 resources accounting for this individual's less negative $\delta^{13}C$ value. Millet and sorghum were staple crops amongst many traditional societies of north-central Africa, including much of the Sahel region (Harris 1976). Interestingly, although millet consumption has been documented in other areas of West Africa, these areas are characterized as rice and vegecultural zones owing to their traditionally greater reliance on rice, root crops and plantains (Carney 2001; Harris 1976). Therefore, an immigrant originating from the millet-sorghum zone of northern West Africa would be expected to possess a higher $\delta^{13}C_{ca}$ value than one originating from other locations in West Africa (Schroeder et al. 2009). Thus the combined isotopic evidence supports an interpretation of West African natal residence and can be used to further constrain this individual's childhood origins. We tentatively propose that individual CM45 may have originated from the millet-sorghum zone of West Africa (based on $\delta^{13}C_{ca}$); did not originate from the area underlain by the West African craton (based on $^{87}Sr/^{86}Sr$); and may have originated from a more inland region (based on $\delta^{18}O$).

7.6 Characterizing Caribbean Paleomobility

Strontium isotope analysis of 360 ancient human remains from multiple sites reported in this chapter demonstrates complex patterns of mobility throughout the Caribbean. Intriguing patterns were revealed in terms of intra- and inter-site variation in the proportions of nonlocals at each site, the demographic composition of local and nonlocal groups, differential mortuary treatment and dietary practices, and the geographic origins of nonlocal individuals. The integration of these results with those provided by carbon and oxygen isotope analysis of 50 ancient human remains has complemented the primary study and confirmed the presence of several foreign migrants originating from distant lands. In the next chapter, I present the major findings and conclusions of the present work in the context of current discussions and debates concerning the prehistory of the Caribbean.

CHAPTER 8 CONCLUSIONS

8.1 Introduction

In this final chapter, I present a summary of the most significant findings of this research project. Subsequently, I discuss the implications of these findings for our understanding of human mobility and migration in the circum-Caribbean with reference to specific models and ongoing debates within the archaeology of the region. This is followed by an assessment of the methodological approaches developed and employed for this research project. Lastly, I conclude by presenting some final thoughts concerning several of the more critical questions provoked by this study, and end this dissertation with a discussion of possible avenues for future research including specific suggestions on how to further develop and expand upon this research.

8.2 Biosphere Strontium Isotope Variation in the Caribbean

One of the most important outcomes of this research project is that there appears to be substantial spatial variation of biosphere $^{87}Sr/^{86}Sr$ within and across the Caribbean region, indicating that it possible to use strontium isotope analyses to infer past human migrations. This outcome may seem self-evident, especially based on the relatively diverse geological settings of the region and the fairly heterogeneous $^{87}Sr/^{86}Sr$ ratios of geological materials in the Antilles. However, the relative contributions of bedrock weathering versus atmospheric sources to the Sr budgets of local terrestrial ecosystems and thus the nature of spatial variation of biosphere $^{87}Sr/^{86}Sr$ in the Antillean biosphere were poorly understood before this study was conducted. The results of the biosphere mapping study have clearly demonstrated that despite highly variable and sometimes substantial contributions of atmospheric Sr to local terrestrial ecosystems in the Antilles, bedrock weathering remains the primary source. As such, biosphere ^{87}Sr/^{86}Sr in the Antilles is spatially variable although with considerable overlap in the ranges of ^{87}Sr/^{86}Sr ratios between some islands and regions.

8.3 Human Strontium Isotope Variation in the Caribbean

In general, there is a high degree of correspondence between the biosphere and human strontium isotope datasets, in terms of the range and dispersion of ratios, and their spatial patterning. The broad similarities between the two datasets are reflected at the scale of the entire region and at the scale of individual sites; although the absolute ranges of ^{87}Sr/^{86}Sr ratios are larger for the human Sr isotope results at both scales. In fact, the human strontium isotope results from the Caribbean display substantial inter- and intra-population variability but (similar to the biosphere data) with considerable overlap between certain populations. The relatively high degree of intra-population variability in human Sr isotope ratios and particularly the presence of extremely high or low ^{87}Sr/^{86}Sr ratios for certain individuals relative both to the main cluster(s) of human ^{87}Sr/^{86}Sr ratios and to the local range of biosphere ^{87}Sr/^{86}Sr ratios, indicates the presence of nonlocals amongst all of the larger burial populations analyzed in this study. Additionally, several individuals possess ^{87}Sr/^{86}Sr ratios that are substantially elevated relative to the total range of biosphere variation for the Antilles, indicating non-Antillean (e.g., mainland) origins.

In total, 74 individuals out of a total of 360 human samples have been identified as nonlocal amongst the skeletal populations analyzed of this study. The absolute and proportional number of nonlocals is highly variable between the different populations of this study. These results suggest that long-distance or inter-island migrations were fairly common in the pre- and proto-historic periods of the Caribbean. Several caveats concerning this pattern merit further discussion. For most of the populations in this study, both local biosphere and human Sr isotope data were assessed to estimate the local range of ^{87}Sr/^{86}Sr and to identify nonlocals. For the sample populations for which there are a large number of samples with consistent and similar results, there is a higher degree of confidence that the overall range of variation is reflected in the resulting dataset. For the sample populations for which available data are limited, the inclusion of future results could theoretically expand the estimated ranges of variation and thus the identification of certain individuals as locals or nonlocals. This is particularly possible for nonlocals with $^{87}Sr/^{86}Sr$ ratios that fall outside, but are not extremely different from, the estimated range of local isotope variation. In contrast, the inclusion of more data will not substantially alter the overall structure and pattern of the current dataset and would be unlikely to change the assessment of locality for the vast majority of individuals in this study. In other words, while it is important to note the possible existence of false positives amongst the individuals identified as nonlocals (i.e., the misidentification of locals as nonlocals), the possibility that there are a substantial number of false positives is somewhat unlikely.

Nonetheless, several specific interpretations and more general conclusions can be proposed both from the overall structure and patterning of the Sr isotope data for each population and through comparative analysis of residential (local/nonlocal) origins relative to other specific parameters such as biological sex, age at death, chronological age, grave goods, and dietary practices. These comparative analyses provide the opportunity to investigate some specific questions concerning patterns of human mobility and migration in the region, specifically in reference to the composition of migrant groups and by extension to the types of migration that may have occurred in the ancient Antilles. Analyses of these patterns also permit me to propose some possible relationships between (im)migrants and local groups, and provide the opportunity to offer some suggestions concerning the implications of these for extant models of migration and mobility in the Caribbean. Furthermore, the integration of multiple lines of evidence, including the structure and distribution of the isotope data presented herein, facilitates an exploration of the origins of certain nonlocal individuals within this study and in some cases specific areas of origin can be tentatively proposed.

8.4 Residential Origins and Biological Sex

Amongst the entire dataset, there are roughly equal numbers and proportions of female nonlocals and male nonlocals. Clearly both males and females were migrating to distant communities. However, at smaller scales there are some potentially interesting trends within this general pattern. For example, there are proportionally more nonlocal males than nonlocal females amongst the (protohistoric) population from El Chorro de Maíta, Cuba and the percentage of nonlocal males is the highest in this study. In contrast, amongst the prehistoric populations in this study (i.e., not including El Chorro de Maíta) there are proportionally more nonlocal females than nonlocal males. This pattern was consistently observed amongst nearly all of the prehistoric populations in this study regardless of the wide variation in their spatial-temporal contexts.

There are multiple possible interpretations of these observed sex-based differences in the proportions of nonlocals. First of all, the observed pattern may simply indicate that multiple types of migration (e.g., cross-community migration; colonization; post-marital residential mobility) by migrant groups composed of both males and females were occurring amongst these populations. Alternatively, if the inferred patterns of residential mobility were primarily the result of post-marital residential relocation then it was not solely structured according to purely matrilocal or patrilocal rules of residence. At face value, this could be taken to provide tentative support for the existence of other forms of residence rules. For example, Keegan and Maclachlan (1989) [see also (Keegan 1991; Keegan et al. 1998)] have proposed that avunculocal residence patterning was characteristic of Taíno elites in the Greater Antilles. Such a system of residence would entail the migration of both males and females from their natal communities at different stages of their life courses and might account for the presence of both male and female nonlocals amongst the different populations in this study. Neil Whitehead has proposed a similar sentiment for the Island Carib and indigenous societies of the Caribbean more generally, “for the Carib, the social basis of chieftancy was the control and distribution of marriage partners. Among these other groups the creation of elite ruling lineages was engineered by the practice of an avunculocal residence rule and so possession of such a residence rule, where combined with evidence as to intermarriage, might be seen as defining a regional polity covering the whole Caribbean" (Whitehead 1995a:96).

The slightly higher proportions of females amongst most of the prehistoric populations studied herein may also indicate that at least in prehistoric times, females were the more mobile sex in terms of long-term or permanent relocation of residence.

One possible explanation for this pattern is that some of the nonlocal females represent captured brides and/or more generally patterns of long-distance, exogamous, marriage exchanges. In fact, the use of marriage exchange between distant communities in the circum-Caribbean region as a political phenomenon (e.g., in the development and maintenance of alliances) embedded within traditional kin-based social structures has been noted by a number of researchers (Boomert 2000; Helms 1988; Helms 1979; Keegan and Maclachlan 1989; Keegan et al. 1998; Whitehead 1995a). The contrasting pattern observed for El Chorro de Maíta, with higher proportions of nonlocal males relative to nonlocal females compared to the other populations, may indicate that the mechanisms and underlying causes of migration may differ for the population of this site relative to the others. Roberto Valcárcel Rojas has proposed that the settlement of El Chorro de Maíta may have been incorporated into the encomienda system of labor exploitation and management characteristic of the early colonial period in the West Indies (Valcárcel Rojas, 2012). If true, some of the nonlocals amongst this population may represent examples of forced migration. The observed pattern is consistent with the reported demographic structure of European and African migrating groups and colonies, which were heavily biased towards adult males particularly in the early decades of the colonization of the Caribbean (Sauer 1966).

In contrast, there is conflicting evidence concerning the demographic composition of migrant groups in general, and forced migrants in particular, within the early colonial period. For example, Sued Badillo has critically examined the extant literature on some of the documents pertaining to slave raids and auctions from this period and concluded that females and children were overrepresented amongst the large populations of Amerindian slaves that were brought to the Greater Antilles in the early decades of the Spanish colonization of the region. In particular he notes that "Three lists of captives sold at public auction are known and from its content the following facts can be established: first, that 90 percent of the captives were women and children, that 70 percent of these were natives of Puerto Rico found in Guadeloupe; and third, that they varied in ages from newborn babies to old women" (Sued Badillo 1995:82). Interestingly, one of the nonlocals from El Chorro de Maíta with proposed mainland origins (72B) is an adult female of Amerindian ancestry, while the only individual of African ancestry within this population (45) is an adult male. Whether or not this is a reflection of a broader pattern of sex-biased migration, the various factors influencing the demographic composition of migrant and local groups and the changes that these underwent throughout the prehistoric era and into the colonial period clearly require more research.

In summary, despite some degree of inter-population differences, the burial populations analyzed for this study generally contain both local and nonlocal males and local and nonlocal females in similar but somewhat variable proportions. At this time, it is not possible, based on the Sr isotope results and the biological sex of these individuals, to determine which types of migration account for these observed patterns. However, some of the patterns concerning the age at death and dating (chronological age) of nonlocals presented in the following sections may shed some light on the likelihood and prevalence of different types of migration, and should permit some initial assessment of the size and composition of migrant groups, the timing of their arrival and, by consequence, the types of migration that best match these observed and inferred patterns.

8.5 Residential Origins and Age at Death

For the entire dataset, a clear correlation exists between natal origins and broad categories of age (adult versus subadult). One possible implication of this pattern is that migration may have been linked to life cycle, life course, or life history processes, including possibly marriage (i.e., if at least some of the nonlocals were exogamous marriage partners). This pattern matches the general pattern revealed through cross-cultural studies of migration, where adults are generally highly overrepresented amongst migrant groups (Manning 2005). In contrast, the identification of at least a few nonlocal juveniles probably indicates that some of the migrating groups may have been composed of families or other kin-based groups (Curet 2005). Migration occurring after marriage (post-marital or marriage-related migration) would be expected to occur at the scale of individuals, while the existence of migrant groups that include subadults (e.g., adults with their dependent children) is more characteristic of other types of migration (e.g., colonization, fissioning, or the cross-community migration of kin-based groups).

The general tendency for adults to be more mobile than subadults amongst the entire dataset also holds true at smaller scales. The differences between adults and subadults in terms of residential origins for most of the populations in this study are not statistically significant. However, this lack of significance at the scale of individual populations is probably the result of small population sizes. For example, the only population with a statistically significant difference in this regard is El Chorro de Maíta, which did not possess substantially larger proportions of nonlocal adults but is simply a larger sample population overall. An additional caveat concerning attempts to compare residential origins with age at death is that the age at migration remains an unknown factor. In other words, nonlocal adults could have migrated anytime after the mineralization of the sampled tooth. For most teeth analyzed in this study, this would roughly reflect infancy to middle childhood (~birth to 8 years of age). Thus it is not possible to determine (at least based on the analysis of a single element) the age(s) at which migration(s) occurred. In fact, even for the nonlocal adults identified in this study, migration could have occurred anytime between approximately middle childhood and death (or even post-mortem, see below).

Although it is difficult, based on demographic data alone, to determine the size and composition of migrating groups and hence to distinguish between different types of migration, the structure and patterning of the Sr isotope data are potentially insightful in this regard. For most of the populations of this study, the $^{87}Sr/^{86}Sr$ ratios of nonlocal individuals were not only distinct from the local population but tended to be highly variable as a group. For example, some of the nonlocals possess $^{87}Sr/^{86}Sr$ ratios that were higher than the local range and others possess $^{87}Sr/^{86}Sr$ ratios that were lower. Furthermore, even amongst these migrants there was substantial heterogeneity of $^{87}Sr/^{86}Sr$ ratios that would preclude similar origins for all of the nonlocals at these sites. In other words, most nonlocals at each site appear to have rather diverse origins and even when nonlocals shared similar $^{87}Sr/^{86}Sr$ ratios, and thus possibly similar foreign origins, these were generally few in number. Therefore, overall, the available evidence seems to be consistent with a general pattern of migration characterized more by the movement of individuals or relatively small migrant groups than by the movement of large migrant groups. This suggests that these migrations may have been the result of a combination of different types of migration including possibly colonization and the cross-community of small groups but that they were likely dominated by the cross-community migration of individuals. These individuals were probably primarily adults migrating as settlers, itinerants, marriage partners, forced migrants, or a combination of these. The chronological evidence presented in the following section also lends some support to this interpretation.

8.6 Residential Origins and Chronological Age

There is a clear and statistically significant difference in the proportions of nonlocals dating to the Early and Late Ceramic Ages for the entire dataset as a whole. Specifically, the proportion of nonlocals was much larger during the Early Ceramic Age. In terms of assessing the chronology of migration(s) at the scale of specific populations, some differences between dating and natal origins were observed. Most notably, for the site of Maisabel, there is also a statistically significant difference between the proportions of nonlocals amongst the Early Ceramic Age and Late Ceramic Age populations. These differences clearly have potential implications for models and hypotheses concerning settlement histories, demography, and patterns of regional interaction at multiple scales (macro-regional and site-level).

