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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.

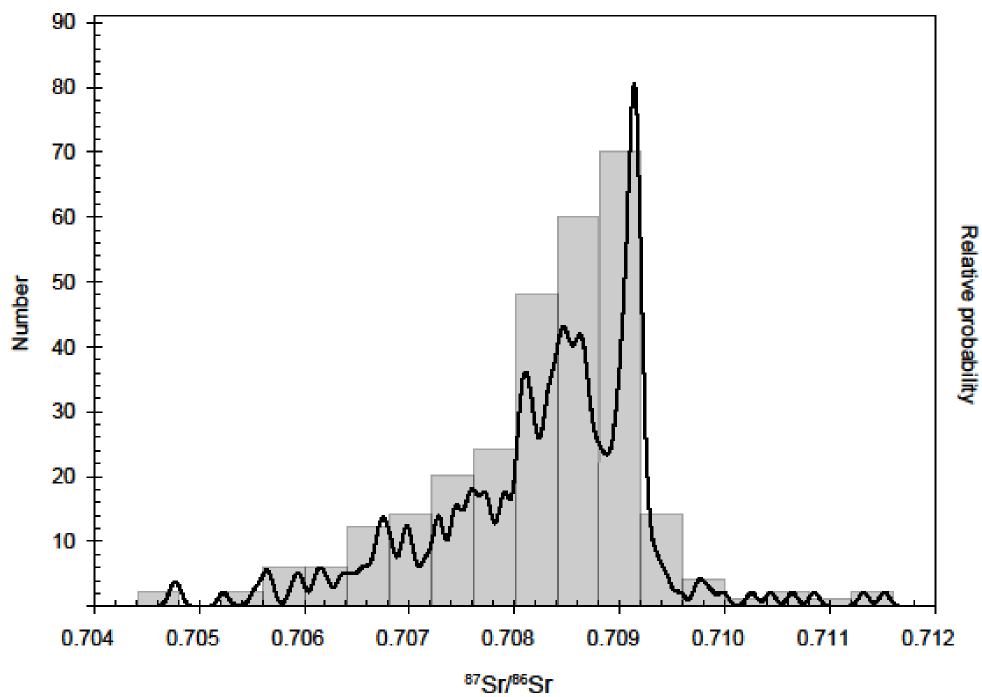

Figure 4 Relative probability diagram and histogram of biosphere $^{87}Sr/^{86}Sr$ data.
Note: a blanket error of 0.0001 was applied to all measurements to construct the density curve.

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*

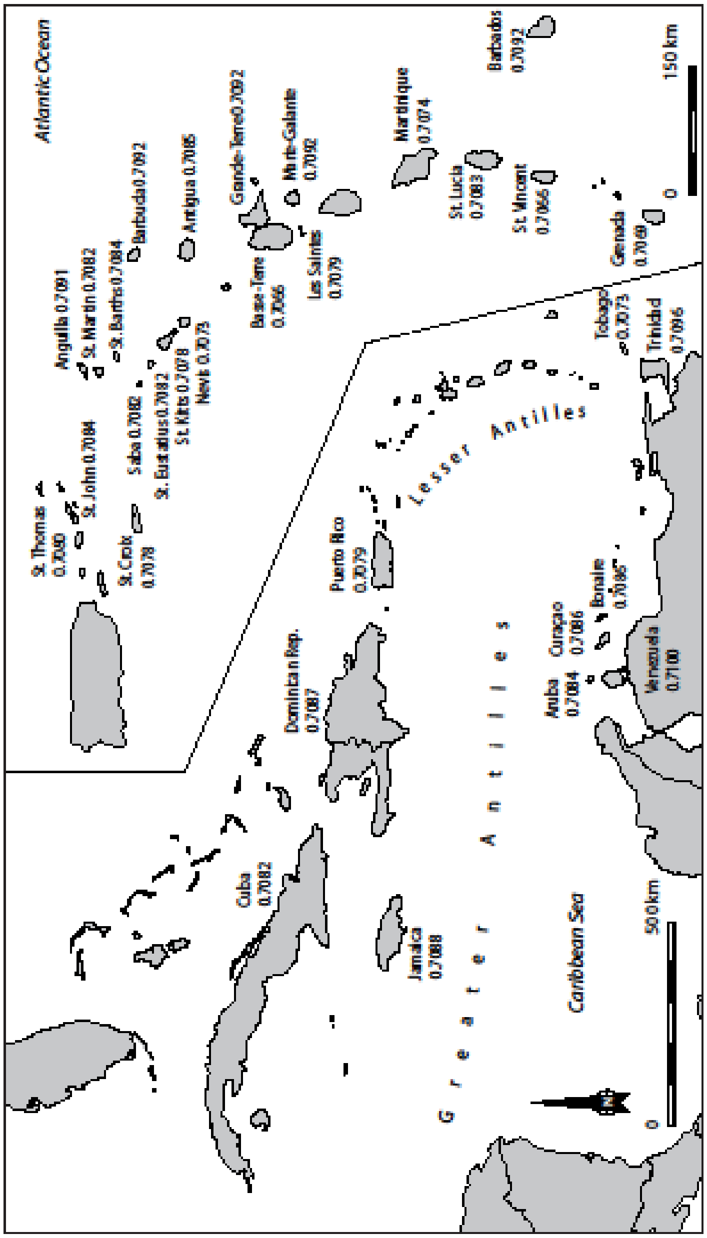

Figure 5 **Map of the Caribbean displaying mean biosphere $^{87}Sr/^{86}Sr$ per island/region.**

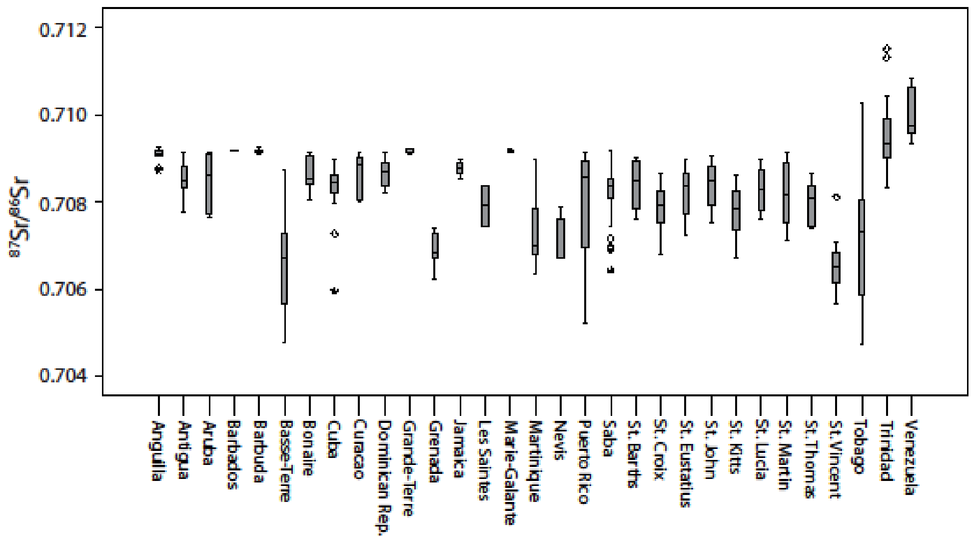

Figure 6 Boxplot of biosphere $^{87}Sr/^{86}Sr$ data by island/region.
Key: mid-lines represent medians, shaded boxes represent lower and upper quartiles, whiskers represent 1.5 IQR, circles are outliers, and stars are extreme ratios, circles are outliers, and stars are extreme ratios.

