

# Isotope Analysis and Radiocarbon Dating of Prehistoric Human Bone from the Manzanilla (SAN 1) Site, Trinidad

Paul F. Healy, Anne Keenleyside, and Marc C. Dorst

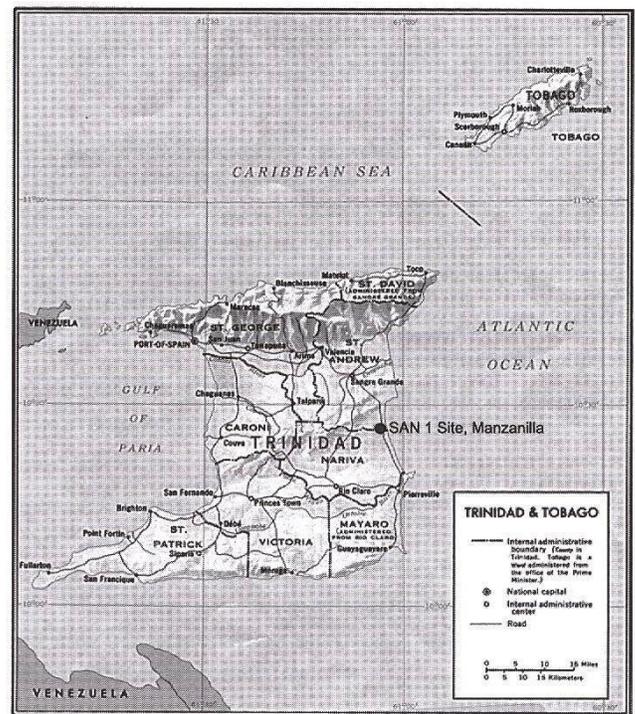
## Abstract

The archaeological site of Manzanilla (SAN 1) is located on Cocos Bay, of the east coast of Trinidad. Although the shell-midden site has been known for at least 60 years, it was examined closely by professionals only in 1997. Larger scale excavations were conducted by a University of Leiden archaeological team in 2001-2007. The results indicated that the 50,000 m<sup>2</sup> site, situated atop a 15 m tall hill, was largely intact. Based on ceramic remains and preliminary radiocarbon analysis, Manzanilla (SAN 1) was initially dated to the Late (Cedrosan) Saladoid through Arauquinoid periods. Excavations unearthed quantities of artifacts (ceramics, lithics, worked shell), ecofacts (animal bone and shell), evidence of two house structures, and other features (including burials). This paper reports on the stable carbon and nitrogen isotope analysis of human bone samples derived from burial features, and compares this data to isotope studies done elsewhere in the Caribbean. Based on the stable isotope values, observations are made about subsistence and diet in ancient Trinidad. In addition, two new radiocarbon determinations on the same bone samples indicate that at least a portion of the habitation at Manzanilla (SAN 1) occurred later (until AD 1400) than original chronological estimates.

## Introduction

The archaeological site of Manzanilla (SAN 1) is located on the sloping coastal region of the Central Range of Trinidad (Boomert 2000:27; Boomert et al. 1997) (Figure 1). Situated near the modern village of

Lower Manzanilla, on the central east coast of the island, the site has been known since at least 1940, but was only closely examined in 1997. During this site survey, Manzanilla (SAN 1) was mapped, systematically auger-tested, and three small test pits were dug in the midden deposits. This revealed that the total site area covers 200 m x 250 m. On the plateau of the hill, four "empty" zones (lacking midden deposits) were located. These have been interpreted as "swept areas", or vacant spaces, where houses and plazas were once situated. Each of the habitation areas measured about 30 x 60 m. Several initial radiocarbon dates indicated habitation at the site spanned from AD 400-900 (Nieweg and Dorst 2001: Table 1). Surrounding these vacant spaces were midden deposits, most of which were washing down the slopes of the hill (Dorst 2000; Nieweg and Dorst 2001).



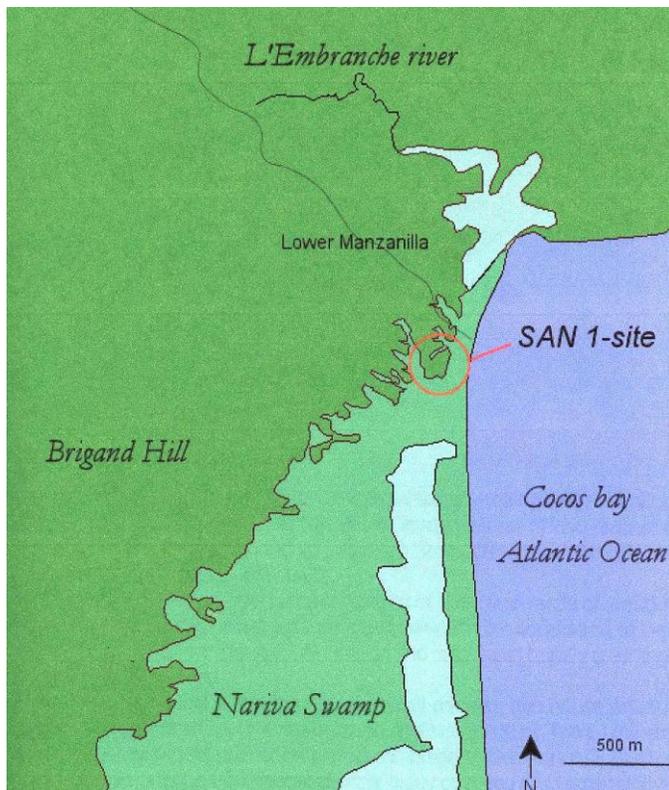
**Figure 1.** Location of the Manzanilla (SAN-1) Site, Trinidad and Tobago (after Jansen and Dorst 2007: Figure 1)