At Maisabel, the larger proportions of nonlocals from the earlier component of the burial population would be consistent with the presence of initial colonists within this group or possibly longer migration distances during the early period. As very few of these nonlocals from the early period date to the initial occupation of the site, the latter interpretation is perhaps more likely. If so, this would be in agreement with proposed models of Early Ceramic Age (especially Saladoid) interaction, which was generally more regionally focused possibly owing to low population densities and more dispersed settlement patterns. In reference to the hypothesized transition from a more regional to a more localized focus of exchange systems throughout the course of the Ceramic Age in the Antilles, Boomert notes "While there is no reason to assume that during the Early Cedrosan epoch this system of ceremonial exchange encompassed the entire West Indies, by the end of this era interaction waned, leading to lessening of the previously shared high degree of symbolic communication and, moreover, cessation of the long-distance trade patterns… In Late Cedrosan times trade and interaction took a somewhat less region-wide character, allowing the development of localized interaction spheres" (Boomert 2000:438) [see also (Hofman et al. 2007a; Hofman et al. 2011)]. Under such circumstances, larger migration and marriage distances, might be expected to result simply from relatively larger inter-village distances [see specific discussions in (Keegan and Maclachlan 1989; Keegan 2010; Oliver 2009)]. If patterns of marriage exchange and associated marriage-related mobility were even partly conditioned by demographic factors (Moore 1991), then it would not be overly surprising to find fewer migrants (nonlocals) with less diverse origins amongst populations from later periods. Nonetheless, explorations for both the temporal trend noted for Maisabel and the general lack of such a trend at other sites spanning this time period (e.g., Tutu) clearly merit further research.

As discussed above, except for Maisabel, there is little chronological clustering of nonlocals at each site. This lack of clustering also has implications concerning the possible size and composition of migrating groups and the nature of relationships between donor, migrant, and local communities. For example, in the previous section, I noted that the generally low proportions of nonlocal subadults and the relatively high variance of Sr isotope signals amongst nonlocals did not support a pattern of migration characterized by the movement of larger migrant groups (e.g., colonization or village fissioning). The general lack of chronological clustering, particularly amongst nonlocal individuals with similar $^{87}Sr/^{86}Sr$ ratios, would seem to be the final piece of evidence enabling the refutation of the idea that migrant groups of substantial size characterized patterns of migration in the prehistoric Caribbean (at least for the populations included in this study). In other words, the combination of the strontium isotope results (namely the variance and dispersion of $^{87}Sr/^{86}Sr$ ratios amongst nonlocals), with demographic and chronological evidence is much more consistent with an overall pattern of migration characterized by the movement of individuals (or very small groups) from disparate origins, arriving to the sites in question over several generations or centuries (i.e., a 'trickle model' of prehistoric migration in the ancient Antilles).

To summarize, the overall lack of chronological clustering amongst nonlocals in general suggests that the individuals identified as migrants (amongst each population) do not represent a single episode or event of migration such as the contemporaneous arrival of a colonizing group. The totality of the available evidence seems to indicate that for the most part migrating groups were relatively small and that migration flows can be characterized more as ‘trickles’ than ‘waves’ or even ‘streams’ [see also (Bright 2003)]. Based on the available demographic information, the living (contemporaneous) population(s) of the sites in this study must have been fairly modest (tens, not hundreds, of individual residents). As such, if migrants were spread out over many generations, at most only a few individuals of every generation probably had nonlocal (or foreign) natal origins. Given the relatively small population sizes, the origins of individuals (both local and nonlocal) were probably widely known to most if not all members of the resident community. If so, this has implications for the observed correlations between the origins of specific nonlocals and the associated material remains of their burial contexts, as discussed in the following section.

8.7 Residential Origins and Grave Goods

In general, there are no clear correlations between natal residence and the *presence or absence* of grave goods as noted in the previous chapter. However, there are some very intriguing correlations between nonlocal residence and certain *types* of grave goods, especially at the site of Anse à la Gourde, and to a lesser extent at Manzanilla and El Chorro de Maíta. One possible interpretation of this pattern is that specific foreign materials and/or objects were purposefully interred with nonlocal residents. Interestingly, there also appears to be some tentative evidence for the opposite pattern at the site of Anse à la Gourde, where ceramic vessels placed over the face or upper torso of the deceased are almost exclusively associated with local individuals. There are multiple implications of these patterns in reference to the treatment of nonlocals vis-à-vis locals [see also (Hoogland et al. 2010)]. For example, it is possible that local individuals may have been purposely interred with pottery vessels if these objects were associated with specific crafts or wares of local production, a hypothesis that could be further tested though characterization and sourcing of these specific vessels [see e.g., (Isendoorn et al. 2008) for relevant research in this vein].

The association between specific types of nonlocal materials or artifacts may also symbolize nonlocal origins via associations with specific markers of supralocal status [*sensu* (Peebles and Kus 1977)] or alternatively to more general associations with the far-away, distant, exotic, or esoteric [*sensu* (Helms 1988; Helms 1979); see also (Boomert 2000; Mol 2007) on the roles of primitive valuables in the ancient Caribbean]. The fact that females are primarily associated with exotic grave goods is very interesting and may reflect the role of "women as producers and distributors of high status goods" (Keegan and Maclachlan 1989:91) [see also discussions in (Las Casas 1951; Oliver 2009)] as observed for the Taíno in the contact period. The unique roles of females in Amerindian societies of this region, in terms of their activities concerning mediations between the local and nonlocal, both in the natural and supernatural worlds, may also be reflected in their representations in 'female figurines' that have been documented in a wide variety of contexts in this region during the Late Ceramic Age (Bright 2011; Bullen and Bullen 1970; Hofman and Branford 2011). In reference to the possible position of women amongst Amerindians of the circum-Caribbean, Neil Whitehead notes "Participation in such a [sic] Arawakan macro-polity is also reflected in regard of women's status within an avunculocal marriage system. Such a post-marriage residence rule is held to produce, as it did among the Iroquois, female chiefs or situations where 'clan-mothers' have considerable power, as in the disposal of war captives" (Whitehead 1995a:99).

In terms of other aspects of mortuary treatment, no significant correlations were found between residential origins and burial type (primary/secondary) or burial orientation. Several other lines of evidence would seem to further diminish the possibility that there were systematic differences in the overall mortuary treatment of locals versus nonlocals (with the exception of the types of associated grave goods just discussed). First, preliminary demographic data seems to indicate that the burial populations are most likely not representative of living populations. This is evidenced most clearly by the general absence or under-representation of infants and young juveniles amongst most of the populations in this study. Thus at least some members of the larger community, namely the very young, seem to have frequently received differential treatment in death in terms of the location of their interment. Hoogland (2010) has proposed that his may reflect a different social status for children amongst Amerindian societies of the region. However, the presence of nonlocals within most of the burial populations studied herein provides evidence that a nonlocal natal origin did not preclude burial in the same spatial context as locally-born individuals. Furthermore, many of the nonlocals were buried not only in very close spatial proximity to locals but they were also generally received similar mortuary treatments in terms of burial type, positioning and orientation. However, this overall lack of patterning at the group level may be somewhat misleading, as the Sr isotope evidence seems to clearly indicate that at least for some of the populations in this study the nonlocal individuals possess diverse origins and thus probably should not be pooled into a single group. In fact, patterning between mobility (and origins more specifically) and mortuary treatment, at least in terms of types of grave goods (and their origins), is most apparent at the scale of specific individuals. The similarities in the origins of specific grave goods and the possible origins of the nonlocals with which they are interred are probably not coincidental but the specific mechanisms or processes conditioning such patterning are difficult to assess. The foreign objects and materials found in association with specific nonlocals may be personal possessions (for example brought with them when they migrated); symbols representing their association(s) with specific (and possibly well known) distant locations; general symbols of their status as nonlocals, immigrants, or foreigners; objectification of their status as possessors of esoteric knowledge of distant lands or peoples; and/or material manifestations of social relationships or interactions with other groups, just to name a few (non-mutually exclusive) possibilities.

8.8 Residential Origins and Dietary Practices

The spatial patterning of human collagen carbon and nitrogen isotope values in the Antilles is probably at least partially reflective of biogeographic principles in terms of differential resource availability related to local geographic and ecological conditions

(Stokes 1998). In the Antilles, there is clear spatial structure and patterning of human dietary practices, especially in terms of protein sources and the relative contribution of marine versus terrestrial protein. In general, populations from the smaller islands of the Lesser Antilles and Bahamas have elevated carbon and nitrogen (collagen) values relative to populations from the larger islands of the Greater Antilles (de Vos 2010; Keegan and DeNiro 1988; Laffoon and de Vos 2011; Norr 2002; Pestle 2010; Stokes 1998, 2005). These inter-population differences are distinct with relatively little overlap in the dispersion of these isotope ranges (at 1 sigma).

At the scale of site populations, systematic differences between locals and nonlocals in terms of overall dietary practices was most clear for Maisabel, where nonlocals as a group have a statistically significantly lower mean $\delta^{15}N$ (~1%) than locals. Chronological differences cannot account for this pattern as there are more nonlocals amongst the early group and yet the early group is characterized by higher (not lower) mean $\delta^{15}N$ values. However, the possible causes of this correlation are unclear at present as these may simply indicate that nonlocals retained distinct dietary practices after migration. An alternative, but not mutually exclusive, hypothesis is that at least some of the nonlocals originated from regions with distinct dietary patterns and that the isotopic composition of their bones had not yet equilibrated to the 'local' dietary pattern.

At the scale of pooled groups (locals and nonlocals), there are little or no systematic differences for most of the other populations in this study (with the exception of Maisabel). There are multiple possible interpretations of the lack of such a pattern, including that most of the nonlocals either originated from a region with similar dietary practices or that they had resided amongst the local population long enough for their bone values to isotopically equilibrate to the local pattern. However, at the scale of individuals, for the three populations for which we have extensive dietary isotope data, the most distinctive and extreme carbon and nitrogen isotope values are more common amongst nonlocal individuals. Based on this premise, the geographic origins of certain nonlocal individuals could potentially be explored based on comparisons of their distinctive carbon and isotope values with the range of published dietary isotope values for different sites and islands within the Caribbean.

If this overall pattern is also characteristic of other populations of the region, then it is possible that intra-site (population) variation in dietary practices in the prehistoric Antilles is more homogenous, and inter-site (population) differences more distinct, than previously recognized. In other words, it might be possible to establish the existence of one of the basic tenets of the 'provenance postulate', namely that differences between sources exceed the variation within them (Weigand et al. 1977). The implication of this proposed scenario is that carbon and nitrogen isotope data may also be very useful for human provenance studies by permitting assessments of individual geographic origins, in addition to their traditional use for dietary reconstructions, as has already been demonstrated for colonial period populations in the Antilles (Schroeder et al. 2009) [see also (Sparkes et al. in press)] and has been suggested for prehistoric populations as well (Pestle 2010:350).

8.9 Multiple Isotopes and Individual Origins

The main findings of the carbon and oxygen isotope analyses are summarized in this section. With the exception of a few outliers, $\delta^{18}O_{ca}$ values display limited variability and a large degree of overlap in $\delta^{18}O_{ca}$ values between different islands. The overall pattern of limited intra-Caribbean variation in enamel $\delta^{18}O$ may indicate that oxygen isotope data may be of limited utility for tracking intra-Antillean mobility. However, our understanding of oxygen isotope variation within human skeletal tissues in the Caribbean is still in its infancy and will require additional research on larger sample populations from different regions to determine if the initial lack of spatial patterning revealed by this study holds true at larger scales.

Most $\delta^{13}C$ values reported herein also display limited variability, indicating relatively modest levels of C_4 consumption overall and relatively limited spatial patterning of $\delta^{13}C$ values with the possible exception of Manzanilla, Trinidad. Several individuals from Manzanilla possess slightly elevated $\delta^{13}C$ values indicating a somewhat greater reliance on either marine protein sources or C_4 plant resources (or both) relative to other Antillean populations. The ranges of enamel $\delta^{13}C_{ca}$ in this study were also generally in good agreement with previously published bone $\delta^{13}C_{ap}$ from the Antilles. For a small number of individuals it was possible to make direct comparisons between enamel and bone $^{13}C_{ca}$ values. In general these results are fairly similar with most individuals possessing enamel (childhood) and bone (adult) $^{13}C_{ap}$ values that are within ~2% of each other. However, a few individuals possess much larger differences between their bone and enamel $\delta^{13}C_{ap}$ values. For a few of these nonlocals this difference is larger than what could be explained simply by age-related changes to diet and thus might indicate migration from an area with distinct dietary practices. As a corollary, this may also tentatively indicate a substantial period of local residence during which the bone values equilibrated to the local dietary pattern.

The preliminary oxygen and carbon isotope results additionally seem to indicate that in certain cases these may be successfully employed in the identification of extra-Antillean migrants and the investigation of their possible origins. The strongest case in this regard pertains to three individuals from the site of El Chorro de Maíta, Cuba that are depleted in $\delta^{18}O_{ca}$ and enriched in $\delta^{13}C_{ca}$ relative to local Caribbean populations. The $\delta^{18}O$ signals of two of these individuals (CM72B and CM45) are more consistent with foreign origins than with Antillean origin(s). The extremely high (less negative) $\delta^{13}C$ values of these two individuals (which are two of the highest $\delta^{13}C_{ca}$ values recorded to date for this region) probably indicate a much greater reliance on C_4 resources than is the case for indigenous Antillean populations. Specifically, the very high $\delta^{13}C_{ca}$ value of CM72B is more similar to published $\delta^{13}C_{ca}$ values from Mesoamerican populations and is consistent with an origin from a region where maize was a staple crop and a primary source of dietary carbon, for example amongst the ancient Maya(Johannessen and Hasdorf 1994). The highly elevated $\delta^{13}C_{ca}$ value of individual CM45 on the other hand is enriched in ^{13}C relative to published $\delta^{13}C_{ca}$ of African born slaves from a Caribbean cemetery population in Barbados(Schroeder et al. 2009), and most likely reflects an origin from a region of West Africa where C_4 plants, such as millet or sorghum, were traditional staple crops. In both cases, comparisons of these individuals' $^{87}Sr/^{86}Sr$, $\delta^{18}O$ and $\delta^{13}C$ signatures with published isotope results from Mesoamerican and African-born populations permit more nuanced explorations of their natal origins.

8.10 Summary and Implications of Main Findings

In a recent critical review of interaction studies in Caribbean archaeology, and more specifically concerning migration studies, Curet noted that "the use of the concept of migration tends to be very superficial and normally simply involves the movement of people. At best some speculative discussion about the reasons of migration is included in the discourse. Most of the time arguments shine for the lack of details on the type of migration, who migrated, the steps involved in the process of migration, and the relationship between the parent, migrant, and local communities" (Curet and Hauser 2011:7). In the course of this chapter, I have attempted to address this poignant and timely critique, although the extent to which certain details could be explored was highly variable.

In some cases, I have been able to address some of these concerns and propose tentative (and in some cases admittedly speculative) interpretations. For example, in regard to who migrated (e.g., the size and composition of migrating groups) I have proposed that the totality of evidence is more consistent with the migration of individuals or very small migrant groups. I have also proposed certain types of migrations that would be most amenable to the inferred patterns of migrations, particularly in light of who migrated as these two topics (e.g., who migrated and the types of migration) are inextricably intertwined. In particular, I have suggested that the broad-scale pattern of human migrations identified in this study is probably more consistent with a combination of different types of migration, characterized primarily by multiple cross-community migrations of individuals occurring over long periods of time. Of the different types of cross-community migrants proposed by Patrick Manning, the migrants identified in this study probably comprise a mixture of colonists, sojourners, itinerants, and settlers with a particular emphasis on the latter, i.e., “those who move to join an existing community that is different from their own, with the intention of remaining at their destination” (Manning 2005:9).

Despite a few notable exceptions discussed in the previous sections, the overall pattern for most site populations is of a lack of statistically significant differences between local and nonlocal *groups* in terms of demography, dating, burial practices, or dietary patterns. The absence of systematic differences at this scale is most likely the result of pooling individuals of diverse origins into a single category (nonlocals or locals) and indicates that the individual is probably the more appropriate unit of analysis. In other words, the general lack of correlations probably arises primarily from treating nonlocals for example as a coherent and unit of analysis, which may not be appropriate considering the multiple lines of evidence indicating diverse origins for many nonlocals even within a single burial population. This point may be equally valid for local populations which are potentially more heterogeneous than the Sr isotope results indicate owing to the possible presence of false negatives (i.e., nonlocals possessing similar Sr isotope ratios as the local population) amongst the isotopically local groups, as previously discussed. As such, it is perhaps not overly surprising that at least some of the individuals identified as nonlocal within this study are highly diverse, and in some cases as different from each other as they are from the local population(s) with whom they were ultimately interred (in terms of diet, chronology, and grave goods).