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*

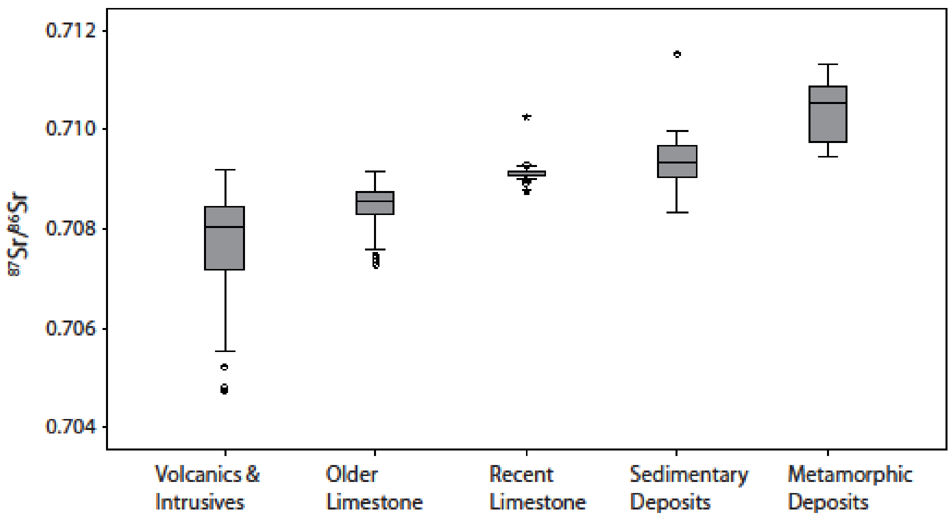

Figure 7 Boxplot of biosphere $^{87}Sr/^{86}Sr$ variation by geological subregion. Key: mid-lines represent medians, shaded boxes represent lower and upper quartiles, whiskers represent 1.5 IQR, circles are outliers, and stars are extreme ratios, circles are outliers, and stars are extreme ratios.

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).

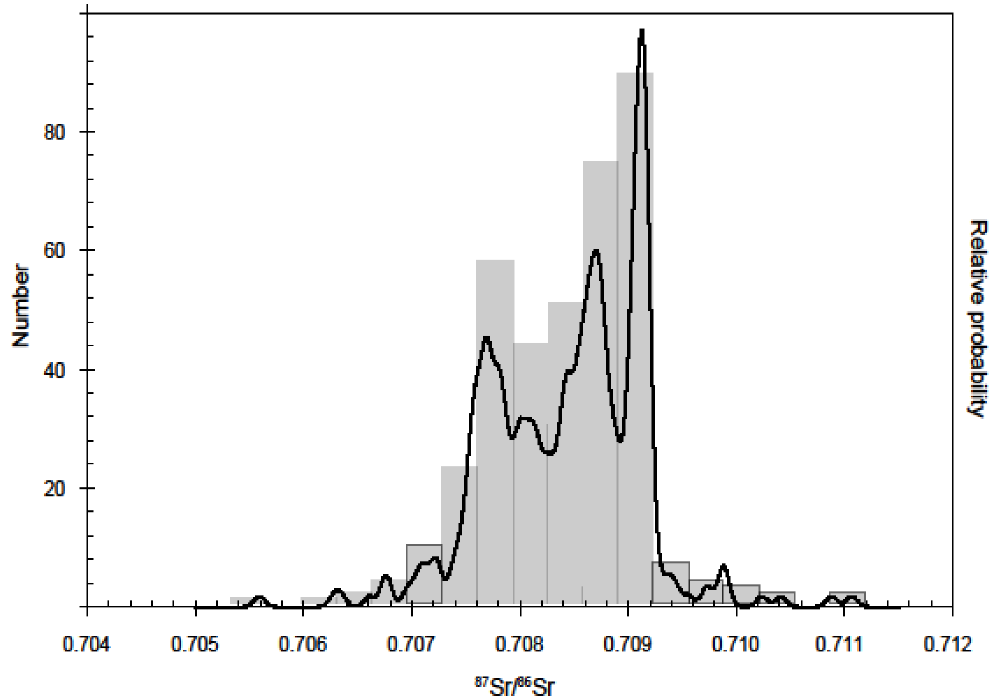

Figure 8 Relative probability diagram and histogram of human $^{87}Sr/^{86}Sr$ data. Note: a blanket error of 0.0001 was applied to all measurements to construct the probability curve. One extreme (high) $^{87}Sr/^{86}Sr$ ratio from Manzanilla, Trinidad not displayed at this scale

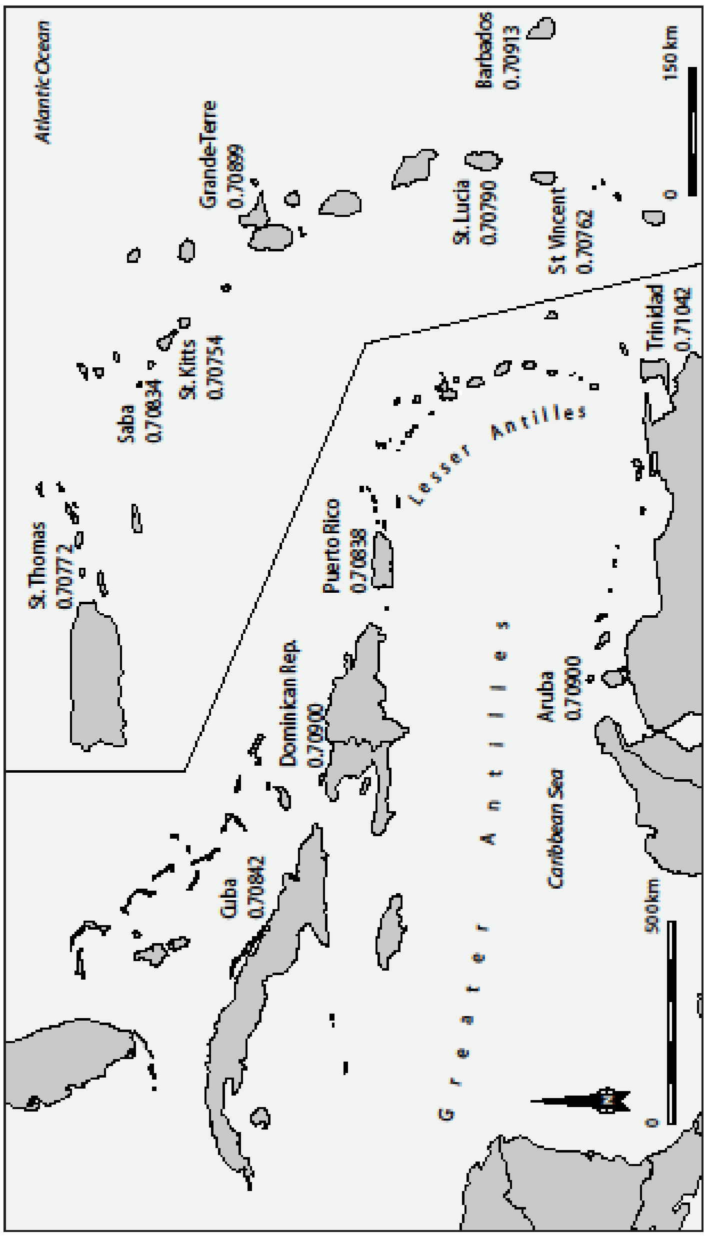

Figure 9 Map of the Caribbean displaying mean human $^{87}Sr/^{86}Sr$ per island.