One of these habitation areas was excavated intensively in 2001, and produced subsoil features such as postholes and burials, suggesting that Manzanilla (SAN 1) marked the location of a long-term settlement (Dorst et al. 2003). Fieldwork continued from 2003 to 2007 (Dorst 2007, 2008;

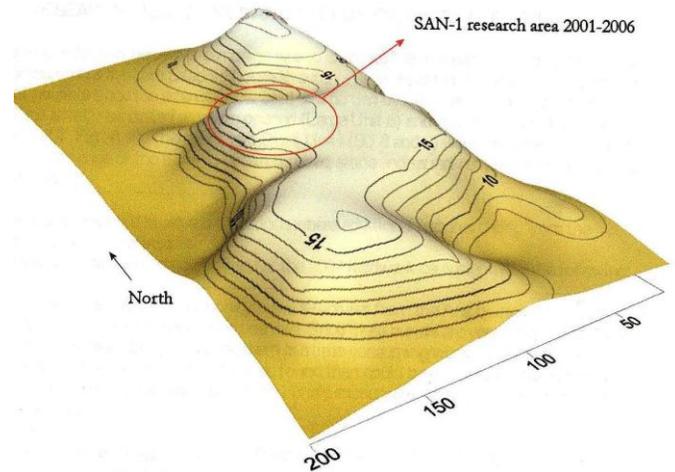
Dorst et al. 2001, 2003, 2004), with results confirming a lengthy Pre-Columbian occupation, including both Early Ceramic Age (Palo Seco) and Late Ceramic Age (Araquinoid) components.

### The Site and Setting

The site of Manzanilla (SAN 1) overlooks Cocos Bay, Trinidad (Figure 2). It is close to the shore, at the northern edge of the large Nariva Swamp, and about 1 km south of the mouth of the L'Ebranche River and its adjacent mangrove tidal woods. Today, the site is atop a large hill marked by quantities of eroding prehistoric pottery fragments and exposed shell, locally termed *Chip-Chip*, a variety of the small coquina clam (*Donax* sp.). The relatively flat summit of the site is surrounded by sloping edges, and considerable amounts of Pre-Columbian artifactual material have eroded from the hillsides (Figure 3).



**Figure 2.** Location of the Manzanilla (SAN-1) Site on Cocos Bay, Eastern Trinidad (after Dorst 2008: Figure 1)



**Figure 3.** Topographic Map of the Manzanilla (SAN-1) Site, Trinidad (after Dorst 2008: Figure 2).

Based on faunal remains recovered at Manzanilla (SAN 1), it appears that settlers exploited three distinct nearby ecozones: tropical forest, coast, and swamp.<sup>2</sup> From the identified faunal remains it is known that the forest exploitation included, especially, the agouti (*Dasyprocta agouti*), paca (*Agouti paca*), collared and white-lipped peccary (*Tayassu tajacu* and *T. pecari*), and red brocket deer (*Mazama Americana*) (Dorst 2000, 2007, 2008; Dorst et al. 2003; Grouard 1998). Other forest animals identified from the site include tapir (*Tapirus* sp.), nine-banded armadillo (*Dasybus novemcinctus*), porcupine (*Coendou prehensilis*), as well as howler (*Alouatta seniculus*) and capuchin (*Cebus albifrons*) monkeys.

From the coast and sea, fish and shellfish, marine species of turtles, iguana (*Iguana* sp.), and crabs were obtained. Marine fish included primarily jacks (Carangidae), grunts (Haemulidae), bonefish (Albulidae), squirrelfish (Holocentridae), and shark (Chondrichthyes). Tortoises (Testudinae) and sea turtles (Cheloniidae) were also caught. About 90% of the faunal material recovered from Manzanilla (SAN 1) consists of marine shells, most of which are bivalves found today in nearby Cocos Bay (Dorst et al. 2003). These include coquina clams (*Donax striatus*), by far the most abundant species at the site, plus trigonal tivela (*Tivela macroides*), Brazilian ark (*Anadara brasiliiana*), West Indian crown conch (*Melongena melongena*), green-star shell (*Astrea tuber*), and conch (*Strombus costatus*) (Nieweg 2000; Dorst et al. 2003).

Freshwater and mangrove swamp areas occur

nearby, and were also exploited for their abundance of animals, birds, and shellfish. Remains of the West Indian manatee (*Trichechus manatus*) and the crab-eating raccoon (*Procyon cancrivorus*) have been recovered. Remains of caiman (cf. *C. crocodiles*), and possibly anaconda (*Boidea sp.*), have also been identified. Various waterfowl, such as ducks and ibis, freshwater and land turtles, and iguana are present in the swamp today and may have also been exploited. Freshwater to brackish water fish species included catfish (*Arius proops*), and probably mullet (*Mugil sp.*) and snook (*Centropomus sp.*). Remains of the mangrove oyster (*Crasostrea rhizophorae*) also appear in the shell midden of the site and likely were derived from this ecozone (Dorst et al. 2004).

On the basis of faunal remains, by intensity of exploitation of major habitats, Boomert (2000: Table 46) suggests that the marine ecozone (including inshore/estuarine, banks/reefs, offshore/pelagic, and beach) was most heavily exploited (54.5%) by the settlers of Manzanilla (SAN 1), followed by the terrestrial habitat (44.4%), with the freshwater habitat the least well represented (1.1%), based on total faunal remains. This calculation does *not* include marine shellfish, which would have tipped the balance of exploitation even more to the marine habitat.

Unfortunately, until recently, there has been little direct evidence recovered for plant use at Manzanilla (SAN 1). At the time of Contact, based on ethnohistoric accounts, many aboriginal groups of the Greater and Lesser Antilles had an agricultural economy growing maize (*Zea mays*) and several varieties of root crops, especially manioc (*Manihot sp.*). Fragments of ceramic griddles found at Manzanilla (SAN 1) suggest possible preparation of manioc (or cassava) bread, although other crops may also have been processed (DeBoer 1975; Mickleburgh and Pagan-Jimenez 2012; Rodriguez Suarez and Pagan Jimenez 2008). Isotope analyses of human bone from burials at Manzanilla (SAN 1), reported below, provide new insights to subsistence and diet, and indirect evidence for the use of plants and animals.