In summary, all of the larger sample populations studied herein contained individuals with nonlocal origins, and in most cases these nonlocal individuals possess relatively variable Sr isotope signals indicating potentially diverse origins. In fact, the general lack of correlation between origins and certain other variables further illustrates the relatively high degree of variation at the individual level. This suggests the presence of plural communities comprised of complex combinations of locally-born individuals and individuals with diverse nonlocal origins amongst the populations of the prehistoric and protohistoric Caribbean region. In some cases, it was possible to explore the possible origins of nonlocals based on a wide variety of evidence. These patterns indicate that migration most likely occurred at multiple scales ranging from intra-island; inter-island; inter-archipelagic, and Mainland-Antillean (possibly including individual origins from the Guiana Shield Region, the Venezuelan littoral, lowland Mesoamerica, and West Africa).

Thus, the high degree of cultural and social diversity or plurality that has been previously noted as a possible characteristic of indigenous peoples of the Caribbean (Whitehead 1995a; Wilson 1993, 2001) may also extend to smaller scales, such that even local communities were comprised of an eclectic mix of locally born residents, and nonlocally born residents who migrated from near and far, and ultimately resided (or at least were interred) in the same settlement or village. The diversity of origins revealed via isotope analysis may reflect the existence of diverse communities in general, which would be consistent with Heckenberger's (Heckenberger 2005:61) characterization of Xinguano (and by extension Arawak) *habitus* "predisposed to reproduce… regional integration (particularly coupled with a social preoccupation with exchange and a cultural aesthetic that places great symbolic value upon foreign things including not only objects, but also relationships, names, songs, dances, among other esoteric knowledge) and a foreign policy commonly characterized by *accommodation and acculturation of outsiders*" [emphasis mine].

Here, I take the opportunity to make several suggestions concerning the possible steps involved in the process of migration and the potential relationships between parent and local communities. In the majority of cases, the Sr isotope ratios of nonlocal individuals are consistent with (although not definitive of) natal origins within the same region or same island as the local populations. For a relatively small number of nonlocals the Sr isotope results indicate extra-insular origins, in that they fall well outside the range of biosphere Sr ratios for the island in question. For a few individuals (two or three from Cuba, one from Trinidad, and possibly one from Aruba) multiple lines of evidence point to likely non-Antillean origins.

In reference to extra-insular (and of course extra-Antillean) origins, migration process must have included travel over open seas, thus necessitating the possession or at least the use of watercraft (and the requisite knowledge of seafaring) as a means of transportation. Possibly, many of the intra-insular migrations may have also utilized watercraft as well, as travel via inland waterways (streams and rivers) and along coasts may have been faster and easier than overland travel in much of the Antilles, particularly in regions with rugged terrain. Some of the types of watercraft used for inter-insular voyages may have been fairly large (Bérard et al. 2011; Callaghan 1993, 1995, 1999; Keegan 1985, 1992), requiring the cooperative efforts of a substantial number of rowers to successfully navigate on open seas. This possibility raises certain questions concerning the size of migrating groups relative to the size of the groups required to operate such vessels. For example, if larger vessels were the sole or primary means of inter-island voyaging then it may not have been possible for smaller migrant groups (such as households, nuclear families, or individuals) to independently decide to migrate in the absence of the cooperation of others. In reference to possible political aspects of emigration, Curet (2005:53) has proposed that “people can vote with their feet”. Although certainly true to some extent, the distance that such a vote can take someone on a small island is somewhat limited and migrations over longer distances requiring sea voyaging might necessitate that ‘people vote with their paddle’. If larger vessels were being used, this would also require the collaboration of larger groups of people and perhaps even the tacit approval and cooperation of elites or members of society with direct access to, or control of, transportation technologies and associated knowledge. In other words, the social logistics and political implications of ancient seafaring in the Caribbean have yet to be fully explored and represent topics deserving of increased research attention [see for example the work of (Altschul and Grenda 2002) in the Channel Islands of southern California].

In reference to relationships of interaction between parent and local communities, if, as I have proposed, most of the migrants identified in this study represent cases of individuals or small groups immigrating into extant communities (e.g., the cross-community migration of settlers, *sensu* Manning), this would presuppose an existing relationship between the parent and local communities based on current anthropological theories on migration. As previously discussed (in chapter two), cross-cultural studies of contemporary cases of migration indicate that people rarely, if ever, migrate to places of which they have no preexisting knowledge (Duff 1998) except possibly in extreme cases of refugees. As such, it is likely that there was some degree or form of social interaction (and direct or indirect knowledge) between parent and local communities prior to migration between them. There may, in fact, be some evidence to support this contention for several of the populations in this study (e.g., the consistency between possible natal origins and the origins of specific grave goods).

There are numerous archaeological implications of these inferred patterns of migration, and the widespread presence of nonlocally born individuals within prehistoric communities of the Caribbean more specifically that are beyond the scope of this dissertation [see e.g., (Curet and Hauser 2011b; Curet 2005; Hofman et al. 2011)]. For example, there are some indications that migrations had an impact on the migrants themselves in terms of adaptation to, or learning of, different dietary, environmental, and perhaps most importantly, social contexts (Rockman and Steele 2003). The arrival of migrants, whether as individuals or groups, also has obvious demographic consequences for both parent and local communities. An example of this is well illustrated by Alistair Bright who noted in reference to Windward Island communities "In this sense, idiosyncratic processes, such as the character of individual immigrants and/or the composition of small migratory groups could have had large seemingly random effects on the composition and diversity of various material culture assemblages throughout the islandscape" (Bright 2011:231). Thus, the potential cultural, material, social, political, economic, and demographic consequences and implications of the migrations discussed herein are many and varied and will require much additional future research to disentangle.

8.11 Methodological Assessment

In this section, I take the opportunity to briefly evaluate four aspects of the methodological approach taken in this study, namely: sample sizes, biosphere mapping, analytical precision, and contextual information. First, in terms of sample sizes, we attempted to include as many individuals as possible for the skeletal populations sampled in this study. This intensive sampling strategy permitted the exploration of patterns of mobility for as much of the burial population(s) as possible and allowed us to avoid extrapolating broader patterns based on a relatively few number of samples from each site (Pestle 2010). This is a potentially important consideration, as partial sampling of site populations could potentially miss a small number of individuals with distinct Sr isotope ratios. As a whole, the human Sr isotope dataset generated for the present work represents one of the largest databases of its kind worldwide and has substantially increased our understanding of human Sr isotope variation in the Caribbean Region.

Second, in terms of the biosphere mapping project (Laffoon et al. 2012a), the overall correspondence between the human and biosphere Sr isotope datasets both as a whole and at the site scale; the degree of spatial variation within the biosphere data; and the lack of correspondence between the geological and biosphere data for some locations and regions have certainly validated the enormous investment of time, energy, and resources invested in this endeavor. In many cases, the interpretation of the human Sr isotope data would not have been possible without the associated biosphere Sr data and in more than a few cases, a reliance on published geological Sr isotope data would have led to different (and apparently incorrect) interpretations and conclusions. Additionally, it could be argued that this aspect of the project has the greatest potential for a broader scientific impact from the perspective that the generated database is potentially useful for a broad array of different types of provenance studies in the region. These include not only implications within the field of archaeology, but also to studies of animal migration, environmental patterns and processes, and even forensic applications.

Third, in terms of analytical precision, the strontium isotope measurements obtained via TIMS have extremely low standard errors relative to the inter-individual, and intra- and inter-population variance of our sample populations. This provides some reassurance that the observed variation is 'real' and not simply an artifact of the analytical method employed. In fact, the small standard errors for individual sample measurements are essentially invisible at the scale of most of the figures included in the present work. Additionally, the relatively low standard deviation of repeat measurements of the international reference standard and the small differences obtained for repeat measurements of a small subset of the samples provide further indications of the overall consistency and reproducibility of the results presented herein. In other words, the extra investment of time required by TIMS measurements (versus other methods) were justified by the greater degree of confidence that can be placed upon the obtained results.

Lastly, our sampling design primarily focused on human skeletal populations for which a broad array of relevant, contextual, archaeological data was available. Nonetheless, there is a high degree of variation in the availability of this information across the different assemblages of this study. It became evident throughout the course of this work that the possibility of deriving nuanced and contextualized interpretations, and drawing inferences more generally, was highly dependent on the quality and quantity of this data. The extent or degree to which possible geographic origins could be explored, and interpretations of patterns of migration proposed, generally co-varied with the amount and degree of detailed information available for the sample populations, and in particular with the availability of relevant data at the scale of individuals. Investigations of possible origins clearly benefited in cases where different lines of evidence (mortuary, osteological, and multiple isotope data) could be integrated. In contrast, these explorations were fairly limited in cases where such data were sparse or unavailable. Nonetheless, the isotope results from the smaller sample populations, for which relatively little contextual data exist provide an important contribution to the development of baseline human strontium isotope variation for this region. I have also included the results from these smaller populations in the present work not only for the sake of general assessments of Sr isotope variation in the region but also in the hope that the acquisition of relevant contextual information in the future may permit a more thorough appraisal of these data.

8.12 Future Research Directions

I conclude this final chapter by offering some proposals for future research directions. In reference to the spatial mapping of biosphere $^{87}Sr/^{86}Sr$ for the circum-Caribbean region, two direct actions can be taken to substantially improve upon the work generated in the course of this study. First, spatial coverage should be greatly expanded in the Antilles themselves. This will require extensive collection and analysis of biosphere samples, particularly from regions and islands that were not included in this study (for example in the northwestern Antilles). Additionally, while fairly robust databases and maps of biosphere $^{87}Sr/^{86}Sr$ now exist for much of the Antilles and Mesoamerica, the spatial variation of biosphere $^{87}Sr/^{86}Sr$ in most of Central America and northern South America is still poorly understood. Furthermore, the development and testing of models of spatial variation of $^{87}Sr/^{86}Sr$ in circum-Caribbean ecosystems that explicitly incorporate multiple sources of strontium to local environments provide the opportunity to improve our understanding of the various parameters influencing the variation of $^{87}Sr/^{86}Sr$ in the biosphere and our ability to predict this variation based on these principles (Bataille and Bowen 2012; Bataille et al. in press).

In reference to obtaining more human isotope data from Antillean contexts, not only of strontium but also of other isotope systems (particularly oxygen but also carbon and nitrogen), some initial proposals can be put forward. First, isotope studies would greatly benefit from expanded temporal coverage. The results generated from this study are heavily biased to the Late Ceramic Age while later (protohistoric and colonial) and earlier (Early Ceramic Age and Archaic) contexts are under- or unrepresented. To date, only a few isotope studies have been conducted on protohistoric and colonial contexts in the Antilles [for notable exceptions see (Laffoon et al. 2012b; Schroeder et al. 2009; Sparkes et al. in press; Varney 2003, 2007)]. This is somewhat surprising, as the current evidence would seem to suggest that these are the very contexts that would be most amenable to study via isotope methods given the known high variability in the geographic origins of migrants during these time periods, the potentially large differences in dietary practices both between the different regions of origin and between them and local Antillean populations, and the proposed rapid changes to Caribbean ecosystems and food-ways associated with the Columbian Exchange (Crosby 2003; Mann 2011; Valcárcel Rojas et al. 2011). Second, to date, skeletal populations from the Antilles that have been analyzed for strontium isotopes are also somewhat unequally distributed spatially. This study represents the first application of this method for most of the islands of the Antilles and many of the islands remain unstudied in this regard.

One recommendation that our research group has already initiated is the analyses of these skeletal collections for non-metric dental traits. Such data are possibly informative of the morphological variation within and between prehistoric populations of the Antilles and thus can be used, in conjunction with isotope data, to assess the biological ancestry of nonlocals with proposed long-distance origins. In fact, previous biodistance studies in this region have revealed a considerable degree of phenotypic heterogeneity amongst the indigenous populations of the Caribbean (Coppa et al. 2008; Ross 2004).

The feasibility of using multiple isotopes, other than strontium, for human provenance studies in the Caribbean formed an explicit component of this research project. Specifically, the preliminary dataset of oxygen isotopes indicates that they may be particularly useful for identifying long-distance migrants originating from outside of this region (Laffoon et al. 2012b). The high degree of spatial clustering of bone stable isotope values and the relatively distinct dietary patterns amongst many of the nonlocal individuals identified in this study seem to indicate the substantial, and largely unexplored, potential of carbon and nitrogen isotope systems for human mobility and provenance studies in the Caribbean region. Several other isotope systems, including lead (Pb) and sulphur (S) also offer much unexplored potential for both paleomobility and provenance studies in this region.

One of the many questions raised by the present study is the timing or age at which migration(s) occurred within the lifetime of a nonlocal individual. More refined estimates of the age(s) at which migration occurred should be possible based on multiple isotope analyses and serial sampling of different skeletal elements from the same individual, for example by comparing an earlier (M1) and later forming tooth (M3). A pilot project utilizing this approach has been initiated and by focusing on individuals that have already been identified as nonlocals (as part of this study) enables time and resources to be used most efficiently.

Lastly, a large number of teeth from larger animals, particularly animal tooth pendants of exotic or non-endemic species, were analyzed in conjunction with the research project presented in this study. The isotope results from this pilot project have shown great promise not only for identifying nonlocal faunal remains and for examining the geographic origins of these social valuables (teeth pendants) but also for inferring patterns of exchange and trade within and between the prehistoric island and mainland communities of the circum- Caribbean region and beyond (Laffoon et al. in prep).

On a final note, throughout the course of conducting this study and presenting the preliminary results to audiences in the Caribbean and beyond, I have been more than gratified by the degree of enthusiasm and the lively discussions generated by this research. I sincerely hope that I have demonstrated some of the potentials and pitfalls of applying isotope analyses to the study of ancient human migrations in the Caribbean, and that this work has provided some insights into the histories of individuals that once inhabited the ancient Antilles.

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SUMMARY

Patterns of paleomobility in the ancient Caribbean were studied through an inter-disciplinary approach using a combination of archaeological, osteological, mortuary, and isotopic data. Samples of human dental enamel from 360 individuals from multiple sites spanning a broad range of geographic and temporal contexts in the Caribbean were analyzed for strontium isotope composition. These results were interpreted in reference to a database of strontium isotope variation for the Caribbean biosphere created especially for this purpose through the analysis of 288 modern and archeological animal and plant samples. These combined strontium isotope datasets contributed to assessments of the spatial patterning of bioavailable strontium isotope variation in the region and to estimations of the local range of strontium isotope variation for the different site populations included in this study. These ranges contributed to determinations of whether individuals were of local or nonlocal origin. These results were then subsequently analyzed to examine inter- and intra-population variation in patterns of migration, with a specific focus on testing possible relationships between residential origins and biological sex, age at death, chronology, grave goods, and dietary practices. Finally, carbon and oxygen isotope analyses of dental enamel were conducted on 50 individuals representing a subset of several of the larger human sample populations to assess the potential of these isotope systems for provenance studies in the Caribbean region and for investigating the origins of suspected long-distance migrants.