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

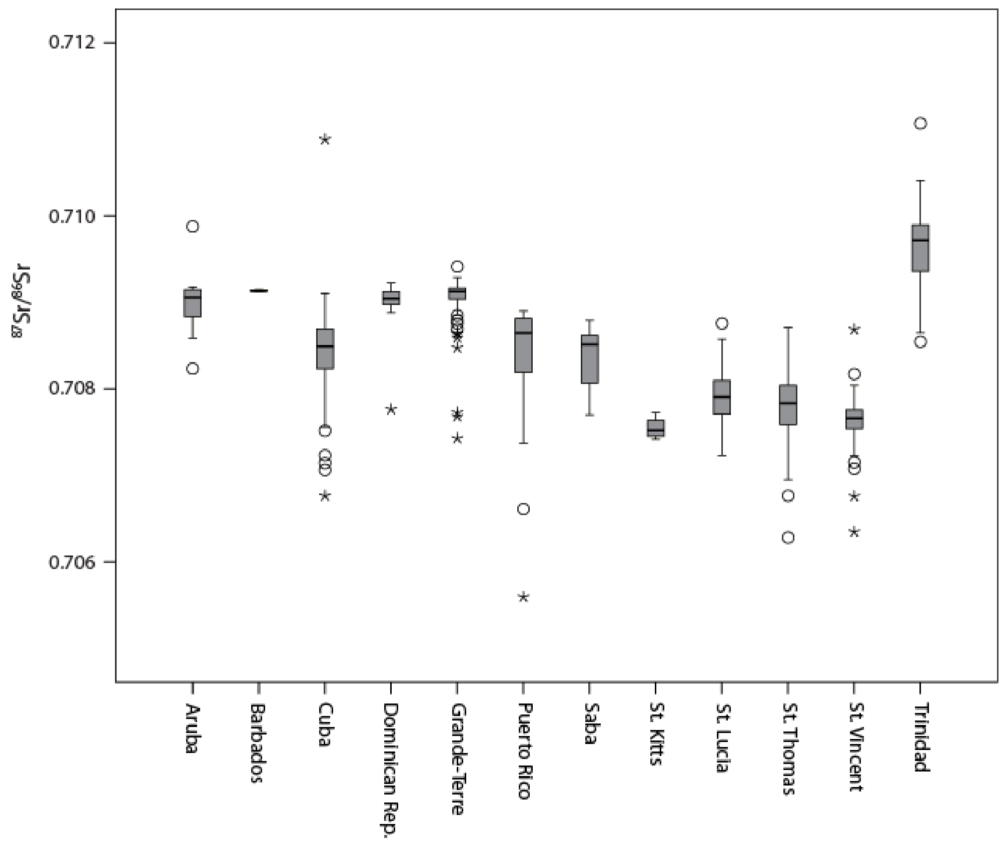

Figure 10 Boxplot of human $^{87}Sr/^{86}Sr$ data by island.
Key: mid-lines represent medians, shaded boxes represent lower and upper quartiles, whiskers represent 1.5 IQR, circles are outliers, and stars are extreme ratios, circles are outliers, and stars are extreme ratios. Note: One extreme (high) $^{87}Sr/^{86}Sr$ 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

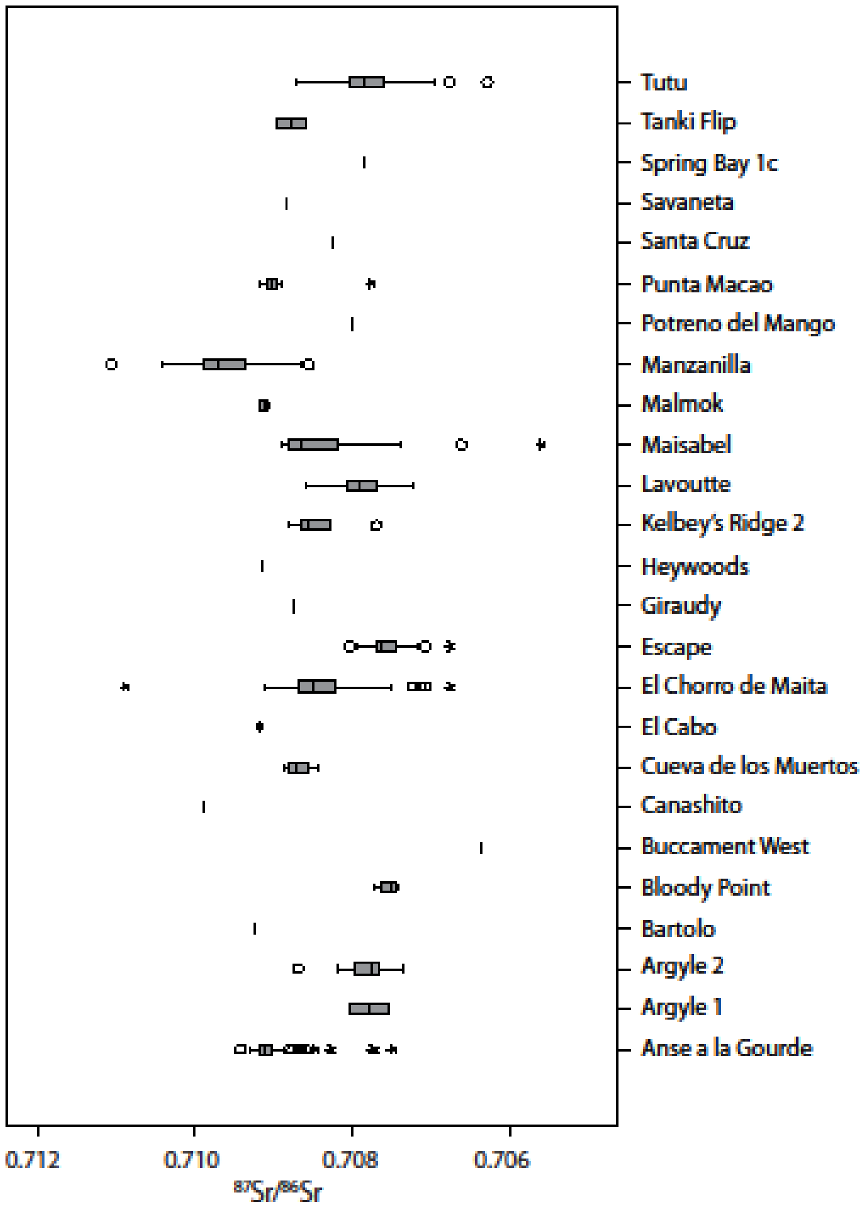

Figure 11 Boxplot of human $^{87}Sr/^{86}Sr$ data by site.
Key: mid-lines represent medians, shaded boxes represent lower and upper quartiles, whiskers represent 1.5 IQR, circles are outliers, and stars are extreme ratios. Note: One extreme (high) $^{87}Sr/^{86}Sr$ ratio from Manzanilla not displayed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

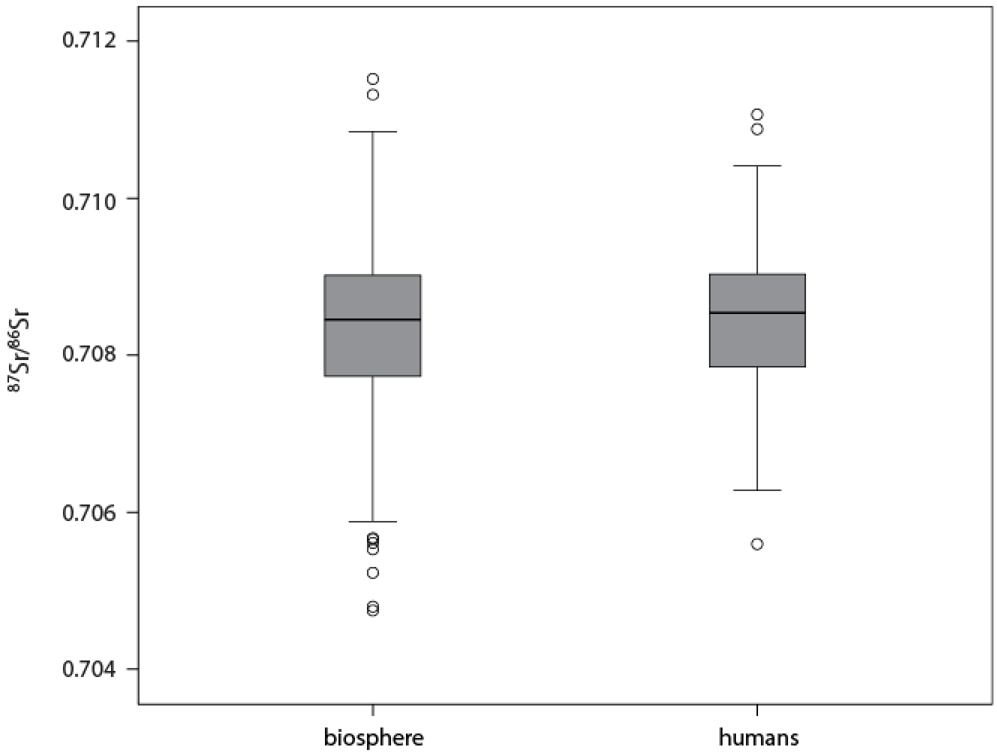

Figure 12 Boxplot comparing biosphere and human $^{87}Sr/^{86}Sr$ data.
Key: mid-lines represent medians, shaded boxes represent lower and upper quartiles, whiskers represent 1.5 IQR, circles are outliers, and stars are extreme ratios. Note: One extreme (high) human Sr isotope ratio from Manzanilla not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