## Excavations

Excavations at Manzanilla (SAN 1) included several long trenches, an intensive 1m x 1m interval auger test program, and both small and large excavation units (Dorst 2007, 2008; Dorst et al. 2001,

2003, 2004). In total, over 500 m<sup>2</sup> were excavated. Tests were carried to a maximum depth of 180 cm below the modern surface for the midden deposits and some 40 cm below the present day surface on the plateau area. Insights to the stratigraphy and layout of the ancient community were gained from these excavations.

Since the total excavated area remains small, the interpretation of the spatial layout of structures at Manzanilla (SAN 1) is still preliminary. Jansen and Dorst (2007) suggest that two different habitation phases are present within the excavated area of the site, a Late Cedrosan Saladoid (Palo Seco) component, and an Arauquinoid (Bontour) component. A large, (late) Palo Seco midden deposit, with five associated burials, represents the initial habitation phase. It is assumed that houses of this period are located on the eastern (seaside) part of the excavated area. The Arauquinoid (Bontour) phase is represented by at least two house structures, pits, burials, and a small midden deposit. Based on mapped postholes, two perishable wood-and-thatch structures have been reconstructed.

The first house, called Structure A, was round-to-oval in shape, measuring 6 x 8m, with one central post (the hole containing a secondary burial), seven side posts, and one repair post. The second house, Structure D, is oval-shaped, measuring 9m x 12m, with two central posts and at least 15 side posts (Dorst et al. 2001, 2003, 2004; Jansen and Dorst 2007). At least one shallow hearth, or cooking pit, has been identified as well (Dorst et al. 2001). The Manzanilla (SAN 1) post-based floor plans are interpreted as the remains of houses and are reminiscent of the type of domestic structures excavated at Anse a la Gourde on Guadeloupe (Hofman et al. 1999), the Golden Rock site on St. Eustatius (Versteeg and Schinkel 1992), and the Tutu site on St. Thomas (Righter 2002; Righter et al. 2004).

Boomert (2000:500) classifies Manzanilla (SAN 1) as a multi-component settlement site. Using associated ceramics and stratigraphy, Structures A and D at Manzanilla (SAN 1) were dated to the Arauquinoid phase, and more specifically to AD 650-1400 (Boomert 1983; Harris 1978, 1985; Rouse 1992: Figure 9). Previous radiocarbon dates, recorded from 1997, indicated an earlier occupation, from about AD 400-900 (Dorst 2000:66; Jansen and Dorst 2007; Nieweg and Dorst 2001: Table 1).<sup>3</sup> The suggested late

Palo Seco burials at the site are located below, and in close proximity to, the late Palo Seco midden deposit, suggesting a specific communal burial ground at this time (Altena 2007; Jansen and Dorst 2007). The Arauquinoid burials, by contrast, are found surrounding, and associated with, the two dwellings identified. This pattern suggests a more family-based burial orientation in the latter period (Altena 2007; Dorst et al. 2003, 2004). New radiocarbon dates, reported here, indicate that at least some of the human burials associated with one house (Structure A) are even younger than previously realized.

## Burials

So far, excavations have revealed the presence of 43 whole, or partial, burials at Manzanilla (SAN 1), with 21 excavated (Altena 2007; Baetsen 2003; Dorst et al. 2001; 2004).<sup>4</sup> Very few of the excavated burials have produced mortuary offerings. All of the burials unearthed are in simple graves. The interments were found in a variety of positions (flexed and extended) and orientations, with both primary and secondary burials noted. Some are multiple burials. Many of the burials that are associated with the Arauquinoid occupation are found immediately outside the domicile walls, suggesting a predominantly house-related mortuary disposal practice. The anatomical position of two interments, from Burial Features 16 and 18, identified from Trench 2, are of special interest here, and indicate that these were primary burials. Both individuals were adults, with the individual from Burial Feature 16 possibly being over 70 years old, and the individual from Burial Feature 18 possibly being over 50 years of age.<sup>5</sup> From observations taken in the field, the individual in Burial Feature 16 was female, while the individual from Burial Feature 18 was judged in the field to be a possible female, based on epiphyseal diameter (Bateson 2003; Dorst et al. 2003:50). Additional laboratory analysis confirms this determination. Some of the vertebrae of this individual show signs of osteoarthritis (Dorst et al. 2003:49-50). Bone samples from Burial Feature 16 and 18 were used for the isotope analysis and additional radiocarbon dating reported here.