The main findings of this research project have greatly increased our understanding of isotopic variation in the region and perhaps more importantly have shed unprecedented light onto the individual life histories of the ancient inhabitants of the Caribbean. First, in reference to the biosphere mapping component of this research project, bedrock weathering appears to be the dominant source of strontium to most local terrestrial ecosystems in the Antilles but substantial contributions of non-geological strontium from the atmosphere and the sea significantly alters bioavailable strontium isotope ratios in many areas of this region, especially in the smaller volcanic islands of

the Lesser Antilles. This tendency greatly reduces the utility of using geological isotope data as proxies for estimating strontium isotope ranges in terrestrial Caribbean ecosystems and highlights the importance of utilizing biosphere isotope data in maritime settings. Second, the employed method was successfully applied to identify nonlocal individuals, who were present amongst each of the larger sample populations included in this study. However, the number, proportion, and origins of the nonlocals are highly variable both within and between different populations. Third, although nonlocals are represented by both females and males, there is a bias observed in migration behavior related to biological sex with a larger proportion of nonlocal females amongst nearly all of the prehistoric sites included in this study. In contrast, the opposite pattern was found at the single protohistoric site that was studied where substantially more males than females were identified as nonlocal. Third, there was also a pronounced age-based component to migration behavior in the ancient Antilles, with consistently greater numbers and proportions of nonlocal adults compared to nonlocal subadults. Fourth, although few clear patterns were revealed in terms of correlations between residential origins and many aspects of mortuary treatment, a very intriguing correlation was demonstrated between the presence of foreign or exotic grave goods and nonlocal individual origins. These types of grave goods were more often associated with nonlocals at a number of sites and were found almost exclusively with nonlocal females at the prehistoric site of Anse à la Gourde, Guadeloupe. Fifth, little chronological clustering was observed amongst the nonlocals at each site such that most nonlocals for whom radiocarbon dates were available were temporally dispersed throughout each site's occupation and thus very few were contemporaneous with each other.

Additionally, few systematic differences in dietary practices were observed between local and nonlocal groups amongst each of the site populations. However, at the scale of individuals, the most extreme bone carbon and nitrogen isotope values were consistently associated with nonlocal individuals. Furthermore, these dietary outliers were also fairly heterogeneous even within a single site population. Given the documented spatial patterning of carbon and nitrogen isotope values amongst the prehistoric populations of the Caribbean, the distinct dietary isotope values of some nonlocals possibly indicate natal origins from islands or regions with divergent dietary practices.

The enamel carbon isotope results provide some initial support for this hypothesis for a few of the nonlocals identified in this study that possess enamel carbon isotope ratios that are very different from their bone isotope values. Nonetheless, in general, both the oxygen and carbon isotope results from ancient Caribbean human enamel samples display limited intra- and inter-population variation with the exception of three nonlocal individuals from the site of El Chorro de Maíta, Cuba. Two of these three individuals had been identified as possibly foreign-born individuals originating from Mesoamerica and Africa based on multiple lines of evidence including distinct burial treatment, and a distinctly modified cranium and dentition for the former and morphological characteristics of the skeleton and a relatively high strontium isotope composition for the former. Both of these individuals also possess enamel oxygen isotope values that are significantly lower than those found amongst archaeological populations from the Caribbean, and enamel carbon isotope values that are extremely elevated relative to prehistoric Caribbean populations. Thus the oxygen and carbon isotope data from these two individuals not only support the initial assessment of their nonlocal origins but these data are also consistent with the proposed regions of origin. Furthermore, these results have also permitted a more detailed exploration of possible natal origins within these larger macro-regions.

Therefore, the totality of the evidence, particularly the dispersed radiocarbon dates and highly variable strontium isotope ratios of most nonlocals, is inconsistent with a model of migration characterized by migration 'events' or 'waves', such as colonizations or migrations of large groups arriving from the same origin. Instead, the combined evidence is more consistent with multiple, cross-community migrations of small groups or individual settlers immigrating from disparate origins into already established communities. In summary, this study has revealed the existence of complex and dynamic patterns of migration and mobility in the ancient Antilles. Despite some degree of variation between the different populations, overall past migrations seem to have been at least partly structured by sex and age; differential origins seem to have had implications for how individuals were treated in death; and most of the studied communities were comprised of individuals with variable origins. Many of these ancient migrants likely originated from within the same island or region where they were ultimately interred, while a smaller yet substantial proportion probably migrated from other islands in the Caribbean, but a few of these individuals were migrants who voyaged from various, distant homelands and contributed to the diversity that characterizes the Caribbean's past and present.

SAMENVATTING

Door middel van een interdisciplinaire aanpak bestaande uit archeologie, osteologie, begravings- en isotopendata onderzoekt deze studie patronen in de paleo-mobiliteit van de Cariben. In totaal is de isotopische compositie van 360 monsters geanalyseerd, welke verschillende sites en een breed scala aan geografische en temporele contexten beslaan.

Deze resultaten zijn geïnterpreteerd met behulp van een database waarin de verschillende gehaltes van strontiumisotopen in de Caribische biosfeer verzameld zijn. Deze is speciaal voor dit doel samengesteld door 288 monsters van moderne en archaeologische flora en fauna te analyseren. Deze gecombineerde strontiumisotopen-datasets werpt licht op de regionale variatie van biologisch aanwezige strontium isotopen en de raming van het lokale bereik van de strontiumisotopische variatie van de verschillende sites die onderdeel zijn van deze studie. De informatie over de lokale variatie van strontiumisotopen is gebruikt om te bepalen of individuen van origine lokaal of niet-lokaal waren. De resultaten hiervan zijn vervolgens vergeleken met (osteo-) archaeologische datasets ten einde inter- en intrapopulatie patronen in migratie te kunnen blootleggen. Hierbij lag de focus op het aantonen van relaties tussen residentiële oorsprong en biologische sekse, leeftijd bij overlijden, chronologie, grafgiften en dieet variatie. Tenslotte is er een koolstof en zuurstof isotopenanalyse van het tandglazuur van een subset van 50 individuen ondernomen om het potentieel van deze isotopische systemen voor herkomstbepaling in het Caribisch gebied te kunnen bepalen en voor het verder onderzoeken van de plaats van origine van vermoedelijke lange-afstand migranten.

De resultaten van dit onderzoek hebben het begrip van isotopische variatie in de regio enorm vergroot, maar, wat belangrijker is, het heeft vooral ook een licht geworpen op de individuele levensgeschiedenissen van de prehistorisch bewoners van het Caribisch gebied. Ten eerste heeft de kartering van het isotopengehalte in de biosfeer laten zien dat verwering van het vast gesteente de hoofdbron is van de meeste lokale, terrestrische eco-systemen, maar dat, zeker op de kleinere vulkanische eilanden van de Kleine Antillen, de toevoeging van niet-geologisch strontium uit de atmosfeer en de zee de ratio van de biologisch aanwezige strontiumisotopen significant beïnvloedt. Dit laatste vermindert het vermogen om, in een maritieme setting, geologische isotopendata te gebruiken als een proxy voor strontiumisotopische variatie in terrestrische Caribische ecosystem en laat het belang zien van het gebruik van isotopendata uit de biosfeer zelf. Ten tweede is deze methode met succes ingezet om niet-lokale individuen te identificeren. Deze zijn aangetoond in elk van de bemonsterde populaties, hoewel het aantal, de verhouding en de origine van de niet-lokale individuen hoogst variabel zijn in en tussen populaties. Ten derde, ondanks dat het bestand van niet-lokale individuen zowel mannen als vrouwen beslaat, is er een waarnembare afwijking in de migratie gerelateerd tot biologische sexe: niet-lokale vrouwen zijn oververtegenwoordigd in bijna alle pre-historische sites in deze study. Het tegenovergestelde hiervan is waargenomen in de enige proto-historische site in het sample, waarin er substantieel meer mannen dan vrouwen zijn geïdentificeerd als zijnde niet-lokaal. Ten vierde is het overduidelijk dat leeftijd van grote invloed is op migratiegedrag in de Antillen. Er zijn consequent grotere aantallen en proporties niet-lokale volwassenen dan niet-lokale jongeren aangetroffen in het sample. Ten vijfde, alhoewel er niet veel correlaties zijn aangetoond met betrekking tot residentiële origine en grafgebruiken, is er een intrigerende samenhang aangetroffen tussen de aanwezigheid van vreemde of exotische grafgiften en een niet-lokale origine. Op een paar sites worden dit type grafgiften vaker geassocieerd met niet-lokale individuen en daarnaast werden, op de site van Anse à la Gourde in Guadeloupe, deze objecten exclusief gevonden bij niet-lokale vrouwen. Ten zesde is er weinig chronologische clustering vastgesteld tussen de niet-lokale individuen op alle sites, zodat, voor diegenen waarvoor radio-koolstof dateringen beschikbaar waren, kan worden aangetoond dat niet-lokale individuen chronologisch verspreid waren en er dus weinigen gelijktijdig dezelfde site bewoonden.

Daarnaast zijn er enkele systematische verschillen in dieet geobserveerd tussen lokale en niet-lokale groepen in de populatie van elk van de sites. Op de schaal van het individu werden de meest extreme koolstof- en stikstofistopenwaardes in het bot geassocieerd met niet-lokale individuen. Deze uitschieters zijn bovendien zelfs redelijk heterogeen binnen een enkele populatie. Gebaseerd op de reeds bekende patronen van de koolstof- en stikstofisotopengehaltes bij de verschillende populaties in de Cariben, kunnen we zeggen dat de verschillende dieet-isotopische waarden van niet-lokale individuen waarschijnlijk duiden op een plaats van geboorte waar voedingsgewoonten verschilden van de plaats van begraving. Voor een paar van de niet-lokale individuen in deze studie kan worden vastgesteld dat de waarde van koolstofisotopen uit het emaille erg verschillen met die uit het bot, wat extra steun biedt voor deze hypothese. Over het algemeen genomen laten de resultaten van de zuur- en koolstofistopen in menselijk emaille niettemin relatief weinig verschillen zien binnen en tussen populaties. De enige uitzondering hierop zijn drie individuen uit de site van El Chorro de Maíta, Cuba. Op basis van meerdere lijnen van bewijs (met name het specifieke grafgebruik, gemodificeerde cranium en gebit bij één en de relatief hoge strontiumisotopisch compositie van de ander) kunnen twee van deze drie individuen worden geïdentificeerd als niet-lokale individuen met een mogelijke herkomst in Midden Amerika en Afrika. Vergeleken met de archeologische populaties uit de Cariben heeft het emaille van deze beide individeen ook een significant lager gehalte zuurstofisotopen en een extreem hoge waarde aan koolstofisotopen. Daarmee bieden de waardes van zuur- en koolstofisotopen niet enkel steun voor de eerste beoordeling van deze individuen als niet-lokaal, maar zijn ze ook consistent met hun voorgestelde regio van herkomst. Daarnaast bieden deze resultaten de ruimte om een meer gedetailleerde verkenning te doen van mogelijke plaats van geboorte binnen deze grotere regio's.

Het totaal aan bewijs, met name de verspreiding in de radio-koolstofdateringen en hoogst variable strontiumisotopen ratios van de meeste niet-lokale individuen, is in strijd met een model dat migratiegolven of "*events*" benadrukt. Het gecombineerde bewijs is in plaats daarvan in overeenstemming met een type mobiliteit wat gekarakteriseerd wordt door meervoudige migraties van kleine groepen of individuele immigranten van uiteenlopende herkomst in reeds bestaande gemeenschappen. Samenvattend: deze studie heeft het bestaan van complexe en dynamische patronen van migratie en mobiliteit in de Antillen aangetoond. Enige mate van variatie daargelaten, is het algemene beeld dat naar voren komt dat migraties over het algemeen gedeeltelijk gestructureerd werden door sekse en leeftijdsverschillen, verschillen in de herkomst leidde tot een verschillende behandeling van het individu bij begraving en de meeste van de bestudeerde gemeenschappen bestonden uit individuen van variabele herkomst. Veel van de migranten hadden waarschijnlijk een herkomst binnen hetzelfde eiland of regio waarin zij uiteindelijke begraven werden. Weer anderen waren afkomstig van eilanden in de Cariben zelf. Een paar van de migranten waren echter reizigers uit verscheidene, ver afgelegen thuislanden en droegen daarmee bij aan de diversiteit die karakteristiek is voor het vroegere en hedendaagse Caribische gebied.

APPENDICES

Table 14: Appendix A – Biosphere sample information and strontium isotope results
Note: d = dynamic mode; s = static mode.

Sample ID	Site	Region	Cat.	Type	d/s	$^{87}Sr/^{86}Sr$	± 2 S.E.
3201	Governor's Office	Anguilla	plant	grass	s	0.709078	0.000010
3206	Lower South Hill	Anguilla	plant	grass	s	0.709219	0.000009
PN194	Sandy Ground	Anguilla	rodent	enamel	d	0.708721	0.000009
PN227	Sandy Ground	Anguilla	rodent	enamel	d	0.708777	0.000018
PN268	Sandy Ground	Anguilla	rodent	enamel	d	0.709066	0.000005
PN224	Sandy Ground	Anguilla	rodent	enamel	d	0.709083	0.000010
3202	Sandy Hill	Anguilla	plant	grass	s	0.709050	0.000009
PN 410	Shoal Bay East	Anguilla	rodent	enamel	d	0.709140	0.000011
PN364	Shoal Bay East	Anguilla	rodent	enamel	d	0.709148	0.000016
PN406	Shoal Bay East	Anguilla	rodent	enamel	d	0.709163	0.000008
3205	Shoal Bay East	Anguilla	plant	grass	s	0.709247	0.000011
3203	Windward Point	Anguilla	plant	grass	s	0.709171	0.000011
B5 34-37	Brook Site	Antigua	rodent	enamel	d	0.708861	0.000033
3306	Dow’s Hill	Antigua	plant	grass	s	0.709020	0.000010
3305	Dow’s Hill	Antigua	snail	shell	s	0.709134	0.000006
3303	English Harbour	Antigua	snail	shell	s	0.708820	0.000012
3308	Golden Grove	Antigua	plant	grass	s	0.708339	0.000011
3301	Lyons Estate	Antigua	plant	grass	s	0.708305	0.000010
26-34	Mill Reef	Antigua	rodent	enamel	d	0.708509	0.000007
107/108B	Mill Reef	Antigua	rodent	enamel	d	0.708534	0.000008
37-41	Mill Reef	Antigua	rodent	enamel	d	0.708679	0.000011
3307	Morris Bay	Antigua	plant	grass	s	0.707893	0.000010
3304	Muddy Bay	Antigua	snail	shell	s	0.708333	0.000011
3302	Piccadilly	Antigua	plant	grass	s	0.707752	0.000010
3309	Stadium	Antigua	plant	grass	s	0.708483	0.000009
3904	Arikok	Aruba	plant	grass	s	0.708613	0.000009
3905	Boca Grandi	Aruba	plant	grass	s	0.709103	0.000009
3901	Malmok	Aruba	plant	grass	s	0.709132	0.000009
3903	Santa Cruz	Aruba	plant	grass	s	0.707721	0.000010
3902	Tanki Flip	Aruba	plant	grass	s	0.707644	0.000009
6600	Lion Statue	Barbados	snail	shell	s	0.709179	0.000010
3407	Cay Club Road	Barbuda	plant	grass	s	0.709116	0.000010
3404	Gunshop Hill	Barbuda	plant	leaves	s	0.709282	0.000010
3402B	Indian Town Trail	Barbuda	rodent	enamel	s	0.709137	0.000010
3402A	Indian Town Trail	Barbuda	snail	shell	s	0.709091	0.000011
3406	Sandy Ground	Barbuda	plant	grass	s	0.709152	0.000010