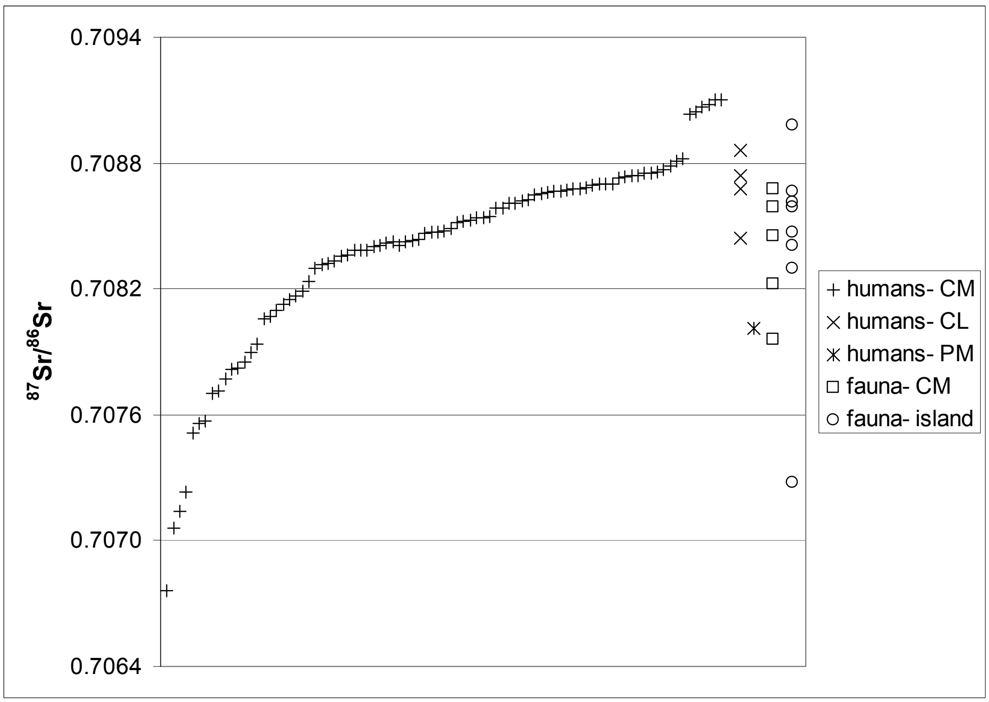

Figure 13 Strontium Isotope Ratios- Cuba.
Key: CM = El Chorro de Maíta; CL = Cueva de los Muertos; PM = Porteño del Mango.
Note: one extreme (high) outlier not displayed at this scale.

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.

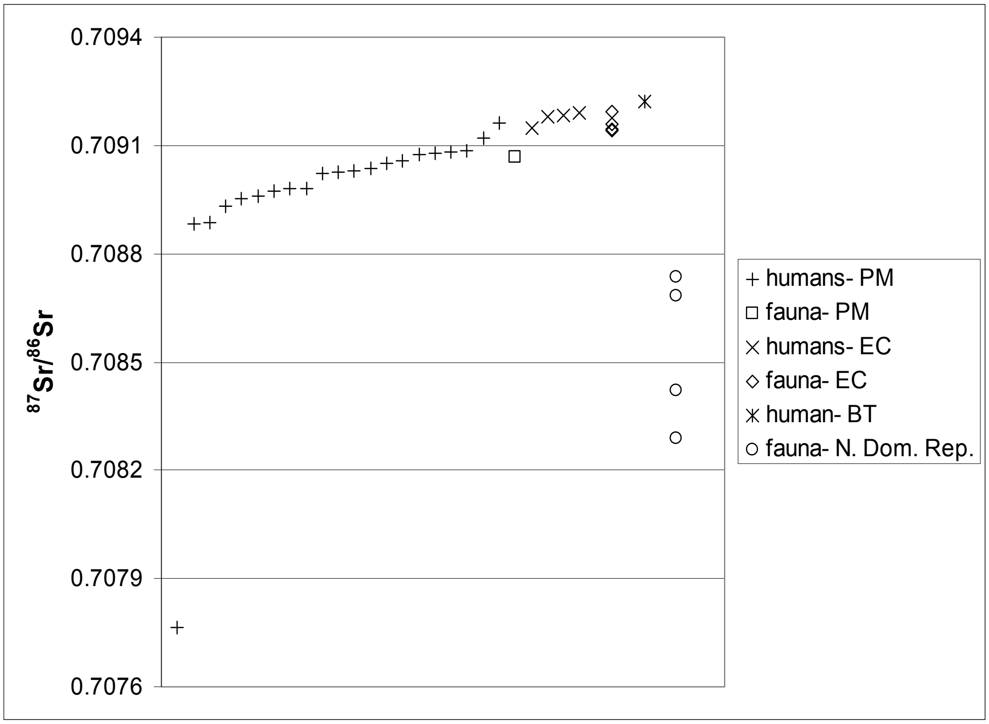

Figure 14 Strontium Isotope Ratios- Dominican Republic.
Key: PM = Punta Macao; EC = El Cabo; BT = Bartolo.

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.

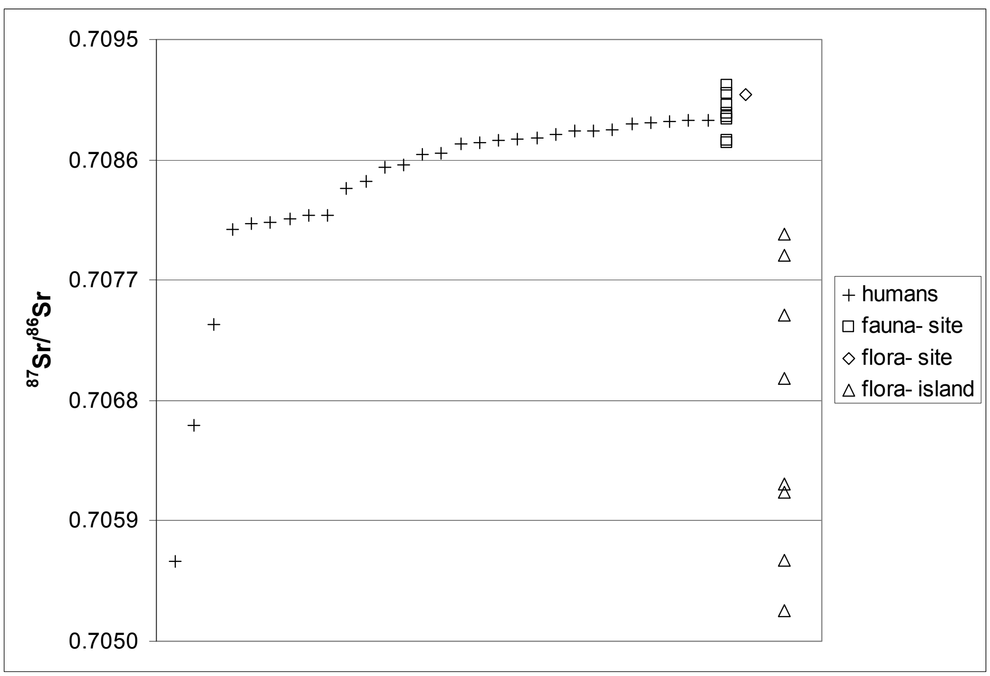

Figure 15 Strontium Isotope Ratios- Puerto Rico.
Key: human and faunal samples and one floral sample are from Maisabel.

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.