## Stable Isotopes and Diet

Stable carbon and nitrogen isotope analysis of bone collagen provides direct evidence of diet, and reflects the average isotopic composition of an individual's intake of dietary protein as well as other nutrients (DeNiro and Epstein 1978; Krueger and Sullivan 1984; Schwarcz 2000) over a period of 10 years or more (Manolagas 2000). Dietary reconstruction using stable carbon isotope analysis of collagen, the major organic component of bone, is based on the fact that different foods differ in their stable carbon isotope ratio,  $^{13}\text{C}/^{12}\text{C}$ , usually expressed as  $\delta^{13}\text{C}$  in per mil (‰) relative to Vienna Pee Dee Belemnite (VPDB). Among plant foods, the main differences in  $\delta^{13}\text{C}$  arise between plants that follow different photosynthetic pathways.  $\text{C}_3$  plants, which include most temperate region plants and some subtropical grasses, including wheat and barley, have  $\delta^{13}\text{C}$  values ranging from -20‰ to -34‰, with an average of -26.5‰ (Deines 1980; DeNiro 1987; Smith and Epstein 1971). In contrast,  $\text{C}_4$  plants, which include maize, millet, and sorghum, have  $\delta^{13}\text{C}$  values ranging from -9‰ to -16‰, with an average of 12.5‰ (Deines 1980; DeNiro 1987; Smith and Epstein 1971). The  $\delta^{13}\text{C}$  value of collagen of humans and large mammals who consume a mono-isotopic diet (i.e., a diet in which the proteins and non-proteins have similar  $\delta^{13}\text{C}$  values) is generally about 5‰ higher than that of their diet although this value can vary when the  $\delta^{13}\text{C}$  values of low- and high-protein foods differ (Ambrose et al. 1997). Thus individuals who consume only  $\text{C}_3$  plants have  $\delta^{13}\text{C}$  values of about -20‰ (Chisholm et al. 1982; Lubell et al. 1994), while individuals who consume a diet rich in  $\text{C}_4$  plants can have  $\delta^{13}\text{C}$  values as high as -10‰ (Schwarcz et al. 1985). Therefore, stable carbon isotope analysis of bone collagen can be used to determine the contribution of  $\text{C}_3$  versus  $\text{C}_4$  plants to the diet. Carbon isotope ratios can also be used to investigate the proportion of terrestrial and marine foods in environments, because marine animals and fish are systematically enriched by about 7‰ with respect to terrestrial consumers (Chisholm et al. 1982).

Dietary reconstruction using stable nitrogen isotope analysis of bone collagen looks at the ratio of the stable isotopes  $^{15}\text{N}$  to  $^{14}\text{N}$ , expressed as  $\delta^{15}\text{N}$  in

per mil relative to atmospheric N<sub>2</sub> (AIR). These values principally reflect trophic level, or the position of an individual in the food chain. Carnivores have δ<sup>15</sup>N values that are approximately 3‰ higher than the herbivores they consume which, in turn, have values that are 3‰ higher than the plants they consume (DeNiro and Epstein 1981; Schwarcz and Schoeninger 1991). The δ<sup>15</sup>N value of human bone collagen is therefore about 3‰ higher than the δ<sup>15</sup>N value of the protein that the human has ingested (Ambrose 1993; DeNiro and Epstein 1981). Marine organisms tend to have higher δ<sup>15</sup>N values than terrestrial organisms due to the higher values of their source nitrogen and the greater length of trophic chains in marine environments (Norr 2002; Schoeninger 2010). One exception is reef fish, which have δ<sup>15</sup>N values comparable to those of terrestrial animals due to the higher level of nitrogen fixation that occurs in reef environments. Thus individuals who consume only terrestrial protein sources have lower δ<sup>15</sup>N values of about 8.5‰, while those who obtain the majority of their dietary protein from marine foods have higher δ<sup>15</sup>N values of about 13‰ (Lubell et al. 1994). Among coastal populations where the consumption of marine foods can yield δ<sup>13</sup>C values within the range of C<sub>4</sub> plant consumers, stable nitrogen isotope analysis is combined with stable carbon isotope analysis in order to distinguish between dietary protein derived from marine resources vs. terrestrial foods (Larsen et al. 1992; White 1994).

Stable isotope analysis of bone carbonate, the mineral component of bone, provides a profile of δ<sup>13</sup>C of the total diet (Ambrose and Norr 1993; Norr 1995) but must be approached with caution due to the greater likelihood of alteration of the structural carbonate by diagenesis. Furthermore, the fractionation (isotopic offset) between diet and the mineral component of bone is not precisely known, although it has been found to vary from about 9‰ to 14‰ (Passey et al. 2005). The difference between δ<sup>13</sup>C values of bone collagen (δ<sup>13</sup>C<sub>co</sub>) and those of bone carbonate (δ<sup>13</sup>C<sub>ca</sub>), expressed as Δ<sup>13</sup>C<sub>ca-co</sub>, has also been used to reconstruct diet, with spacings of approximately 7‰ reported for herbivores, 5‰ for omnivores, and 3-4‰ for carnivores (Krueger and Sullivan 1984; Lee-Thorp et al. 1989). In situations where individuals may

have been consuming a mixture of foods, however, the carbonate to collagen spacing may not accurately reflect the diet (Ambrose et al., 1997; Froehle et al. 2012; Kellner and Schoeninger, 2007). Ambrose and colleagues (1997) suggest that individuals who consume a mono-isotopic diet will have a Δ<sup>13</sup>C<sub>ap-co</sub> value of 4.4‰, while those who consume a mixture of foods will have higher (in the case of C<sub>3</sub> proteins and C<sub>4</sub> carbohydrates) or lower (in the case of marine/C<sub>4</sub> proteins and C<sub>3</sub> carbohydrates) values. More recently, Kellner and Schoeninger (2007) have argued that comparing δ<sup>13</sup>C<sub>co</sub> to δ<sup>13</sup>C<sub>ca</sub> rather than looking at the absolute value of Δ<sup>13</sup>C<sub>ca-co</sub> provides a more accurate dietary reconstruction, although they acknowledge that their model discriminates poorly between C<sub>4</sub> and marine protein in the diet. In an attempt to rectify this problem, Froehle and colleagues (2012) incorporate nitrogen isotope data into their model and generate discriminant functions that can be used to classify individuals according to diet. In environments where individuals consume lower trophic level reef fish and shellfish and thus have depleted δ<sup>15</sup>N values, this model may, however, misidentify these individuals as having consumed C<sub>3</sub> and C<sub>4</sub> protein sources (Rand et al. 2013).