Sample ID	Site	Region	Cat.	Type	d/s	^{87}Sr/^{86}Sr	± 2 S.E.
3405	Sea View	Barbuda	plant	leaves	s	0.709154	0.000010
3401B	Sea View	Barbuda	snail	shell	s	0.709198	0.000010
3401A	Sea View	Barbuda	snail	shell	s	0.709165	0.000010
3403	Two Foot Bay	Barbuda	plant	grass	s	0.709224	0.000010
US2006GU	Catedral	Basse-Terre	rodent	enamel	d	0.705674	0.000012
US1072F5	Catedral	Basse-Terre	rodent	enamel	s	0.706121	0.000033
US1080E5	Catedral	Basse-Terre	rodent	enamel	s	0.706614	0.000020
US1080E3	Catedral	Basse-Terre	rodent	enamel	d	0.706821	0.000025
US2008G11	Catedral	Basse-Terre	rodent	enamel	d	0.707002	0.000007
2.4	Grandes Rivieres	Basse-Terre	plant	grass	s	0.708718	0.000010
2.2	St. Claude	Basse-Terre	plant	grass	s	0.705528	0.000010
2.5	Traverse Nord	Basse-Terre	plant	grass	s	0.704796	0.000010
2.3	Trois Rivieres	Basse-Terre	plant	grass	s	0.707763	0.000010
2.1	Val de Orge	Basse-Terre	plant	grass	s	0.707266	0.000010
4005	Karpata	Bonaire	plant	grass	s	0.708055	0.000010
4003	Lagoen Hill	Bonaire	plant	grass	s	0.708523	0.000009
4004	San Jose	Bonaire	plant	grass	s	0.709149	0.000009
4002	Ceru Largu	Bonaire	plant	grass	s	0.708417	0.000010
4001	Washington Park	Bonaire	plant	grass	s	0.709048	0.000008
CM-fa7	Cueva Muertos	Cuba	snail	shell	d	0.708409	0.000008
CM-fa5	Chorro de Maíta	Cuba	rodent	enamel	d	0.707958	0.000009
CM-fa4B	Chorro de Maíta	Cuba	rodent	enamel	d	0.708676	0.000010
CM-fa9	Chorro de Maíta	Cuba	rodent	enamel	s	0.708222	0.000010
CM-fa10	Chorro de Maíta	Cuba	snail	shell	s	0.708454	0.000011
CM-fa6	Chorro de Maíta	Cuba	snail	shell	d	0.708590	0.000011
CM-fa8	El Porvinir	Cuba	snail	shell	d	0.708589	0.000007
LH-fa-1	La Habana	Cuba	snail	shell	s	0.708612	0.000010
LJ-fa2	La Juba	Cuba	snail	shell	s	0.708469	0.000010
LB-fa1	Los Buchillones	Cuba	rodent	enamel	s	0.708298	0.000010
LJ-fa1	near La Juba	Cuba	rodent	enamel	s	0.705950	0.000010
PdM-fa1	Potreño Mango	Cuba	rodent	enamel	s	0.707277	0.000010
PdM-fa2	Potreño Mango	Cuba	snail	shell	s	0.708668	0.000007
PV-fa1	Pueblo Viejo	Cuba	snail	shell	s	0.708982	0.000011
3803	San Juan	Curaçao	plant	grass	s	0.708078	0.000010
3804	San Juan	Curaçao	snail	shell	s	0.708057	0.000010
3807	Santa Barbara	Curaçao	plant	grass	s	0.708980	0.000010
3808	Santa Barbara	Curaçao	snail	shell	s	0.709013	0.000010
3801	St. Christoffel	Curaçao	plant	grass	s	0.709139	0.000008
3802	St. Christoffel	Curaçao	snail	shell	s	0.709145	0.000009
3809	St. Joris Baai	Curaçao	plant	grass	s	0.708032	0.000010
3810	St. Joris Baai	Curaçao	snail	shell	s	0.708022	0.000011
3805	St. Michielsberg	Curaçao	plant	grass	s	0.708922	0.000010

Sample ID	Site	Region	Cat.	Type	d/s	$^{87}Sr/^{86}Sr$	± 2 S.E.
3806	St. Michielsberg	Curaçao	snail	shell	s	0.708777	0.000010
DR-EC-fa3	El Cabo	Dom. Rep.	snail	shell	s	0.709144	0.000012
DR-PM-fa7	Punta Macao	Dom. Rep.	rodent	enamel	d	0.709067	0.000025
8001	Punta Rucia	Dom. Rep.	plant	grass	s	0.708207	0.000010
DR-PR-fa8	Punta Rucia	Dom. Rep.	snail	shell	s	0.708735	0.000009
DR-SF-fa4	Sitio Frances	Dom. Rep.	snail	shell	d	0.708288	0.000010
DR-SLP-fa5	Sitio Los Perez	Dom. Rep.	snail	shell	d	0.708683	0.000010
DR-SP-fa6	Sitio Pijolo-1	Dom. Rep.	snail	shell	d	0.708422	0.000007
AAG k623	Anse à la Gourde	GrandeTerre	rodent	enamel	d	0.709132	0.000009
AAG k628	Anse à la Gourde	GrandeTerre	rodent	enamel	d	0.709149	0.000013
AAG k617	Anse à la Gourde	GrandeTerre	rodent	enamel	d	0.709205	0.000011
AAG k619	Anse à la Gourde	GrandeTerre	rodent	enamel	d	0.709207	0.000007
AE-IIIB	Anse à l'Eau	GrandeTerre	rodent	enamel	d	0.709096	0.000010
AE-II	Anse à l'Eau	GrandeTerre	rodent	enamel	d	0.709106	0.000007
AE-IIIA	Anse à l'Eau	GrandeTerre	rodent	enamel	d	0.709125	0.000008
AE-I	Anse à l'Eau	GrandeTerre	rodent	enamel	d	0.709143	0.000008
PdHc1e1	Pointe du Helleux	GrandeTerre	rodent	enamel	d	0.709136	0.000009
PdHc1e5	Pointe du Helleux	GrandeTerre	rodent	enamel	d	0.709206	0.000012
4302	Old Airport	Grenada	plant	grass	s	0.706823	0.000008
4305	Constantine	Grenada	plant	grass	s	0.707400	0.000010
4303	Mt. Alexander	Grenada	plant	grass	s	0.706223	0.000009
4304	Rosemont	Grenada	plant	grass	s	0.706730	0.000008
4301	Westerhall Bay	Grenada	plant	grass	s	0.707272	0.000009
7201	Bamboo Avenue	Jamaica	snail	shell	s	0.708547	0.000010
7203	Bamboo Avenue	Jamaica	snail	shell	s	0.708794	0.000010
7202	Bamboo Avenue	Jamaica	snail	shell	s	0.708967	0.000012
LS-GA1-D-6	Grande Anse	Les Saintes	rodent	enamel	d	0.707440	0.000010
LS-GA1-D-3	Grande Anse	Les Saintes	rodent	enamel	d	0.708384	0.000008
MGTz4s3N1	Tourlourous	MarieGalante	rodent	enamel	d	0.709142	0.000011
MGTs3p42.2	Tourlourous	MarieGalante	rodent	enamel	d	0.709150	0.000008
MGTs3p41/2	Tourlourous	MarieGalante	rodent	enamel	d	0.709151	0.000014
MG-Ts3n5	Tourlourous	MarieGalante	rodent	enamel	d	0.709230	0.000033
Mart D I3	Dizac	Martinique	rodent	enamel	s	0.706752	0.000008
Mart D B1	Dizac	Martinique	rodent	enamel	s	0.706937	0.000018
Mart D H5	Dizac	Martinique	rodent	enamel	s	0.707017	0.000010
Mart D C	Dizac	Martinique	rodent	enamel	d	0.707713	0.000009
Mart D D5	Dizac	Martinique	rodent	enamel	d	0.708434	0.000007
Mart D C2	Dizac	Martinique	rodent	enamel	d	0.708977	0.000008
4401	Lafayette	Martinique	plant	grass	s	0.706660	0.000010
4403	Le Robert	Martinique	plant	grass	s	0.706821	0.000010
Mart M B2	Macabou	Martinique	rodent	enamel	s	0.707621	0.000019
4404	Macabou	Martinique	plant	grass	s	0.706342	0.000008

Sample ID	Site	Region	Cat.	Type	d/s	^{87}Sr/^{86}Sr	± 2 S.E.
4405	Taupinière	Martinique	plant	grass	s	0.707950	0.000010
3503	Mannings	Nevis	plant	grass	s	0.707893	0.000010
3504	Pond Hill	Nevis	plant	grass	s	0.706704	0.000011
3502	Spring Hill	Nevis	plant	grass	s	0.706728	0.000010
3505	Sulfur Glut	Nevis	plant	grass	s	0.707624	0.000008
3501	Vaughans	Nevis	plant	grass	s	0.707596	0.000007
6305	Adjuntas	Puerto Rico	plant	grass	s	0.706967	0.000008
6303	Arecibo	Puerto Rico	plant	grass	s	0.707889	0.000010
6304	Caguana	Puerto Rico	plant	grass	s	0.707442	0.000009
6309	Candelero	Puerto Rico	plant	grass	s	0.705231	0.000010
PR-Ma-fa8	Maisabel	Puerto Rico	rodent	enamel	s	0.708906	0.000009
PR-Ma-fa7	Maisabel	Puerto Rico	rodent	enamel	s	0.708917	0.000010
PR-Ma-fa6	Maisabel	Puerto Rico	rodent	enamel	s	0.709006	0.000010
6310	Maisabel	Puerto Rico	plant	grass	s	0.709086	0.000090
PR-Ma-fa5	Maisabel	Puerto Rico	snail	shell	d	0.708731	0.000008
PR-Ma-fa3	Maisabel	Puerto Rico	snail	shell	d	0.708744	0.000008
PR-Ma-fa2	Maisabel	Puerto Rico	snail	shell	d	0.708944	0.000008
PR-Ma-fa4	Maisabel	Puerto Rico	snail	shell	d	0.709094	0.000010
PR-Ma-fa1	Maisabel	Puerto Rico	snail	shell	d	0.709158	0.000008
6308	Maunabo	Puerto Rico	plant	grass	s	0.706118	0.000010
6307	Santa Isabel	Puerto Rico	plant	grass	s	0.705608	0.000010
6306	Tibes	Puerto Rico	plant	grass	s	0.706179	0.000009
6301	Vega Baja	Puerto Rico	plant	grass	s	0.708041	0.000010
6302	Vega Baja	Puerto Rico	snail	shell	s	0.708410	0.000010
3001	Boiling House	Saba	plant	grass	s	0.709036	0.000011
3057	Crispeen Track	Saba	plant	grass	d	0.708153	0.000006
3053	Flat Point Airport	Saba	plant	grass	d	0.708450	0.000011
3011	Fort Bay Road	Saba	plant	grass	s	0.708622	0.000011
3051	Fort Hill	Saba	plant	grass	d	0.708265	0.000009
3035	Giles Quarter	Saba	plant	grass	d	0.706435	0.000011
3021	Grey Hill	Saba	plant	grass	d	0.708024	0.000009
3018	Grey Hill	Saba	plant	grass	d	0.708173	0.000010
3023	Grey Hill	Saba	plant	grass	d	0.708593	0.000008
KR2 F271	Kelbey's Ridge	Saba	rodent	enamel	d	0.707706	0.000010
KR2 F289	Kelbey's Ridge	Saba	rodent	enamel	s	0.708070	0.000012
KR2 F331	Kelbey's Ridge	Saba	rodent	enamel	d	0.708105	0.000011
KR2 F331	Kelbey's Ridge	Saba	rodent	enamel	d	0.708111	0.000014
KR2 F123	Kelbey's Ridge	Saba	rodent	enamel	s	0.708172	0.000040
KR2 F138	Kelbey's Ridge	Saba	rodent	enamel	d	0.708181	0.000009
KR2 F266	Kelbey's Ridge	Saba	rodent	enamel	d	0.708185	0.000008
KR2 F467	Kelbey's Ridge	Saba	rodent	enamel	d	0.708252	0.000019
KR2 F138	Kelbey's Ridge	Saba	rodent	enamel	d	0.708394	0.000041

Sample ID	Site	Region	Cat.	Type	d/s	^{87}Sr/^{86}Sr	± 2 S.E.
KR2 F164R	Kelbey's Ridge	Saba	rodent	enamel	s	0.708422	0.000032
KR2 F243	Kelbey's Ridge	Saba	rodent	enamel	d	0.708448	0.000010
KR2 F251	Kelbey's Ridge	Saba	rodent	enamel	d	0.708454	0.000024
KR2 F260	Kelbey's Ridge	Saba	rodent	enamel	d	0.708493	0.000012
KR2 F241B	Kelbey's Ridge	Saba	rodent	enamel	d	0.708539	0.000010
KR2 F169	Kelbey's Ridge	Saba	rodent	enamel	d	0.708541	0.000014
KR2 F206	Kelbey's Ridge	Saba	rodent	enamel	d	0.708552	0.000012
KR2 F260	Kelbey's Ridge	Saba	rodent	enamel	d	0.708591	0.000012
KR2 F202	Kelbey's Ridge	Saba	rodent	enamel	d	0.708717	0.000014
KR2 F202	Kelbey's Ridge	Saba	rodent	enamel	d	0.708900	0.000009
3054	Kelbey's Ridge	Saba	plant	grass	d	0.708481	0.000011
Sa-KR-fa1	Kelbey's Ridge	Saba	snail	shell	d	0.707170	0.000011
F129	Kelbey's Ridge	Saba	snail	shell	s	0.708232	0.000010
F169	Kelbey's Ridge	Saba	snail	shell	s	0.708345	0.000009
F360	Kelbey's Ridge	Saba	snail	shell	s	0.708469	0.000011
F253	Kelbey's Ridge	Saba	snail	shell	s	0.708509	0.000010
F127b	Kelbey's Ridge	Saba	snail	shell	s	0.708645	0.000010
3020	Lower Grey Hill	Saba	plant	grass	d	0.708545	0.000008
3010	Lower Hells Gate	Saba	plant	grass	s	0.708622	0.000011
3052	Mary’s Point	Saba	plant	grass	d	0.706969	0.000008
3015	Maskerhorne Hill	Saba	plant	grass	s	0.707565	0.000011
3031	Mount Scenery	Saba	plant	grass	d	0.708160	0.000008
3029	Mount Scenery	Saba	plant	grass	s	0.709196	0.000010
3007	Partial House	Saba	plant	grass	s	0.708486	0.000006
3034	Plum Piece	Saba	plant	grass	d	0.706987	0.000012
3055	Spring Bay	Saba	plant	grass	d	0.708788	0.000007
3058	Spring Bay Flat	Saba	plant	grass	d	0.706914	0.000008
3059	Thais Hill	Saba	plant	grass	d	0.707446	0.000009
3013	The Level	Saba	plant	grass	s	0.708083	0.000009
3009	The Level	Saba	plant	grass	s	0.708601	0.000010
3025	Wells Bay	Saba	plant	grass	d	0.707731	0.000009
3056	Windward Side	Saba	plant	grass	d	0.708027	0.000010
3702	Anse de Grande	St. Barths	plant	grass	s	0.708125	0.000010
3701	Camaruche	St. Barths	plant	grass	s	0.709025	0.000010
3705	La Grand Vigie	St. Barths	plant	grass	s	0.707605	0.000010
3704	Le Gouveneur	St. Barths	plant	grass	s	0.708845	0.000008
6005	East End	St. Croix	plant	grass	s	0.707910	0.000011
6002	Orange Grove	St. Croix	plant	grass	s	0.706784	0.000007
6001	Salt River Bay	St. Croix	plant	grass	s	0.708244	0.000009
6004	South Side Road	St. Croix	plant	grass	s	0.707512	0.000010
6003	Upper Bethlehem	St. Croix	plant	grass	s	0.708643	0.000010
7306	Compagnie	St. Eustatius	plant	grass	s	0.708796	0.000010