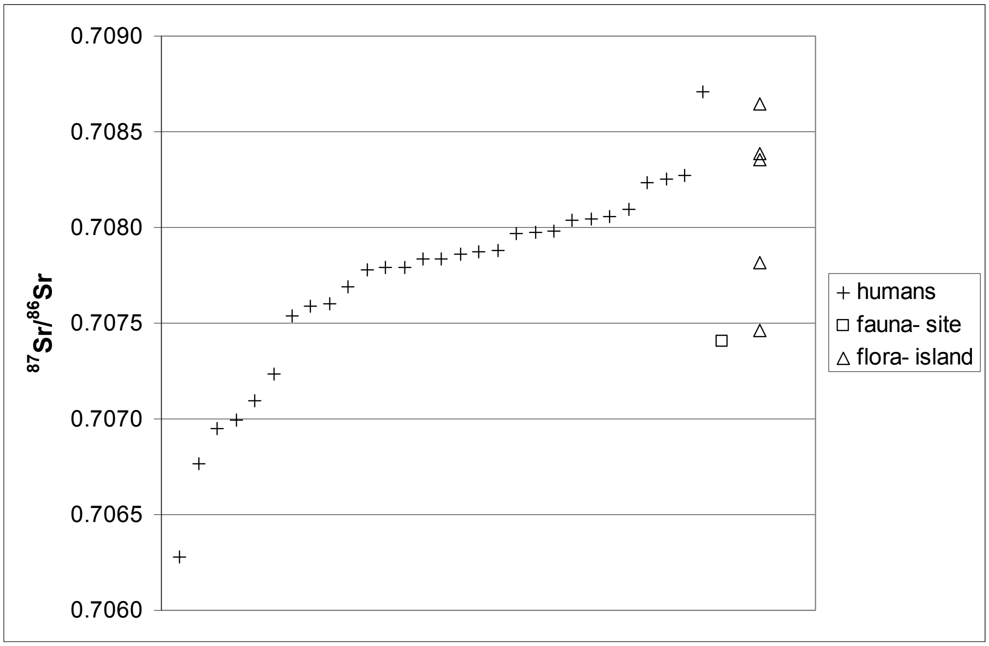

Figure 16 Strontium Isotope Ratios- St. Thomas.
Key: human samples and one faunal sample are from Tutu.

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.

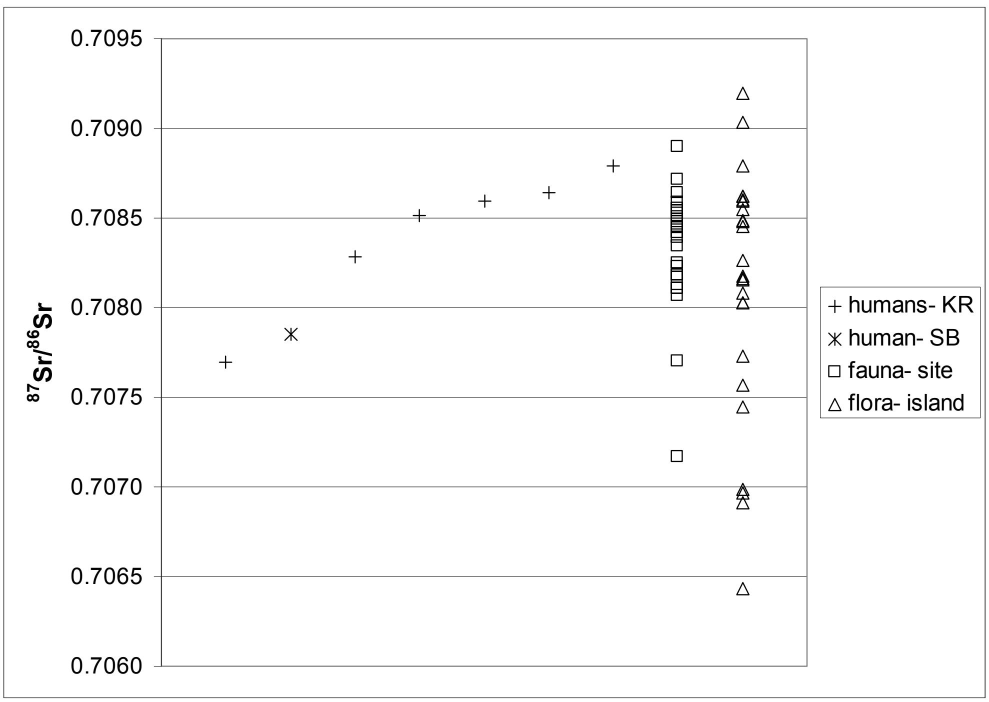

Figure 17 Strontium Isotope Ratios- Saba.
Key: KR = Kelbey's Ridge 2; SB = Spring Bay 1c.

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.

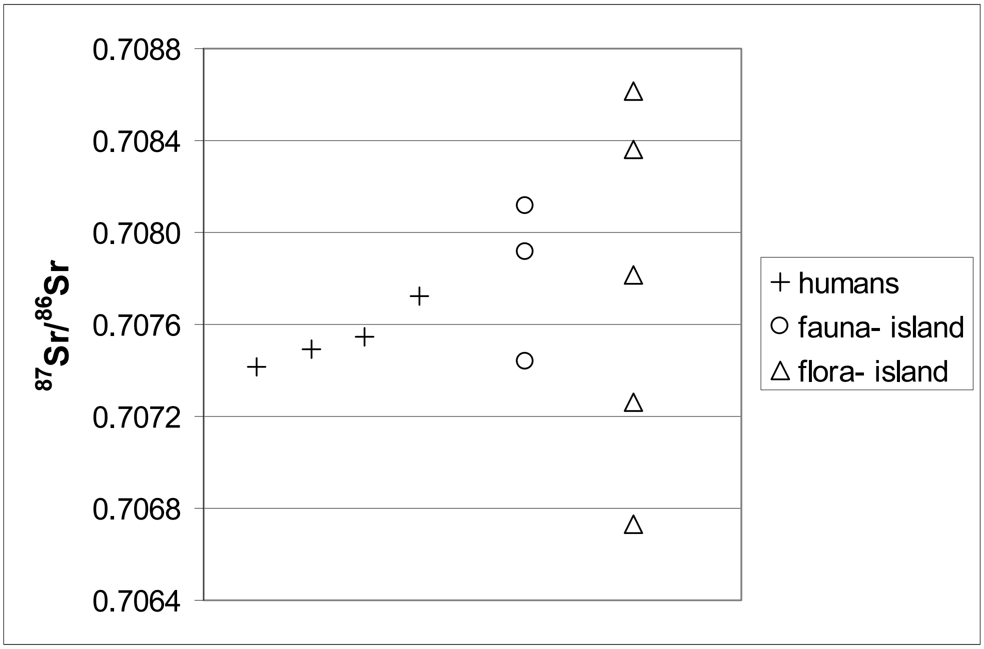

Figure 18 Strontium Isotope Ratios- St. Kitts.
Key: human samples are from Bloody Point, and faunal samples are from Sugar Factory Pier.

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.

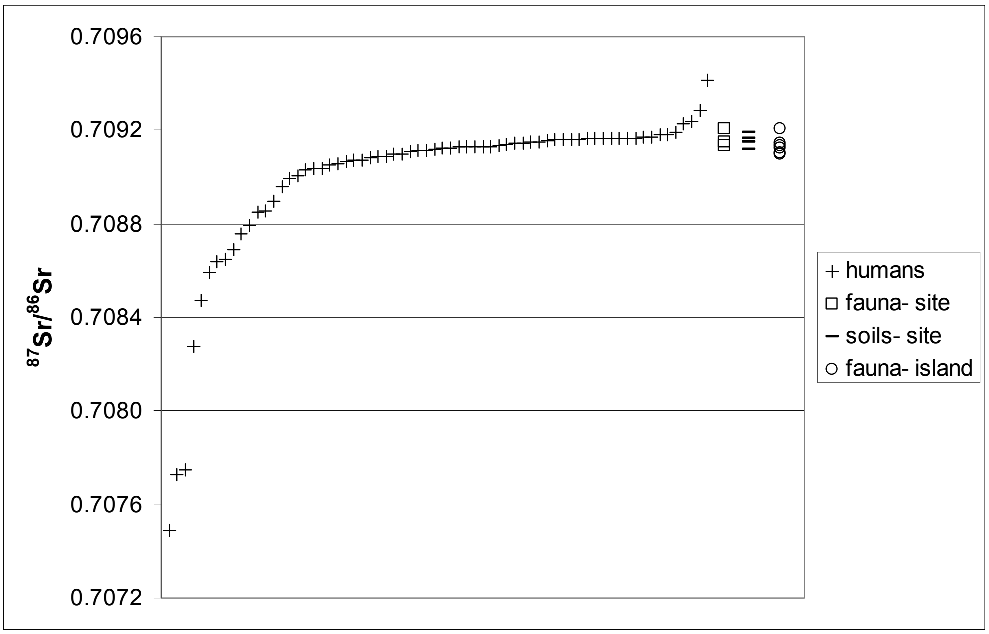

Figure 19 Strontium Isotope Ratios- Grande-Terre, Guadeloupe.
Key: human and soil samples and four faunal samples are from Anse à la Gourde.