## Materials and Methods

A small collection of human bone fragments from the Manzanilla (SAN 1) site was provided by the University of the West Indies (UWI) for stable isotope analysis. The collection consisted of rib and/or long bone fragments from two individuals: an adult female from Burial Feature 16 (2 samples), and another adult, possibly female, from Burial Feature 18 (1 sample). For analysis of δ<sup>13</sup>C<sub>co</sub> and δ<sup>15</sup>N<sub>co</sub>, collagen was extracted from the samples following the procedures outlined in Longin (1971) and modified by Chisholm et al. (1983).<sup>6</sup> In order to assess the degree of preservation and quality of the samples, the collagen yield (weight of collagen/weight of bone x 100) and the carbon to nitrogen ratios (C:N) of each sample were calculated.

Two of the three bone samples (Burial Feature 16 #18, and Burial Feature 18 #64) were also analysed for δ<sup>13</sup>C of bone carbonate (δ<sup>13</sup>C<sub>ca</sub>). The samples were prepared following the methodology outlined in Lee-

Thorp and van der Merwe (1987).<sup>7</sup> In order to test for possible diagenetic alteration of the carbonate, the samples were examined using Fourier transform infrared spectrometry (FTIR), following the procedures outlined in Wright and Schwarcz (1996).<sup>8</sup>

### Results and Discussion of the Isotope Analysis

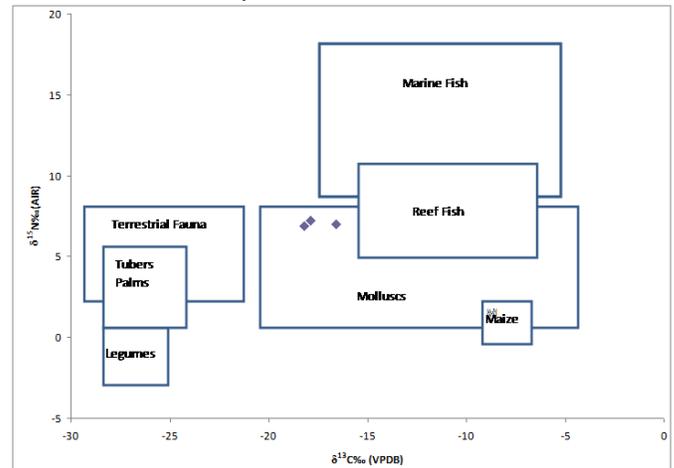
The  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values obtained from the three collagen samples ( $\delta^{13}\text{C}_{\text{co}}$  and  $\delta^{15}\text{N}$ ) are listed in **Table 1**. The  $\delta^{13}\text{C}_{\text{co}}$  values range from -11.6‰ to -13.2‰. The  $\delta^{15}\text{N}$  values range from 9.9‰ to 10.2‰. All three collagen samples had yields greater than the minimum required 1% (Ambrose 1993; Schwarcz and Schoeninger 1991), and the carbon to nitrogen ratios fell within the range of 2.9-3.6 considered acceptable for isotope analysis (DeNiro 1985). The  $\delta^{13}\text{C}$  values for the two bone carbonate samples ( $\delta^{13}\text{C}_{\text{ca}}$ ) are -7.6‰ and -8.2‰, and the carbonate to collagen spacings are 4.0‰ and 4.7‰. Both samples had a crystallinity index of 2.3. This value is lower than that measured in modern human bone (CI=3.1), and indicates low to moderate diagenetic alteration (Wright and Schwarcz 1996).

Sample #	Sex	Age	$\delta^{13}\text{C}_{\text{co}}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}_{\text{ca}}$	$\Delta^{13}\text{C}_{\text{ca-co}}$	C:N ratio	% yield
F16#9	F	Adult	-13.2	9.9	-	-	3.05	4.5
F16#18	F	Adult	-12.9	10.2	-8.2	4.7	3.12	5.3
F18#64	F?	Adult	-11.6	10.0	-7.6	4.0	3.15	1.4

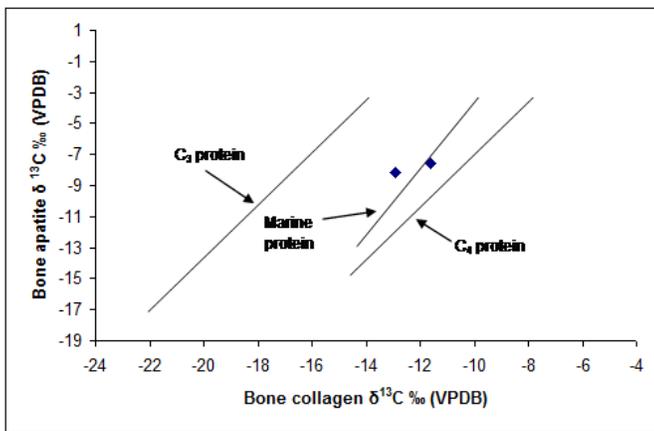
**Table 1.** Stable Isotope Values (‰) for the Human Bone Samples from Manzanilla (SAN 1)

In order to interpret the stable isotope data from Manzanilla (SAN 1), the isotope values measured in the human bone collagen samples were compared to those obtained for a variety of food sources likely to have been available to the inhabitants of this site (**Figure 4**). The  $\delta^{13}\text{C}$  values for bone collagen from the Manzanilla (SAN 1) samples indicate that dietary protein was derived primarily from marine/ $C_4$  resources. The  $\delta^{15}\text{N}$  values are higher than what would be expected for individuals consuming an abundance of maize or other  $C_4$  plants, and indicate that the protein component of the diet was composed of higher trophic level marine and/or terrestrial

species. The  $\delta^{13}\text{C}$  values for the carbonate samples fall between those for  $C_3$  and  $C_4$  diets, suggesting that part of the total diet was derived from  $C_3$  plants, such as the tuberous root crop manioc (or cassava, *Manihot esculenta*), and that some  $C_4$  plants may also have been consumed. When the  $\delta^{13}\text{C}$  collagen values are plotted against the  $\delta^{13}\text{C}$  carbonate values in comparison to the regression lines developed by Kellner and Schoeninger (2007), the values for individual F16#18 fall between the  $C_3$  protein and marine protein lines but closer to the latter, while the values for individual F18#64 fall almost directly on the marine protein line (**Figure 5**). These results are consistent with the expected diet of this population based on the zooarchaeological evidence, the location of the site, and the island ecosystem.