Sample ID	Site	Region	Cat.	Type	d/s	^{87}Sr/^{86}Sr	± 2 S.E.
7304	Fort de Windt	St. Eustatius	plant	grass	s	0.708966	0.000010
SE 7P IV	Golden Rock	St. Eustatius	rodent	enamel	d	0.707262	0.000008
15P-IV	Golden Rock	St. Eustatius	rodent	enamel	d	0.708310	0.000005
7303	Pilot Hill	St. Eustatius	plant	grass	s	0.708477	0.000010
7305	Quill Slope	St. Eustatius	plant	grass	s	0.707300	0.000010
7302	Signal Hill	St. Eustatius	plant	grass	s	0.708414	0.000010
7301	Venus Bay	St. Eustatius	plant	grass	s	0.708148	0.000009
6202	Annabell	St. John	plant	grass	s	0.709052	0.000008
6203	East End	St. John	plant	grass	s	0.708309	0.000010
SJ EP-fa1	Europa Bay	St. John	snail	shell	s	0.708688	0.000011
6204	Lameshur Bay	St. John	plant	grass	s	0.708817	0.000010
6206	Rendevous Bay	St. John	plant	grass	s	0.707540	0.000010
6201	Trunk Bay	St. John	plant	grass	s	0.707913	0.000010
3602	Bird Rock	St. Kitts	plant	grass	s	0.707264	0.000010
3604	Brimstone Hill	St. Kitts	plant	grass	s	0.708363	0.000006
3601	Great Salt Pond	St. Kitts	plant	grass	s	0.708618	0.000010
3603	Mansion	St. Kitts	plant	grass	s	0.707812	0.000010
SKSF2409B	Sugar Factory	St. Kitts	rodent	enamel	s	0.707522	0.000010
SKSF2407	Sugar Factory	St. Kitts	rodent	enamel	d	0.707915	0.000013
SKSF2080C	Sugar Factory	St. Kitts	rodent	enamel	d	0.708113	0.000014
3605	Trinity East	St. Kitts	plant	grass	s	0.706729	0.000009
4502	Giraudy	St. Lucia	plant	grass	s	0.708645	0.000011
4510	Lavoutte	St. Lucia	rodent	enamel	s	0.707731	0.000011
4511	Lavoutte	St. Lucia	rodent	enamel	s	0.707852	0.000009
SL-AL-fa1	Lavoutte	St. Lucia	snail	shell	d	0.707682	0.000005
SL-AL-fa1	Lavoutte	St. Lucia	snail	shell	s	0.708304	0.000010
4501	Pointe Caraïbe	St. Lucia	plant	grass	s	0.708105	0.000010
4508	Pointe Hardy	St. Lucia	plant	grass	s	0.707613	0.000009
4504	Saltibus Point	St. Lucia	plant	grass	s	0.708845	0.000009
4505	Saltibus Point	St. Lucia	plant	grass	s	0.708879	0.000010
4503	Saltibus Point	St. Lucia	plant	grass	s	0.708996	0.000010
4507	Soufrière	St. Lucia	plant	grass	s	0.708667	0.000010
SMBP2803A	Baie aux Prunes	St. Martin	rodent	enamel	d	0.709147	0.000010
SMBP2403D	Baie aux Prunes	St. Martin	rodent	enamel	d	0.709153	0.000010
SMBP2402D	Baie aux Prunes	St. Martin	rodent	enamel	d	0.709157	0.000024
3102	Colombier	St. Martin	plant	grass	s	0.708152	0.000010
3105	Grand Fond	St. Martin	plant	grass	s	0.707139	0.000010
3104	Guana Bay	St. Martin	plant	grass	s	0.708341	0.000010
SMHE3308	Hope Estate	St. Martin	rodent	enamel	d	0.707169	0.000011
SMHE3311C	Hope Estate	St. Martin	rodent	enamel	d	0.708091	0.000007
SMHE3305	Hope Estate	St. Martin	rodent	enamel	d	0.708665	0.000006
3101	La Croisade	St. Martin	plant	grass	s	0.707548	0.000009

Sample ID	Site	Region	Cat.	Type	d/s	^{87}Sr/^{86}Sr	± 2 S.E.
3103	Border Monument	St. Martin	plant	grass	s	0.707540	0.000010
6106	Bonne Esperance	St. Thomas	plant	grass	s	0.707461	0.000009
6104	Bordeaux	St. Thomas	plant	grass	s	0.708384	0.000012
6103	Petersborg	St. Thomas	plant	grass	s	0.708644	0.000008
6101	Tutu	St. Thomas	plant	grass	s	0.707819	0.000010
ST-TT-fa1	Tutu	St. Thomas	snail	shell	s	0.707405	0.000010
6105	Upper John Dunko	St. Thomas	plant	grass	s	0.708354	0.000010
4101	Cambden Park	St. Vincent	plant	grass	s	0.708117	0.000010
SVE-fa2	Escape	St. Vincent	rodent	enamel	s	0.706568	0.000008
SVE-fa3	Escape	St. Vincent	rodent	enamel	s	0.706452	0.000009
SVE-fa4	Escape	St. Vincent	rodent	enamel	s	0.705939	0.000007
4103	King's Hill	St. Vincent	plant	grass	s	0.706359	0.000008
4104	Orange Hill	St. Vincent	plant	grass	s	0.706470	0.000007
4105	Owia	St. Vincent	plant	grass	s	0.707081	0.000010
4102	Wallilabou	St. Vincent	plant	grass	s	0.705655	0.000010
4202	Flagstaff Hill	Tobago	plant	grass	s	0.708067	0.000005
4203	Gilpin Trail	Tobago	plant	grass	s	0.705884	0.000008
4204	King Peters Bay	Tobago	plant	grass	s	0.707336	0.000010
4205	Mt. Pleasant	Tobago	plant	grass	s	0.710257	0.000009
4201	Rainbow Falls	Tobago	plant	grass	s	0.704747	0.000010
7119	Atagual	Trinidad	snail	shell	s	0.709175	0.000006
7101	Balandra Bay	Trinidad	plant	leaves	s	0.709438	0.000007
7117	Banwari	Trinidad	snail	shell	s	0.709043	0.000014
7106	Brasso	Trinidad	plant	leaves	s	0.709098	0.000010
7109	Caroni	Trinidad	plant	grass	s	0.709445	0.000010
7107	Cipero	Trinidad	plant	grass	s	0.709327	0.000010
7108	Couva	Trinidad	plant	grass	s	0.709987	0.000010
7118	Grants Trace	Trinidad	snail	shell	s	0.709023	0.000010
7116	Los Iros	Trinidad	snail	shell	s	0.709350	0.000010
7103	Manzanilla	Trinidad	plant	grass	s	0.709860	0.000010
7113	Marac	Trinidad	snail	shell	s	0.708870	0.000011
7110	Maracas	Trinidad	plant	leaves	s	0.710436	0.000010
7104	Poole	Trinidad	plant	grass	s	0.711523	0.000010
7115	Quinam	Trinidad	snail	shell	s	0.708545	0.000011
7105	Rio Claro South	Trinidad	plant	grass	s	0.708320	0.000007
7102	Sangre Grande	Trinidad	plant	leaves	s	0.711322	0.000010
4601	Caracas	Venezuela	plant	grass	s	0.710852	0.000010
VN-fa1	Caracas	Venezuela	snail	shell	s	0.710644	0.000008
4604	Los Taparos	Venezuela	plant	grass	s	0.709775	0.000010
4605	Playa Patanemo	Venezuela	plant	grass	s	0.709740	0.000009
4603	Sanare	Venezuela	plant	grass	s	0.709573	0.000010
4602	Tapiaría Nautica	Venezuela	plant	grass	s	0.709354	0.000010

Table 15: Appendix B – Human sample information and strontium isotope results
Note: d = dynamic mode; s = static mode.

Sample ID	Site	Island	d/s	Sex	Age	Ele.	^{87}Sr/^{86}Sr	± 2 S.E.
CM1	Chorro de Maíta	Cuba	d	F	18+	P	0.708164	0.000014
CM2	Chorro de Maíta	Cuba	d	F	36-45	P	0.708127	0.000008
CM3	Chorro de Maíta	Cuba	d	F	26-35	P	0.708333	0.000017
CM4	Chorro de Maíta	Cuba	d	M	46+	P	0.709065	0.000010
CM6	Chorro de Maíta	Cuba	d	Ind.	6-9	M1	0.708467	0.000011
CM7B	Chorro de Maíta	Cuba	d	Ind.	18+	P	0.708317	0.000010
CM8B	Chorro de Maíta	Cuba	d	Ind.	12-13	P	0.708807	0.000013
CM10	Chorro de Maíta	Cuba	s	Ind.	2-3	m	0.708358	0.000009
CM12	Chorro de Maíta	Cuba	d	Ind.	5-6	P	0.708382	0.000010
CH13	Chorro de Maíta	Cuba	s	Ind.	4-5	I	0.708608	0.000010
CM14B	Chorro de Maíta	Cuba	d	Ind.	6-8	m	0.708677	0.000017
CM16A	Chorro de Maíta	Cuba	d	M	18-25	P	0.708624	0.000009
CM18	Chorro de Maíta	Cuba	s	Ind.	5-6	M	0.708478	0.000010
CM19B	Chorro de Maíta	Cuba	d	Ind.	18+	P	0.708754	0.000013
CM20	Chorro de Maíta	Cuba	d	M	26-35	P	0.707061	0.000008
CM21	Chorro de Maíta	Cuba	d	F	46+	P	0.708740	0.000009
CM22	Chorro de Maíta	Cuba	d	M	16-18	P	0.708418	0.000037
CM24	Chorro de Maíta	Cuba	d	Ind.	10-11	P	0.707141	0.000010
CM25	Chorro de Maíta	Cuba	d	M	26-35	P	0.708548	0.000008
CM26	Chorro de Maíta	Cuba	d	M	18-25	P	0.708608	0.000018
CM28	Chorro de Maíta	Cuba	s	F	18+	I	0.708674	0.000008
CM29	Chorro de Maíta	Cuba	d	M	26-35	P	0.707849	0.000010
CM30	Chorro de Maíta	Cuba	d	F	36-45	M2	0.707556	0.000016
CM32	Chorro de Maíta	Cuba	d	Ind.	7-8	P	0.708424	0.000010
CM34	Chorro de Maíta	Cuba	d	M	26-35	P	0.707230	0.000010
CM35	Chorro de Maíta	Cuba	s	F	18-25	P	0.708653	0.000009
CM36	Chorro de Maíta	Cuba	d	Ind.	14-15	P	0.708096	0.000016
CM37	Chorro de Maíta	Cuba	d	F	18-25	P	0.708735	0.000020
CM39	Chorro de Maíta	Cuba	d	M	46+	P	0.708787	0.000012
CM40	Chorro de Maíta	Cuba	d	M	18+	M1	0.708540	0.000018
CM41	Chorro de Maíta	Cuba	d	Ind.	12-13	P	0.708386	0.000010
CM42	Chorro de Maíta	Cuba	d	M	26-35	P	0.708406	0.000013
CM43	Chorro de Maíta	Cuba	d	M	26-35	P	0.707815	0.000009
CM44	Chorro de Maíta	Cuba	d	F?	36-45	M2	0.707936	0.000009
CM45	Chorro de Maíta	Cuba	d	M	26-35	P	0.710883	0.000016
CM46	Chorro de Maíta	Cuba	d	F	18+	P	0.708436	0.000009
CM47	Chorro de Maíta	Cuba	D	M	26-35	P	0.709102	0.000010

Sample ID	Site	Island	d/s	Sex	Age	Ele.	^{87}Sr/^{86}Sr	± 2 S.E.
CM49	Chorro de Maíta	Cuba	d	F	46+	I	0.708738	0.000017
CM50	Chorro de Maíta	Cuba	d	F	46+	P	0.708296	0.000017
CM51	Chorro de Maíta	Cuba	d	M	18-25	P	0.708678	0.000011
CM52	Chorro de Maíta	Cuba	d	M?	46+	P	0.708364	0.000011
CM53	Chorro de Maíta	Cuba	d	F	26-35	P	0.708403	0.000012
CM55	Chorro de Maíta	Cuba	d	F?	36-45	P	0.708702	0.000010
CM57A	Chorro de Maíta	Cuba	d	F	26-35	P	0.708490	0.000015
CM59	Chorro de Maíta	Cuba	d	M	46+	P	0.707897	0.000010
CM60	Chorro de Maíta	Cuba	d	Ind.	18+	M	0.708768	0.000011
CM61	Chorro de Maíta	Cuba	d	F	18+	P	0.707772	0.000017
CM62	Chorro de Maíta	Cuba	d	M	46+	P	0.708668	0.000009
CM63	Chorro de Maíta	Cuba	d	F	18+	C	0.708586	0.000011
CM64	Chorro de Maíta	Cuba	d	Ind.	10-12	P	0.708386	0.000008
CM65	Chorro de Maíta	Cuba	d	M	18-25	P	0.708422	0.000011
CM67	Chorro de Maíta	Cuba	d	F	18-25	P	0.707821	0.000011
CM68	Chorro de Maíta	Cuba	d	F	18-25	P	0.708472	0.000015
CM69A	Chorro de Maíta	Cuba	s	Ind.	6-8	C	0.708324	0.000010
CM70	Chorro de Maíta	Cuba	d	F	18-25	P	0.707515	0.000009
CM72A	Chorro de Maíta	Cuba	d	Ind.	5-6	M1	0.708620	0.000009
CM72B	Chorro de Maíta	Cuba	d	F	18-25	P	0.707570	0.000007
CM73	Chorro de Maíta	Cuba	d	F	18-25	M	0.708749	0.000007
CM74	Chorro de Maíta	Cuba	d	M	36-45	P	0.708662	0.000010
CM75A	Chorro de Maíta	Cuba	d	F	14-16	P	0.708759	0.000007
CM77	Chorro de Maíta	Cuba	d	Ind.	6-7	P	0.708587	0.000009
CM78	Chorro de Maíta	Cuba	d	M	26-35	P	0.707713	0.000013
CM79	Chorro de Maíta	Cuba	d	Ind.	15-18	P	0.708729	0.000011
CM80	Chorro de Maíta	Cuba	d	Ind.	14-16	P	0.708648	0.000009
CM81	Chorro de Maíta	Cuba	d	F?	18-25	P	0.708152	0.000011
CM82	Chorro de Maíta	Cuba	d	F	14-16	P	0.708703	0.000010
CM83	Chorro de Maíta	Cuba	d	F?	15-16	P	0.707703	0.000016
CM84	Chorro de Maíta	Cuba	d	Ind.	3-5	M1	0.708523	0.000013
CM85	Chorro de Maíta	Cuba	s	Ind.	4-5	M1	0.708681	0.000010
CM86	Chorro de Maíta	Cuba	d	F	18-25	P	0.708233	0.000008
CM87A	Chorro de Maíta	Cuba	d	F	26-35	P	0.709102	0.000011
CM89	Chorro de Maíta	Cuba	d	M	26-35	P	0.706763	0.000019
CM91	Chorro de Maíta	Cuba	d	M?	46+	P	0.708663	0.000014
CM92	Chorro de Maíta	Cuba	d	M	36-45	P	0.709078	0.000012
CM93	Chorro de Maíta	Cuba	d	F	46+	P	0.708072	0.000018
CM94	Chorro de Maíta	Cuba	d	Ind.	9-11	P	0.708189	0.000018
CM95	Chorro de Maíta	Cuba	d	M	26-35	C	0.708539	0.000012
CM97	Chorro de Maíta	Cuba	d	M	26-35	P	0.708472	0.000010