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.

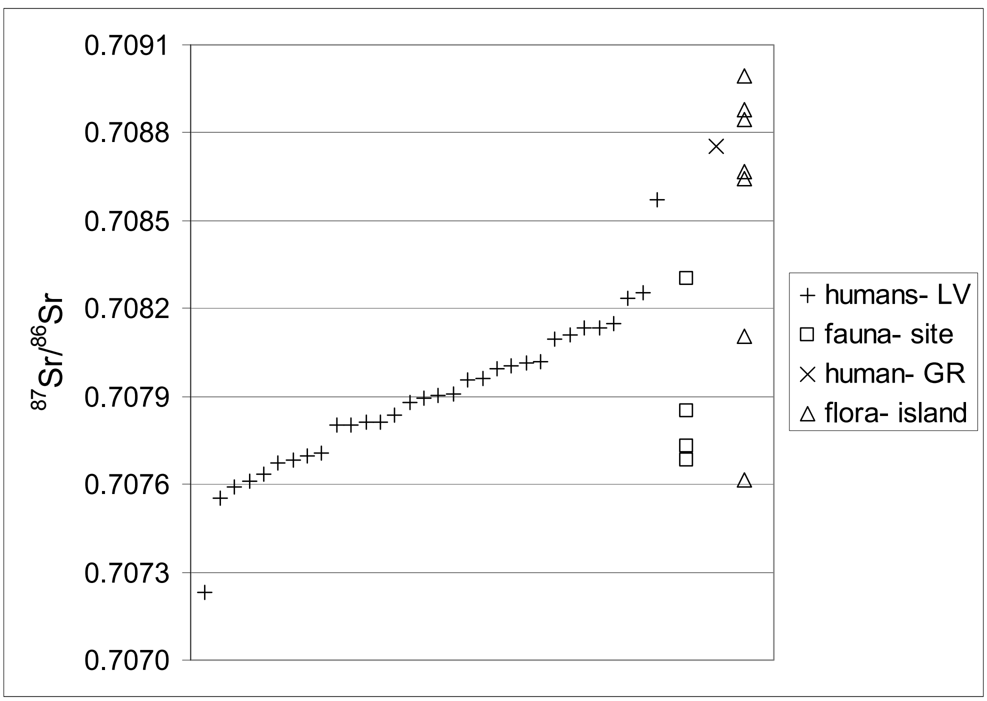

Figure 20 Strontium Isotope Ratios- St. Lucia.
Key: LV = Lavoutte; GR = Giraudy.

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.

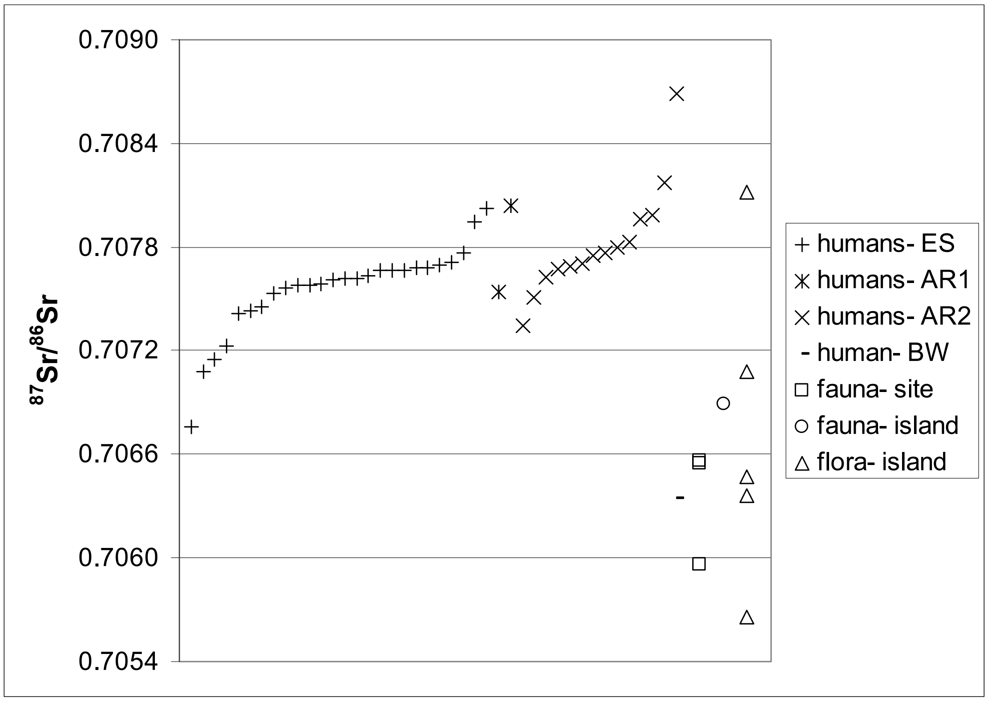

Figure 21 Strontium Isotope Ratios- St. Vincent.
Key: ES = Escape; AR1 = Argyle 1; AR2 = Argyle 2; BW = Buccament West.

<u>6.3.10 Heywoods- Barbados</u>

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).

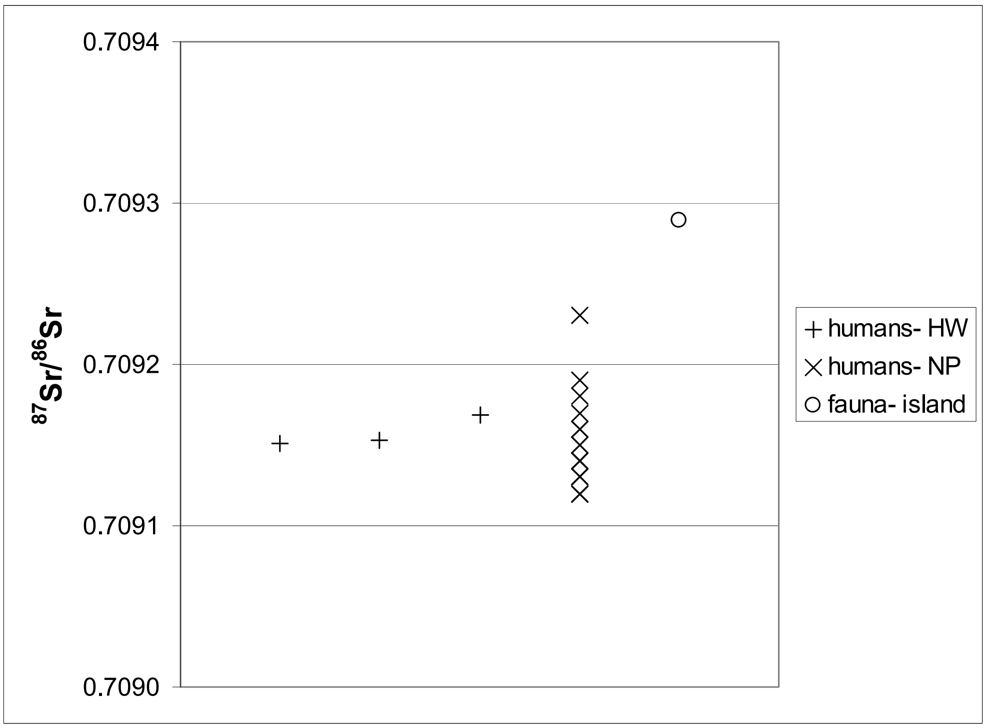

Figure 22 Strontium Isotope Ratios- Barbados.
Key: HW = Heywoods; NP = Newton Plantation. Note: $^{87}Sr/^{86}Sr$ data from NP are from (Schroeder et al. 2009) were not analyzed as part of this study but are displayed for comparison.

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.