**Figure 4.** Human isotope values in bone collagen samples from Manzanilla (SAN 1) compared to the isotopic composition of food resources in the Caribbean region (modified from Norr 2002, Figure 10.1). The human isotope values have been adjusted by 5‰ for  $\delta^{13}\text{C}$  and 3‰ for  $\delta^{15}\text{N}$ .



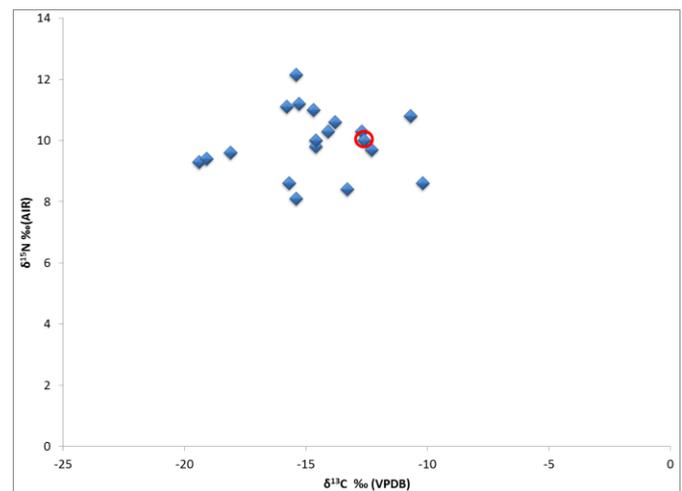
**Figure 5.** Manzanilla (SAN 1) collagen and bioapatite  $\delta^{13}\text{C}$  values plotted on Kellner and Schoeninger's (2007: 1122) bivariate plot with regression lines indicating different protein sources.

We know from ethnohistoric accounts that maize (*Zea mays*) was being cultivated by the Taino on some of the larger Caribbean islands at the time of contact (Oviedo 1959:13-15; Sauer 1966, 1969), and maize pollen and macrobotanical remains have been found at some archaeological sites in the West Indies (Berman and Pearsall 2008; Newson and Deagan 1994). A study by Mickleburgh and Pagan-Jimenez (2012) has recently revealed starch grains and phytoliths trapped in human dental calculus at Caribbean sites, including Manzanilla (SAN 1), suggesting (again) that maize may have been consumed more commonly than previously thought. It could have been ground, baked, and then eaten as bread- as in Mesoamerica. Interestingly, the same study produced no paleobotanical evidence of manioc from the single Manzanilla (SAN 1) sample.

To the best of our knowledge, there are no other published results of isotope analysis of human bone from Pre-Columbian contexts in Trinidad. Isotopic analysis has been performed, however, on human bone samples from a number of other Caribbean archaeological contexts (Buhay et al. 2012; deFrance et al. 1996; Keegan 1985; Keegan and DeNiro 1988; Laffoon and de Vos 2011; Norr, 2002; Stokes, 1998, 2005; van Klinken 1991; Varney 2003). The most significant of these investigations was conducted by Stokes (1998), who analyzed human bone samples from 13 islands, dating to several prehistoric time periods. The results of her research revealed geographic variation in dietary patterns throughout this region, reflecting differences between islands in

the availability of food resources. Her data also revealed dietary differences within islands, reflecting proximity of sites to the coast.

A comparison of mean isotope values measured in the Manzanilla (SAN 1) samples with those from other archaeological sites in the West Indies (Table 2 and Figure 6) reveals the greatest similarities between Manzanilla (SAN 1) and Eleuthera in the Bahamas, both of which are limestone islands. While the samples from both sites are admittedly very small, the isotope data point to the consumption of marine resources, including reef fish and molluscs, and terrestrial  $\text{C}_3$  resources. In contrast, the data derived from other sites indicate a greater reliance on  $\text{C}_3$  protein and energy in the case of Puerto Rico and Haiti, and a greater reliance on marine protein at other sites. Unfortunately, the small sample size from Manzanilla (SAN 1) precludes the analysis of intra-population variation in diet, and additional samples will be required in order to assess the overall dietary pattern at this site. As noted by both Stokes (2005) and Norr (2002), the lack of bone carbonate data from many sites in the Caribbean makes it impossible to interpret the whole diet, and future research within this region will require isotope data from both collagen and carbonate for a more accurate reconstruction of the ancient diet.



**Figure 6.** Scatterplot of mean  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values for human bone collagen samples from Manzanilla (SAN 1) and other Caribbean archaeological sites listed in Table 2. The Manzanilla sample is circled.

Site	$\delta^{13}\text{C}_{\text{co}}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}_{\text{ca}}$	$\Delta^{13}\text{C}_{\text{ca-co}}$
Manigat Cave, La Tortue, Haiti (n=15) <sup>a</sup>	-15.4	8.1	-9.2	6.1
N. Bannerman Cave, Eleuthera, Bahamas (n=1) <sup>a</sup>	-12.3	9.7	-7.7	4.5
Sandy Hill, Anguilla (n=3) <sup>a</sup>	-14.6	9.8	-9.2	5.3
Petite Rivière, La Désirade, Guadeloupe (n=3) <sup>a</sup>	-14.1	10.3	-8.2	5.9
Anse à la Gourde, Guadeloupe (n=21) <sup>a</sup>	-14.6	10.4	-8.2	6.4
Anse à la Gourde, Guadeloupe (n=59) <sup>b</sup>	-14.7	11.0	-	-
Paso del Indio, Puerto Rico (n=11) <sup>c</sup>	-19.4	9.3	-9.8	9.6
Maisabel, Puerto Rico (n=18) <sup>c</sup>	-18.1	9.6	-10.0	8.1
Tutu (pre AD 1000), St. Thomas, U.S. Virgin Islands (n=8) <sup>d</sup>	-15.3	12.2	-10.5	4.9
Tutu (post AD 1000), St. Thomas, U.S. Virgin Islands (n=17) <sup>d</sup>	-15.5	12.1	-10.5	5.0
Grand Bahama (n=2) <sup>e</sup>	-13.3	8.4	-	-
Great Abaco, Bahamas (n=1) <sup>e</sup>	-15.7	8.6	-	-
Eleuthera, Bahamas (n=3) <sup>e</sup>	-12.7	10.3	-	-