Sample ID	Site	Island	d/s	Sex	Age	Ele.	^{87}Sr/^{86}Sr	± 2 S.E.
CM98	Chorro de Maíta	Cuba	d	F	46+	P	0.708823	0.000009
CM99	Chorro de Maíta	Cuba	d	F	36-45	P	0.708702	0.000008
CM100	Chorro de Maíta	Cuba	d	M	46+	P	0.708432	0.000017
CM102	Chorro de Maíta	Cuba	d	Ind.	4-5	m	0.708692	0.000013
CM103	Chorro de Maíta	Cuba	d	M	26-35	P	0.708528	0.000015
CM104	Chorro de Maíta	Cuba	s	M	18-25	I	0.709034	0.000007
CM105A	Chorro de Maíta	Cuba	s	M?	36-45	P	0.709044	0.000010
CM106	Chorro de Maíta	Cuba	d	M	46+	P	0.708056	0.000023
CM107	Chorro de Maíta	Cuba	s	F	18+	C	0.708514	0.000010
CM108	Chorro de Maíta	Cuba	d	F?	36-45	P	0.708410	0.000008
CALM1	Cueva Muertos	Cuba	d	?	18+	P	0.708677	0.000009
CALM2	Cueva Muertos	Cuba	d	?	18+	P	0.708862	0.000010
CALM3	Cueva Muertos	Cuba	d	?	18+	P	0.708441	0.000019
CALM4	Cueva Muertos	Cuba	d	?	18+	P	0.708741	0.000014
PdM1	Potreno Mango	Cuba	d	?	18+	P	0.708011	0.000008
sup.A	Punta Macao	Dom. Rep.	s	?	n/o	P	0.709085	0.000013
sup. B	Punta Macao	Dom. Rep.	d	?	18+	C	0.708974	0.000009
sec.C1	Punta Macao	Dom. Rep.	s	?	18+	P	0.708954	0.000010
B1	Punta Macao	Dom. Rep.	s	F	46+	P	0.709163	0.000012
B2	Punta Macao	Dom. Rep.	s	M	14-16	P	0.709122	0.000010
B5	Punta Macao	Dom. Rep.	s	F	26-35	P	0.707763	0.000010
B6A	Punta Macao	Dom. Rep.	d	F	18-25	P	0.708887	0.000017
B6B	Punta Macao	Dom. Rep.	d	Ind.	4-6	m	0.709023	0.000012
B9	Punta Macao	Dom. Rep.	d	M	46+	P	0.708882	0.000021
B10	Punta Macao	Dom. Rep.	s	Ind.	18+	M	0.709056	0.000009
B11	Punta Macao	Dom. Rep.	s	M	26-35	P	0.709082	0.000011
B12	Punta Macao	Dom. Rep.	d	M	36-45	P	0.709025	0.000013
B13	Punta Macao	Dom. Rep.	d	M	36-45	P	0.709036	0.000011
B14	Punta Macao	Dom. Rep.	d	F	46+	P	0.708980	0.000014
B16	Punta Macao	Dom. Rep.	d	M	18+	C	0.708930	0.000008
B17	Punta Macao	Dom. Rep.	d	Ind.	18-25	P	0.708958	0.000010
B18	Punta Macao	Dom. Rep.	d	M	18-25	P	0.709049	0.000012
B20.1	Punta Macao	Dom. Rep.	d	Ind.	<1	i	0.709077	0.000010
B21	Punta Macao	Dom. Rep.	d	Ind.	<18	M2	0.709076	0.000013
B25	Punta Macao	Dom. Rep.	s	F	26-35	P	0.709028	0.000009
B29.1	Punta Macao	Dom. Rep.	s	M	26-35	P	0.708979	0.000006
F85-34-06	El Cabo	Dom. Rep.	d	?	18+	P	0.709180	0.000008
F85-40-17	El Cabo	Dom. Rep.	d	?	18+	P	0.709183	0.000015
F85-31-01	El Cabo	Dom. Rep.	d	?	18+	P	0.709148	0.000010
F84-29-26	El Cabo	Dom. Rep.	s	?	<1	i	0.709191	0.000010
DR-Ba1	Bartolo	Dom. Rep.	s	?	18+	P	0.709223	0.000012

Sample ID	Site	Island	d/s	Sex	Age	Ele.	^{87}Sr/^{86}Sr	± 2 S.E.
B1	Maisabel	Puerto Rico	s	Ind.	18+	C	0.708725	0.000010
B2	Maisabel	Puerto Rico	s	M	26-35	P	0.708119	0.000010
B3	Maisabel	Puerto Rico	s	Ind.	1-2	m	0.708897	0.000011
B4	Maisabel	Puerto Rico	s	M?	46+	I	0.708754	0.000008
B5	Maisabel	Puerto Rico	s	F?	18+	P	0.708812	0.000010
B6	Maisabel	Puerto Rico	s	M?	46+	M2	0.708640	0.000006
B7	Maisabel	Puerto Rico	s	M	46+	P	0.706610	0.000010
B8	Maisabel	Puerto Rico	s	Ind.	2-3	m	0.708762	0.000011
B9	Maisabel	Puerto Rico	s	M	26-35	M1	0.708646	0.000009
B10	Maisabel	Puerto Rico	s	F	46+	P	0.708868	0.000010
B11	Maisabel	Puerto Rico	s	M?	46+	P	0.708562	0.000010
B13	Maisabel	Puerto Rico	s	Ind.	18-25	P	0.708894	0.000010
B14	Maisabel	Puerto Rico	s	M	18-25	P	0.708188	0.000010
B15	Maisabel	Puerto Rico	s	M?	18+	C	0.708131	0.000008
B16	Maisabel	Puerto Rico	s	Ind.	4-5	i	0.708828	0.000011
B17	Maisabel	Puerto Rico	s	M	26-35	P	0.707371	0.000009
B18	Maisabel	Puerto Rico	s	F	36-45	P	0.708544	0.000010
B19A	Maisabel	Puerto Rico	s	F	36-45	P	0.708788	0.000009
B19B	Maisabel	Puerto Rico	s	M?	18-25	P	0.708820	0.000009
B20	Maisabel	Puerto Rico	s	M?	26-35	P	0.708440	0.000006
B21	Maisabel	Puerto Rico	s	F?	36-45	P	0.705594	0.000010
B22	Maisabel	Puerto Rico	s	M?	18-25	P	0.708879	0.000010
B23	Maisabel	Puerto Rico	s	F	46+	P	0.708082	0.000010
B24	Maisabel	Puerto Rico	s	Ind.	1-1.5	m	0.708718	0.000009
B25	Maisabel	Puerto Rico	s	F	46+	P	0.708160	0.000011
B27	Maisabel	Puerto Rico	s	Ind.	1.5-2	m	0.708890	0.000010
B28	Maisabel	Puerto Rico	s	M?	46+	M1	0.708744	0.000007
B29	Maisabel	Puerto Rico	s	Ind.	46+	P	0.708384	0.000010
B31	Maisabel	Puerto Rico	s	Ind.	2-4	M1	0.708188	0.000009
T01	Tutu	St. Thomas	d	F	45-55	P	0.707984	0.000016
T02	Tutu	St. Thomas	d	F	40-50	P	0.707863	0.000009
T03	Tutu	St. Thomas	d	F	40-50	P	0.707587	0.000005
T04	Tutu	St. Thomas	d	F	18-25	P	0.706947	0.000005
T05	Tutu	St. Thomas	d	F	40-50	P	0.708057	0.000009
T06	Tutu	St. Thomas	d	Ind.	5.5-7	m	0.708041	0.000012
T09	Tutu	St. Thomas	d	M	45-55	P	0.706764	0.000008
T10	Tutu	St. Thomas	d	F	45-55	P	0.707237	0.000009
T12	Tutu	St. Thomas	d	M	45-55	P	0.708275	0.000008
T13	Tutu	St. Thomas	d	F	40-55	P	0.707967	0.000007
T13A	Tutu	St. Thomas	d	F	45-55	P	0.707877	0.000008
T16	Tutu	St. Thomas	d	F	35-45	P	0.708047	0.000010

Sample ID	Site	Island	d/s	Sex	Age	Ele.	$^{87}Sr/^{86}Sr$	± 2 S.E.
T19	Tutu	St. Thomas	d	F	40-50	P	0.707793	0.000007
T20	Tutu	St. Thomas	d	Ind.	9	P	0.707789	0.000008
T21	Tutu	St. Thomas	d	M	40+	P	0.707836	0.000009
T22A	Tutu	St. Thomas	d	Ind.	1.5-3	m	0.707600	0.000010
T22B	Tutu	St. Thomas	d	Ind.	4-5	P	0.707833	0.000016
T23A	Tutu	St. Thomas	d	Ind.	0-0.5	I	0.707538	0.000008
T23B	Tutu	St. Thomas	d	F	35+	P	0.706280	0.000009
T26	Tutu	St. Thomas	d	F	17-21	P	0.706991	0.000009
T27	Tutu	St. Thomas	d	Ind.	<2	c	0.708256	0.000009
T30	Tutu	St. Thomas	d	M	35-45	P	0.707875	0.000010
T31	Tutu	St. Thomas	d	F	35-45	P	0.707094	0.000009
T32A	Tutu	St. Thomas	d	Ind.	5	m	0.707693	0.000008
T33	Tutu	St. Thomas	d	M	35-45	P	0.707972	0.000010
T36	Tutu	St. Thomas	d	Ind.	40-50	P	0.707778	0.000005
T38	Tutu	St. Thomas	d	M	45-50	P	0.708708	0.000010
T39	Tutu	St. Thomas	d	Ind.	8	m	0.708094	0.000016
T41	Tutu	St. Thomas	d	Ind.	1.5	m	0.708236	0.000008
F337	Kelbey's Ridge	Saba	d	Ind.	2-3	m	0.707699	0.000010
F148	Kelbey's Ridge	Saba	d	F?	30+	C	0.708512	0.000007
F313	Kelbey's Ridge	Saba	d	Ind.	11-13	P	0.708281	0.000009
F166.1	Kelbey's Ridge	Saba	d	Ind.	10-12	P	0.708592	0.000012
F132.1	Kelbey's Ridge	Saba	d	F	46+	P	0.708640	0.000009
F068.1	Kelbey's Ridge	Saba	d	M	36-45	P	0.708789	0.000008
SB-F001	Spring Bay	Saba	d	Ind.	2-4	m	0.707852	0.000012
U9F26.1	Bloody Point	St. Kitts	s	?	18+	P	0.707547	0.000010
U9F26.2	Bloody Point	St. Kitts	s	?	18+	P	0.707723	0.000010
U10F25	Bloody Point	St. Kitts	s	?	18+	P	0.707489	0.000010
U10F20	Bloody Point	St. Kitts	s	?	18+	P	0.707416	0.000010
F50A	Anse à la Gourde	Guadeloupe	d	F	18+	P	0.709171	0.000008
F89	Anse à la Gourde	Guadeloupe	d	F	18-25	P	0.709161	0.000007
F108A	Anse à la Gourde	Guadeloupe	d	M	36-45	P	0.709172	0.000015
F137A	Anse à la Gourde	Guadeloupe	d	Ind.	18+	M2	0.709131	0.000014
F139	Anse à la Gourde	Guadeloupe	d	M	46+	P	0.709034	0.000009
F159	Anse à la Gourde	Guadeloupe	d	F	18-25	P	0.709146	0.000009
F171A	Anse à la Gourde	Guadeloupe	d	M	18-25	M1	0.708636	0.000020
F196	Anse à la Gourde	Guadeloupe	d	M	30+	P	0.709038	0.000009
F197	Anse à la Gourde	Guadeloupe	d	M	18-25	P	0.709125	0.000015
F200	Anse à la Gourde	Guadeloupe	d	F	18+	M3	0.709005	0.000010
F202	Anse à la Gourde	Guadeloupe	d	F?	18+	P	0.709127	0.000012
F206A	Anse à la Gourde	Guadeloupe	d	M	18+	P	0.709127	0.000009
F207	Anse à la Gourde	Guadeloupe	d	F	36-45	M1	0.709116	0.000013

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F212	Anse à la Gourde	Guadeloupe	d	F?	18+	P	0.709083	0.000010
F219	Anse à la Gourde	Guadeloupe	d	Ind.	9-11	P	0.709050	0.000016
F238B	Anse à la Gourde	Guadeloupe	d	F	26-35	M2	0.709148	0.000011
F241	Anse à la Gourde	Guadeloupe	d	Ind.	18+	P	0.709058	0.000008
F253	Anse à la Gourde	Guadeloupe	D	F	30+	P	0.709162	0.000015
F288	Anse à la Gourde	Guadeloupe	d	M	26-35	P	0.708646	0.000008
F291	Anse à la Gourde	Guadeloupe	d	Ind.	4-9	M2	0.709088	0.000011
F292	Anse à la Gourde	Guadeloupe	d	M?	36-45	P	0.708755	0.000010
F304	Anse à la Gourde	Guadeloupe	d	F	26-35	P	0.709122	0.000040
F307	Anse à la Gourde	Guadeloupe	d	M	46+	P	0.709165	0.000008
F311	Anse à la Gourde	Guadeloupe	d	F	26-35	P	0.708849	0.000014
F332	Anse à la Gourde	Guadeloupe	d	F	26-35	P	0.708278	0.000009
F335	Anse à la Gourde	Guadeloupe	d	F	18+	M2	0.707725	0.000009
F339	Anse à la Gourde	Guadeloupe	d	M?	18+	I	0.709100	0.000009
F342	Anse à la Gourde	Guadeloupe	d	M	26-35	P	0.709031	0.000007
F348	Anse à la Gourde	Guadeloupe	d	Ind.	18+	I	0.709130	0.000009
F349A	Anse à la Gourde	Guadeloupe	d	M	26-35	P	0.709139	0.000011
F349C	Anse à la Gourde	Guadeloupe	d	F?	26-35	P	0.708590	0.000009
F350	Anse à la Gourde	Guadeloupe	d	F	36-45	P	0.709182	0.000010
F377	Anse à la Gourde	Guadeloupe	d	Ind.	2-3	c	0.709071	0.000027
F378	Anse à la Gourde	Guadeloupe	d	F	18-25	P	0.707490	0.000009
F430	Anse à la Gourde	Guadeloupe	d	F	26-35	P	0.708794	0.000009
F447	Anse à la Gourde	Guadeloupe	d	F	18-25	P	0.709090	0.000011
F450A	Anse à la Gourde	Guadeloupe	d	M	26-35	P	0.708690	0.000009
F451	Anse à la Gourde	Guadeloupe	d	F	26-35	P	0.709113	0.000008
F452	Anse à la Gourde	Guadeloupe	d	F	26-35	P	0.709182	0.000006
F454	Anse à la Gourde	Guadeloupe	d	F	18+	P	0.709164	0.000009
F529	Anse à la Gourde	Guadeloupe	d	F	18-25	P	0.709107	0.000012
F706	Anse à la Gourde	Guadeloupe	d	M	26-35	P	0.709168	0.000018
F726	Anse à la Gourde	Guadeloupe	d	M	26-35	P	0.709228	0.000013
F953	Anse à la Gourde	Guadeloupe	d	F	18+	P	0.709162	0.000012
F1126A	Anse à la Gourde	Guadeloupe	d	F	18+	I	0.709120	0.000008
F1203	Anse à la Gourde	Guadeloupe	d	M	26-35	P	0.709131	0.000012
F1207	Anse à la Gourde	Guadeloupe	d	Ind.	<18	P	0.708957	0.000009
F1226	Anse à la Gourde	Guadeloupe	d	M	26-35	P	0.709068	0.000009
F1413	Anse à la Gourde	Guadeloupe	d	Ind.	3-4	m	0.709193	0.000018
F1496A	Anse à la Gourde	Guadeloupe	d	M	18-25	P	0.709158	0.000007
F1651	Anse à la Gourde	Guadeloupe	d	M	26-35	P	0.709168	0.000006
F1922	Anse à la Gourde	Guadeloupe	d	Ind.	<1	P	0.709136	0.000010
F1944	Anse à la Gourde	Guadeloupe	d	Ind.	5-7	m	0.709287	0.000010
F1945	Anse à la Gourde	Guadeloupe	d	F	26-35	P	0.709166	0.000007