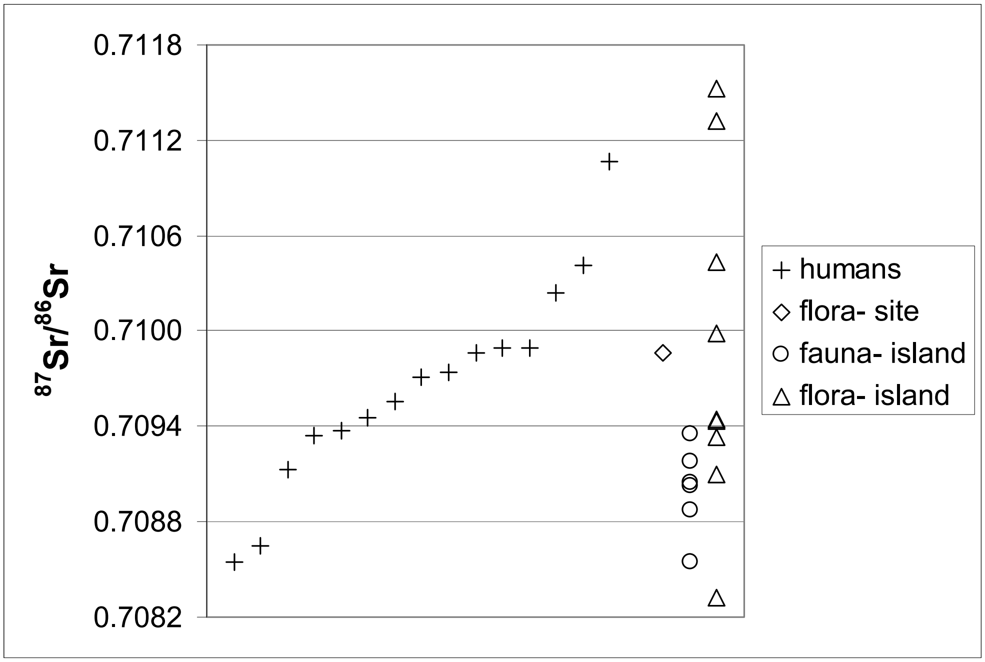

Figure 23 Strontium Isotope Ratios- Trinidad.
Key: all human and one floral sample are from Manzanilla. Note: one extreme (high) human $^{87}Sr/^{86}Sr$ ratio not displayed at this scale.

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.

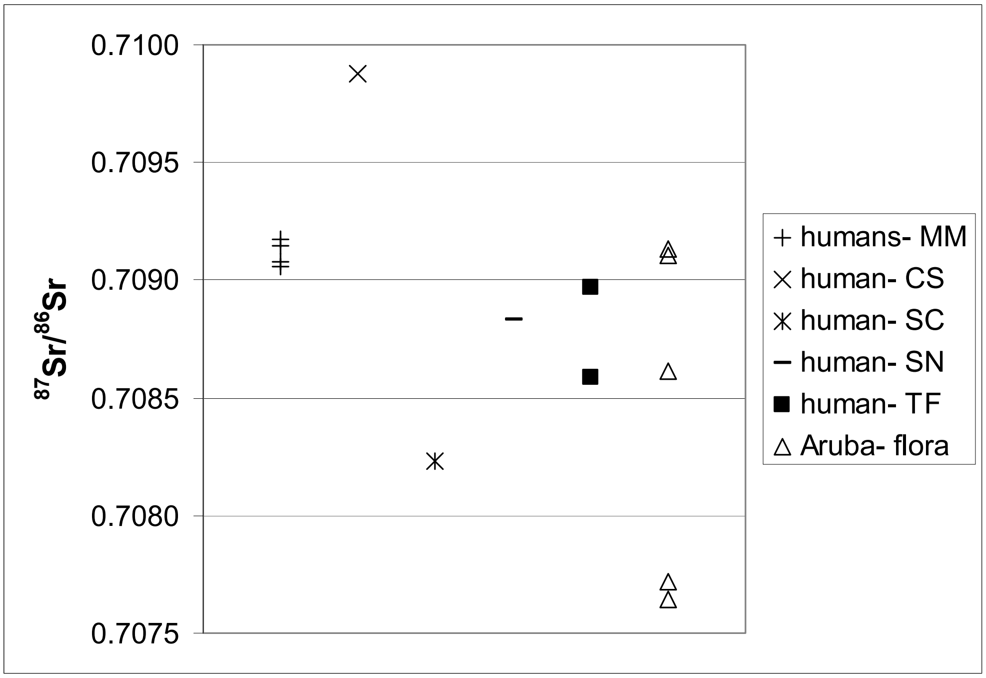

Figure 24 **Strontium Isotope Ratios- Aruba.**
Key: MM = Malmok; CS = Canashito; SC = Santa Cruz; SN = Savaneta; TF = Tanki Flip.

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.

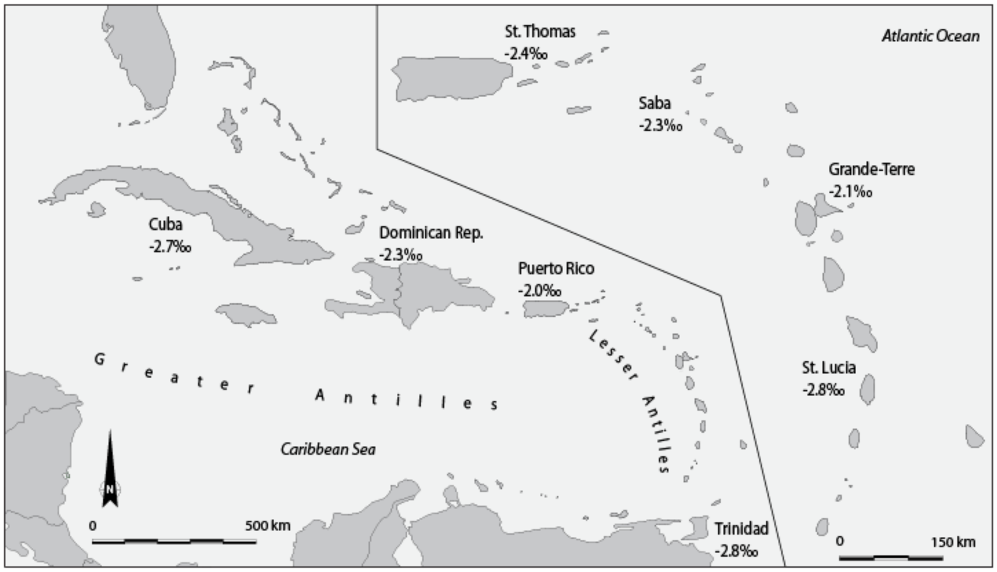

Figure 25 Map of the Caribbean displaying mean human δ^{18}O per island.
Note: mean value for El Chorro de Maíta does not include outliers.

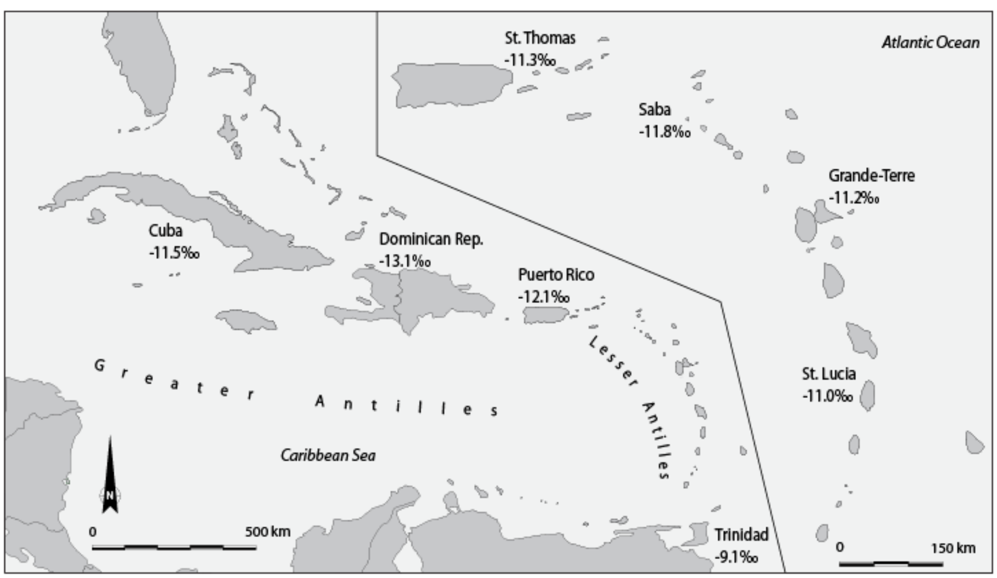

Figure 26 Map of the Caribbean displaying mean human δ^{13}C per island.
Note: mean value for El Chorro de Maíta does not include outliers.