Site	$\delta^{13}\text{C}_{\text{co}}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}_{\text{ca}}$	$\Delta^{13}\text{C}_{\text{ca-co}}$
Rum Cay, Bahamas (n=1) <sup>e</sup>	-10.7	10.8	-	-
San Salvador, Bahamas (n=2) <sup>e</sup>	-14.6	10.0	-	-
Long Island, Bahamas (n=1) <sup>e</sup>	-15.8	11.1	-	-
Crooked Island, Bahamas (n=5) <sup>e</sup>	-13.8	10.6	-	-
Providenciales, Bahamas (n=2) <sup>e</sup>	-10.2	8.6	-	-
Puerto Rico (n=1) <sup>e</sup>	-19.1	9.4	-	-
Canimar Abajo, Cuba (n=28) <sup>f</sup>	-15.3	11.2	-	-

<sup>a</sup>Data from Stokes (1998); mean values given

<sup>b</sup>Data from Laffoon and de Vos 2011; mean values given

<sup>c</sup>Data from Stokes (2005); mean values given

<sup>d</sup>Data from Norr (2002); mean values given

<sup>e</sup>Data from Keegan and DeNiro (1988) ; mean values given

<sup>f</sup>Data from Buhay et al. 2012; mean values given

**Table 2.** Mean Stable Isotope Values (‰) from Archaeological Sites in the West Indies

### Radiocarbon Dating

Radiocarbon determinations were obtained on human bone collagen from the same individuals (from Burial Features 16 and 18) used for the isotope analysis (**Table 3**). Samples were given analysis by Accelerator-Mass-Spectrometer (AMS)<sup>9</sup>. The dates are very consistent, and indicate that both individuals were interred between Cal AD 1290-1410 (at a 95% probability level). This is several centuries more recent than preliminary chronological assignments at the site (given as AD 300-1200), which were based on ceramic identifications and two previous C-14 dates taken on charcoal (Cal AD 406-892; see Nieweg and Dorst 2001: Table 1). Given the artifactual remains at the site, and secure ceramic cross-dating, it is likely that Manzanilla (SAN 1) was occupied for more than

a millennium, from the Late Cedrosan Saladoid (ca. AD 300) to the Arauquinoid (ca. AD 1400) times. Continuous habitation of the investigated part of the site is unlikely, considering the long time span compared to the low number of post holes for clearly identified structures, but only further research can clarify this.

Sample	Radiocarbon Age	Calibrated Age**	Intercepts***
Beta-193442	630+/-40 BP	Ca1 AD 1290-1410	Ca1 AD 1310, 1370, 1380
Feature 16			
Beta-193443	620+/-40 BP	Ca1 AD 1290-1410	Ca1 AD 1310, 1360, 1390
Feature 18			

\* Samples were analyzed by Beta Analytic Inc. (Miami, Florida)

\*\* 2 Sigma, 95% probability

\*\*\* Intercepts of radiocarbon age with calibration curve

**Table 3.** Radiocarbon dates from Manzanilla (SAN 1) Site, Trinidad

## Conclusions

Excavations of the shell midden archaeological site of Manzanilla (SAN 1), located atop a 15 m tall hill on the central east coast of Trinidad, have revealed human occupation between about AD 300-1400. The earliest phase of habitation (Cedrosan Saladoid) is characterized by a late Palo Seco (AD 300-650) midden deposit with at least five associated burials. No other Saladoid features, such as postholes, are present to indicate house structures of this phase in the areas investigated so far. The second habitation phase, Arauquinoid (AD 650-1440), is marked by posthole features, pits, a large number of burials, and a small midden. Two Arauquinoid house structure plans were identified, both with an oval-circular form aligned north-south (long axis), located next to each other. Associated burials are located closely surrounding these houses. The plaza area of this later village ring is present to the east (seaside area) of these houses. Much of the hill's slopes are covered today by shell (midden) refuse.

In total, 43 burials have been found, of which 21 have been excavated and documented. The Arauquinoid burials are found surrounding the identified houses. This is similar to a practice

observed at the Tutu site on St. Thomas (Virgin Islands) for the late occupation (AD 1150-1500) there (Righter 2002:106-8; Righter et al. 2004: 110). At least 20 burials were located around, and associated with, Structure A at Manzanilla (SAN 1) (Dorst et al. 2004:24). These include two interments (Burial Features 16 and 18) from which osteological remains were obtained for the stable carbon and nitrogen isotope analysis and chronological assessment, reported in detail here.

What was the relationship (if any) between these two occupations? Rouse (1947:Fig. 1) developed the first archaeological chronology for Trinidad, which was subsequently refined by Harris (1978:Fig. 6) and, most recently, by Boomert (2000:Fig. 15). The chronology is heavily based on changes in material culture, especially the pottery. Archaeological evidence, when taken in total, is not particularly helpful in distinguishing whether there was a clear, sharp break (e.g., cultural replacement) between the inhabitants of Palo Seco phase Manzanilla and the later Arauquinoid phase population. In Trinidad, the transition between the two shows subtle changes, especially deterioration, in the ceramics over a span of several centuries (Boomert 2000). However, at present it is premature to judge if this perceived change and decline in ceramics reflects an ethnic change, or is an *in situ* evolutionary deterioration in attention to detail and decoration.