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F1947	Anse à la Gourde	Guadeloupe	d	M	46+	P	0.709237	0.000013
F1948	Anse à la Gourde	Guadeloupe	d	M	46+	P	0.708895	0.000009
F1958	Anse à la Gourde	Guadeloupe	d	F?	46+	C	0.708996	0.000010
F2005	Anse à la Gourde	Guadeloupe	d	F?	18-25	P	0.708475	0.000012
F2106	Anse à la Gourde	Guadeloupe	d	M	30+	C	0.709143	0.000009
F2107	Anse à la Gourde	Guadeloupe	d	F?	13-15	P	0.709149	0.000008
F2109	Anse à la Gourde	Guadeloupe	d	F	>18	I	0.709071	0.000010
F2211	Anse à la Gourde	Guadeloupe	d	Ind.	2	m	0.709412	0.000014
F2212	Anse à la Gourde	Guadeloupe	d	F?	46+	P	0.709100	0.000008
F2213	Anse à la Gourde	Guadeloupe	d	F	46+	P	0.708854	0.000008
F2214	Anse à la Gourde	Guadeloupe	d	F?	36-45	P	0.709156	0.000012
F2215	Anse à la Gourde	Guadeloupe	d	F	26-35	P	0.707747	0.000007
F2216	Anse à la Gourde	Guadeloupe	d	M	36-45	P	0.709165	0.000006
F2217	Anse à la Gourde	Guadeloupe	d	F	18-25	P	0.709168	0.000005
F57-17	Lavoutte	St. Lucia	s	F	36-45	I	0.707229	0.000010
F67-18	Lavoutte	St. Lucia	s	Ind.	18+	P	0.707699	0.000011
F57-03	Lavoutte	St. Lucia	s	Ind.	10-12	P	0.707804	0.000017
F57-08	Lavoutte	St. Lucia	s	Ind.	18+	I	0.708572	0.000009
F57-11	Lavoutte	St. Lucia	s	F?	18+	P	0.707671	0.000010
F57-23	Lavoutte	St. Lucia	s	F	26-35	P	0.708132	0.000011
F58-22	Lavoutte	St. Lucia	s	M	36-45	P	0.708150	0.000014
F58-23A	Lavoutte	St. Lucia	s	F	18-25	P	0.707880	0.000010
F58-23B	Lavoutte	St. Lucia	s	M	26-35	P	0.708252	0.000010
F67-05	Lavoutte	St. Lucia	s	F?	26-35	C	0.708109	0.000010
F67-11	Lavoutte	St. Lucia	s	Ind.	18+	P	0.707634	0.000008
F67-12	Lavoutte	St. Lucia	s	F?	18+	P	0.707705	0.000010
F67-13	Lavoutte	St. Lucia	s	M	36-45	C	0.707997	0.000010
F67-14	Lavoutte	St. Lucia	s	Ind.	4-5	M1	0.708021	0.000011
F67-19	Lavoutte	St. Lucia	s	Ind.	18-25	P	0.707956	0.000008
F67-31	Lavoutte	St. Lucia	s	M	36-45	P	0.707591	0.000009
F67-33	Lavoutte	St. Lucia	s	M	46+	P	0.707684	0.000013
F68-01	Lavoutte	St. Lucia	s	M	26-35	P	0.707905	0.000008
F68-04	Lavoutte	St. Lucia	s	M	26-35	P	0.708237	0.000009
F68-05	Lavoutte	St. Lucia	s	F	36-45	P	0.707812	0.000008
F68-07	Lavoutte	St. Lucia	s	M	26-35	P	0.707836	0.000009
F68-08	Lavoutte	St. Lucia	s	Ind.	4-5	m	0.708013	0.000009
F68-11	Lavoutte	St. Lucia	s	F	46+	C	0.708005	0.000007
F68-20	Lavoutte	St. Lucia	s	F	36-45	P	0.707810	0.000008
F69-01	Lavoutte	St. Lucia	s	M	36-45	M	0.708094	0.000011
F69-02	Lavoutte	St. Lucia	s	F?	14-16	P	0.707804	0.000010
F69-05	Lavoutte	St. Lucia	s	Ind.	35-45	P	0.707910	0.000010

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F68-29	Lavoutte	St. Lucia	s	F?	18+	C	0.707553	0.000008
SLL-A1	Lavoutte	St. Lucia	s	M	36-45	P	0.707612	0.000010
SLL-A2	Lavoutte	St. Lucia	s	M	46+	P	0.708132	0.000014
SLL-A3	Lavoutte	St. Lucia	s	F	18+	P	0.707963	0.000010
SLL-A4	Lavoutte	St. Lucia	s	Ind.	5-6	M1	0.707893	0.000008
U7L1.43	Giraudy	St. Lucia	s	n/o	18+	M2	0.708756	0.000012
F23-19	Argyle I	St. Vincent	s	n/o	n/o	P	0.707542	0.000006
F42-15	Argyle I	St. Vincent	s	n/o	n/o	P	0.708043	0.000009
SVA2-B1	Argyle II	St. Vincent	s	M	36-45	P	0.707750	0.000010
SVA2-B2	Argyle II	St. Vincent	s	n/o	18+	P	0.707688	0.000009
SVA2-B3	Argyle II	St. Vincent	s	M	18-25	P	0.708687	0.000009
SVA2-B6	Argyle II	St. Vincent	s	n/o	18+	M1	0.708170	0.000008
SVA2-B7	Argyle II	St. Vincent	s	n/o	n/o	M1	0.707987	0.000006
SVA2-B9	Argyle II	St. Vincent	s	n/o	n/o	M1	0.707629	0.000010
SVA2-B10	Argyle II	St. Vincent	s	n/o	7-9	M1	0.707672	0.000009
SVA2-B11	Argyle II	St. Vincent	s	n/o	adult	P	0.707763	0.000008
SVA2-B12	Argyle II	St. Vincent	s	n/o	n/o	M	0.707703	0.000009
SVA2-B13	Argyle II	St. Vincent	s	n/o	n/o	P	0.707826	0.000010
SVA2-B14	Argyle II	St. Vincent	s	n/o	18+	M	0.707512	0.000009
SVA2-B15	Argyle II	St. Vincent	s	n/o	18+	P	0.707962	0.000010
SVA2-B18	Argyle II	St. Vincent	s	n/o	18+	M	0.707795	0.000009
SVA2-B19	Argyle II	St. Vincent	s	n/o	18+	P	0.707343	0.000008
SVE-B1	Escape	St. Vincent	s	F?	26-35	P	0.707661	0.000009
SVE-B2	Escape	St. Vincent	s	F?	36-45	P	0.707710	0.000008
SVE-B3	Escape	St. Vincent	s	F?	46+	P	0.707576	0.000009
SVE-B4	Escape	St. Vincent	s	n/o	26-35	P	0.706758	0.000011
SVE-B5	Escape	St. Vincent	s	n/o	n/o	P	0.707666	0.000011
SVE-B6	Escape	St. Vincent	s	M?	18-25	P	0.707150	0.000009
SVE-B7	Escape	St. Vincent	s	n/o	18+	P	0.707582	0.000009
SVE-B8	Escape	St. Vincent	s	n/o	26-35	P	0.708023	0.000008
SVE-B9	Escape	St. Vincent	s	n/o	n/o	P	0.707454	0.000010
SVE-B10	Escape	St. Vincent	s	F?	18-25	P	0.707610	0.000012
SVE-B11	Escape	St. Vincent	s	n/o	18+	P	0.707620	0.000012
SVE-B12	Escape	St. Vincent	s	n/o	46+	P	0.707616	0.000010
SVE-B13	Escape	St. Vincent	s	n/o	36-45	P	0.707681	0.000012
SVE-B14	Escape	St. Vincent	s	n/o	26-35	P	0.707630	0.000008
SVE-B15	Escape	St. Vincent	s	n/o	46+	P	0.707532	0.000009
SVE-B16	Escape	St. Vincent	s	n/o	18-25	P	0.707589	0.000009
SVE-B17	Escape	St. Vincent	s	n/o	26-35	P	0.707431	0.000011
SVE-B18	Escape	St. Vincent	S	n/o	16-18	P	0.707661	0.000008
SVE-B19	Escape	St. Vincent	s	F?	26-35	P	0.707692	0.000009

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SVE-B20	Escape	St. Vincent	s	Ind.	5-7	P	0.707225	0.000009
SVE-B21	Escape	St. Vincent	s	n/o	18-25	P	0.707567	0.000012
SVE-B22	Escape	St. Vincent	s	n/o	18+	P	0.707769	0.000010
SVE-B23	Escape	St. Vincent	s	n/o	18-25	P	0.707683	0.000010
SVE-B24	Escape	St. Vincent	s	M?	36-45	P	0.707076	0.000010
SVE-B37	Escape	St. Vincent	s	n/o	18+	C	0.707943	0.000008
SVE-F27	Escape	St. Vincent	s	n/o	18+	M1	0.707418	0.000009
SVBW-1	Bucc. West	St. Vincent	s	n/o	18+	P	0.706346	0.000008
H98/A/11	Heywoods	Barbados	s	n/o	18-25	P	0.709130	0.000010
H98/A/35	Heywoods	Barbados	s	n/o	36-45	P	0.709146	0.000010
H98/D/61	Heywoods	Barbados	s	n/o	18-25	P	0.709128	0.000010
F118	Manzanilla	Trinidad	s	F?	18-25	P	0.709453	0.000010
F119	Manzanilla	Trinidad	s	M	46+	P	0.709714	0.000009
F180B	Manzanilla	Trinidad	s	M	36-45	P	0.709561	0.000010
F189A	Manzanilla	Trinidad	s	Ind.	9-10	P	0.708648	0.000009
F189B	Manzanilla	Trinidad	s	M	26-35	M2	0.708543	0.000008
F214	Manzanilla	Trinidad	s	M	18-25	I	0.709341	0.000009
F244	Manzanilla	Trinidad	s	M?	18-25	P	0.710237	0.000008
F255	Manzanilla	Trinidad	s	M	26-35	P	0.709897	0.000010
F251	Manzanilla	Trinidad	s	F	46+	P	0.709745	0.000009
F267A	Manzanilla	Trinidad	s	Ind.	9-11	P	0.709893	0.000008
F267B	Manzanilla	Trinidad	s	M	18+	P	0.721787	0.000008
F267/9	Manzanilla	Trinidad	s	M?	26-35	P	0.709860	0.000009
F291	Manzanilla	Trinidad	s	Ind.	14-16	P	0.711067	0.000006
F292	Manzanilla	Trinidad	s	Ind.	10-12	P	0.710409	0.000007
F294	Manzanilla	Trinidad	s	M	18-25	P	0.709372	0.000009
F197	Manzanilla	Trinidad	s	Ind.	3-4	M1	0.709125	0.000009
Ma-6	Malmok	Aruba	s	n/o	26-35	M3	0.709176	0.000011
Ma-10	Malmok	Aruba	s	F	26-35	P	0.709057	0.000010
Ma-13	Malmok	Aruba	s	n/o	36-45	P	0.709081	0.000009
Ma-ap490	Malmok	Aruba	s	M	26-35	P	0.709145	0.000010
CC-1959	Ceru Canashito	Aruba	s	n/o	18+	M2	0.709876	0.000008
TF-F200	Tanki Flip	Aruba	s	n/o	18+	P	0.708586	0.000010
TF-F488	Tanki Flip	Aruba	s	n/o	18-25	C	0.708967	0.000009
Sv-237A	Savaneta	Aruba	s	M	26-35	C	0.708835	0.000009
SC-F1	Santa Cruz	Aruba	s	n/o	18-25	M1	0.708233	0.000009

Table 16: Appendix C – Human sample information and carbon and oxygen isotope results

Sample ID	Site	Region	Sex	Element	$\delta^{13}C_{ca}$	$\delta^{18}O_{ca}$
					‰ PBD	‰ PBD
CM25	El Chorro de Maita	Cuba	M	P3	-10.3	-4.3
CM3	El Chorro de Maita	Cuba	F	P3	-12.1	-2.9
CM36	El Chorro de Maita	Cuba	J	P3	-12.3	-2.0
CM45	El Chorro de Maita	Cuba	M	P3	-5.1	-5.4
CM6	El Chorro de Maita	Cuba	J	M1	-11.4	-3.3
CM65	El Chorro de Maita	Cuba	M	P4	-12.3	-2.7
CM72B	El Chorro de Maita	Cuba	F	P3	-3.7	-3.7
CM81	El Chorro de Maita	Cuba	F	P3	-12.9	-2.8
CM84	El Chorro de Maita	Cuba	J	M1	-12.7	-3.3
CM87A	El Chorro de Maita	Cuba	F	P4	-12.7	-2.5
CM89	El Chorro de Maita	Cuba	M	P3	-12.1	-2.7
CM92	El Chorro de Maita	Cuba	M	P3	-11.4	-2.4
B1	Punta Macao	Dominican Rep.	I	P4	-14.2	-1.8
B5	Punta Macao	Dominican Rep.	I	P4	-13.4	-2.7
B6B	Punta Macao	Dominican Rep.	J	m2	-12.8	-2.9
B9	Punta Macao	Dominican Rep.	I	P4	-12.5	-2.5
B1	El Cabo	Dominican Rep.	I	P3	-12.7	-1.9
B21	Maisabel	Puerto Rico	F	P3	-13.1	-2.2
B28	Maisabel	Puerto Rico	M	M1	-11.1	-1.1
B3	Maisabel	Puerto Rico	J	m2	-12.7	-2.0
B31	Maisabel	Puerto Rico	J	M1	-11.1	-2.9
B7	Maisabel	Puerto Rico	M	P3	-12.5	-1.7
T09	Tutu	St. Thomas	M	P3	-12.1	-2.1
T20	Tutu	St. Thomas	J	P4	-11.3	-3.1
T23B	Tutu	St. Thomas	F	P4	-12.0	-2.6
T31	Tutu	St. Thomas	F	P4	-11.6	-1.8
T38	Tutu	St. Thomas	M	P3	-9.3	-2.4
F148	Kelbey's Ridge	Saba	F	C	-11.4	-2.0
F166	Kelbey's Ridge	Saba	J	P3	-12.7	-2.8
F313	Kelbey's Ridge	Saba	J	P4	-12.8	-2.1
F337	Kelbey's Ridge	Saba	J	m1	-11.9	-2.7
F68.1	Kelbey's Ridge	Saba	M	I1	-9.9	-2.2
F207	Anse à la Gourde	Guadeloupe	F	M1	-12.1	-2.0
F2212	Anse à la Gourde	Guadeloupe	F	P4	-11.0	-2.1

Sample ID	**Site**	**Region**	**Sex**	**Element**	**$\delta^{13}C_{ca}$**	**$\delta^{18}O_{ca}$**
F2215	Anse à la Gourde	Guadeloupe	F	P3	-11.2	-2.8
F2216	Anse à la Gourde	Guadeloupe	M	P4	-10.8	-2.1
F311	Anse à la Gourde	Guadeloupe	F	P4	-11.1	-2.2
F430	Anse à la Gourde	Guadeloupe	F	P4	-11.5	-2.2
F450	Anse à la Gourde	Guadeloupe	M	P3	-11.1	-1.3
F57-08	Lavoutte	St. Lucia	I	I1	-11.3	-2.5
F57-17	Lavoutte	St. Lucia	F	I1	-11.5	-3.1
F58-23A	Lavoutte	St. Lucia	F	P3	-9.1	-2.9
F58-23B	Lavoutte	St. Lucia	M	m2	-12.1	-3.4
F68-08	Lavoutte	St. Lucia	J	P3	-11.3	-2.0
F118	Manzanilla	Trinidad	F	P4	-7.2	-2.9
F189B	Manzanilla	Trinidad	M	M2	-7.9	-2.8
F255	Manzanilla	Trinidad	F	P4	-8.3	-3.3
F267B	Manzanilla	Trinidad	M	P4	-12.5	-2.1
F291	Manzanilla	Trinidad	I	P3	-9.5	-2.9

CURRICULUM VITAE

Jason Laffoon was born in 1974 in Waukegan, Illinois in the United States of America. For his secondary education, he attended Huntley High School. Jason did his undergraduate studies at the University of Illinos at Chicago (UIC) where he received his BA in 2003 with a major in Anthropology and a minor in Biology. He stayed at UIC for his early post-graduate studies and obtained his MA in anthropology in 2006 with a focus on biochemical studies of human remains from the prehistoric Caribbean. During this time he participated in archaeological field projects in North America, South America, and the Caribbean. Since 2008, he has carried out his doctoral research *Patterns of Paleomobility in the Ancient Antilles* at Leiden University as part of the NWO-funded VICI research programme 'Communicating Communities in the Circum-Caribbean' (VICI-project no. 277-62-001) directed by Professor C.L. Hofman. In collaboration with the Leiden Caribbean Research Group, Jason has carried out archaeological research throughout the Caribbean, and in 2012 he began employment as a lecturer in Human Osteoarchaeology at the Faculty of Archaeology, Leiden University, The Netherlands