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 $\delta^{18}O$ relative to drinking water, teeth that developed prior to weaning are expected to have elevated $\delta^{18}O$ 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 $\delta^{18}O$ 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).

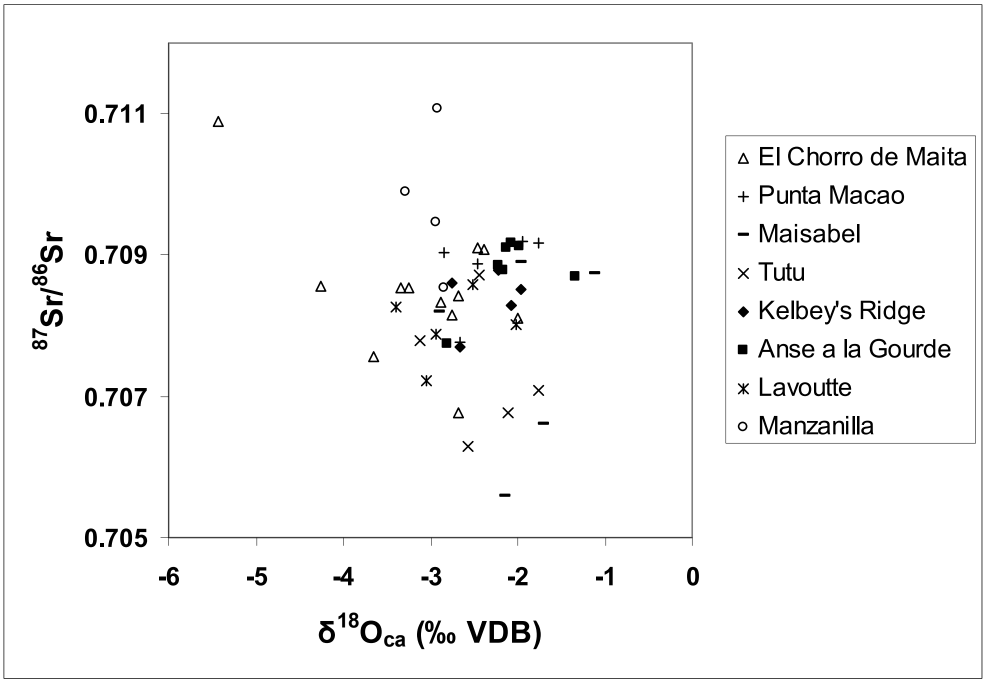

Figure 27 Diagram of human enamel $\delta^{18}O_{ca}$ and $^{87}Sr/^{86}Sr$ data from this study.
Note: one extreme (high) $^{87}Sr/^{86}Sr$ ratio from Manzanilla not displayed at this scale.

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.

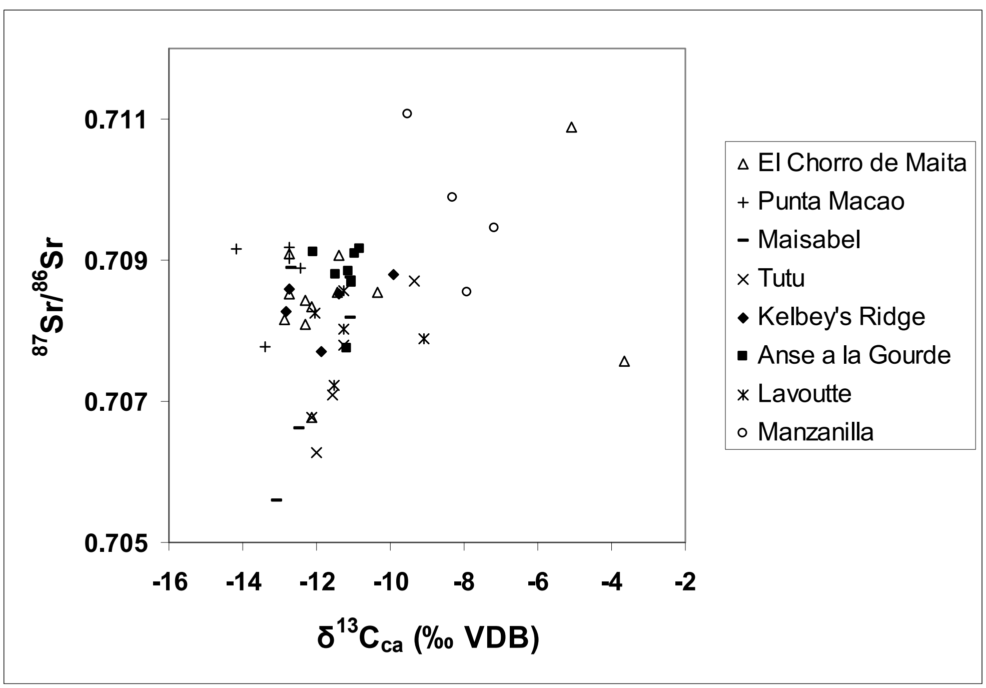

Figure 28 Diagram of human enamel $\delta^{13}C_{ca}$ and $^{87}Sr/^{86}Sr$ data from this study. Note: one extreme (high) $^{87}Sr/^{86}Sr$ ratio from Manzanilla, Trinidad is not displayed at this scale.

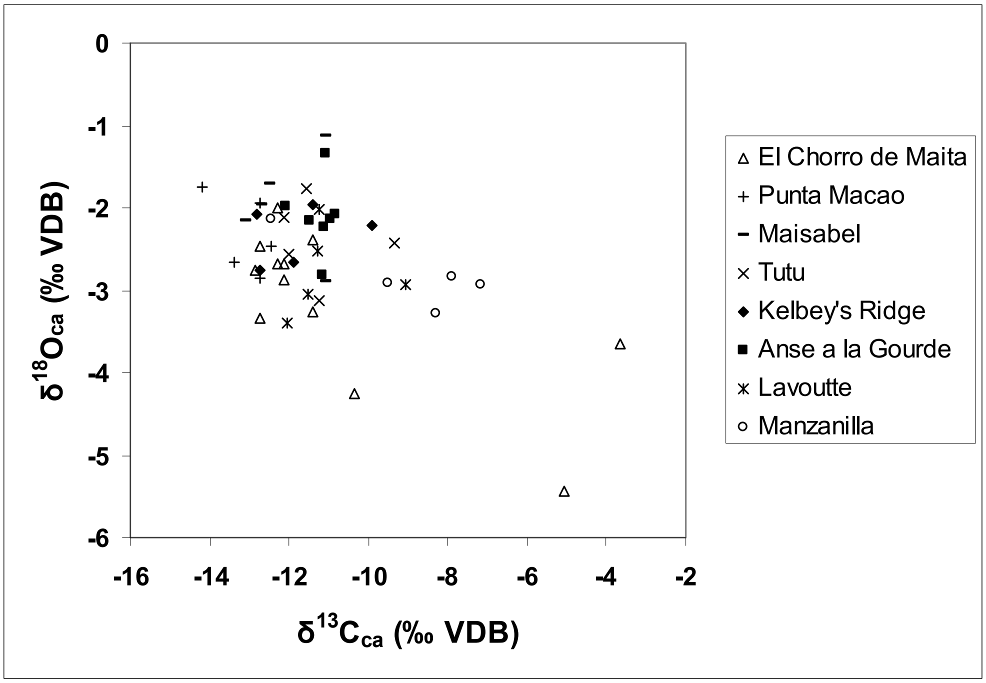

Figure 29 **Diagram of human enamel $\delta^{13}C_{ca}$ and $\delta^{18}O_{ca}$ data from this study.**

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.