New radiocarbon dates on human bone recovered from Burial Features 16 and 18 at Manzanilla (SAN 1) indicate that the site was occupied from AD 1200-1400, extending the previously known habitation span by several centuries, and close to European contact. It suggests that Structure A, with which the burials were associated, was used during the Arauquinoid phase, and significantly post-dated activities and structures associated with the earlier Saladoids.

The long term Amerindian settlement at Manzanilla (SAN 1) is almost certainly a reflection of the extremely rich environment and abundant wild resources in this region of Trinidad. Faunal remains recovered from the site indicate a marine base to the diet, not surprising given the coastal location, but also point to a wide variety of other, terrestrial vertebrates as potential protein sources.

Results of the stable isotope analysis of human remains are the first for Manzanilla (SAN 1), and from Precolumbian Trinidad. They serve to

complement the zooarchaeological data. The initial reconstruction of subsistence for Manzanilla (SAN 1), based on this chemical analysis of human bone, is of a strong reliance on marine resources (fish and shellfish) in the final Pre-Columbian stage of habitation, and likely throughout the long history of the site. Isotope analysis also indicates the consumption of C<sub>3</sub> plant foods, such as manioc (*Manihot esculenta*), supplemented with C<sub>4</sub> plants, such as maize (*Zea mays*).

Using a more inclusive approach to dietary analysis is helping archaeologists to better understand the unique “Caribbean subsistence system” now being defined (Newsom 2008:181). Altogether, we see a broad-based, locally-variable diet at Manzanilla (SAN 1). The Pre-Columbian population here, over a millennium, found and exploited a lush and very diverse environment for habitation. This setting enabled the inhabitants a lifestyle based on hunting, fishing, and shellfish collecting, while also gardening both staple food plants, and an array of wild fruit and vegetables, in a successful form of early, mixed horticulture in the southern Caribbean (Newsom and Wing 2004; Pearsall 2002).

## Acknowledgments

The authors (PFH, AK, and MCD) wish to acknowledge the careful excavations conducted by various teams of Dutch archaeologists at Manzanilla (SAN 1), and the prompt reporting of these by multiple researchers, especially Dr. A. Boomert, S. Grouard, D.C. Nieweg, S. Baetsen, B. Jansen, G.H. de Boer, E. Altena, and R. Jansen. We wish to thank Prof. K.O. Lawrence and Dr. Basil Reid, Department of History, University of the West Indies-St. Augustine (UWI), and the members of the National Archaeology Committee for Trinidad and Tobago, for their cooperation and assistance in Trinidad. Partial funding of excavations at Manzanilla (SAN 1) was granted to MCD from the UWI. MCD offers thanks to the property owner, Mr. Shinanan, for granting permission to work at Manzanilla (SAN 1), and to D.C. Nieweg and the staff of the National Museum of Natural History *Naturalis* (Netherlands), for assistance with faunal identifications. Isotope analysis was conducted at McMaster University (Canada), and AK wishes to acknowledge Dr. Henry P. Schwarcz for his kind cooperation. Drs. Tamara Varney, Anne Stokes,

and Jocelyn Williams are thanked for their useful comments on the isotope data. The authors also wish to thank two anonymous reviewers for their insights, and Beta-Analytic, Inc. for clarification/update about the C-14 samples. Funding to PFH for travel to, and subsistence in, Trinidad was provided by a grant from the Ford Foundation. Funding for radiocarbon dating came from the Trent University (SSHRC) Committee on Research, and is gratefully acknowledged by PFH.

## Notes:

1. Boomert (1984) noted that the site may have been identified as early as the 1930's. He reports that surface collections were made at Manzanilla (SAN 1) in 1963, by T. Cambridge (under the auspices of the Trinidad National Museum), in 1964, by Fr. Neil Rodriguez., and in 1968, 1972, and 1974 by P.O'B. Harris (Boomert 2000:154). The first extensive survey of the site was conducted only in 1997, by a team from Leiden University (Boomert et al. 1997). Manzanilla 1 was formally registered in the Trinidad Archaeological Site Inventory as SAN 1, while another, nearby site was called Manzanilla 2 (now SAN 3) (Boomert 2000:500).
2. Faunal identifications employed here are derived from Boomert (2000:Table 45), based on a preliminary analysis of faunal remains from three excavation pits dug at Manzanilla (SAN 1) in 1997. This analysis was completed by S. Grouard of the Musée National d'Histoire Naturelle in Paris. Later faunal analysis (2001-2004) was done by D.C. Nieweg, working on contract for the Museum of Sea Biology in Scheveningen, and the Museum of Natural History in Rotterdam, both in Holland.
3. Previous radiocarbon dates from Manzanilla (San 1) were provided by the Laboratory for Isotopic Research at the University of Groningen: GrA-13865, Cal AD 406-556; GrA-13866, BP 16,000 (rejected); and GrA-13867, Cal AD 688-892.
4. Artifacts and human remains from Manzanilla (SAN 1) are curated at the Archaeology Centre of the University of the West Indies-St. Augustine, Trinidad.
5. The age estimate of "over 70 years" for the individual in Burial Feature 16 is based on ectocranial obliteration of the coronal and sagittal sutures (Bateson 2003; Dorst et al. 2003:48). The age estimate of 50 years for the individual in Burial Feature 18 is based on considerable progressive changes of the sternal ends of some *costae* (Bateson 2003; Dorst et al. 2003:50).
6. Approximately three grams of each bone sample were cleaned ultrasonically to remove surface dirt, dried at room temperature, then crushed into small pieces using a mortar and pestle. The crushed samples were soaked in 0.25 M hydrochloric acid (HCl) until all of the mineral was dissolved. The remaining collagen samples were soaked in 0.1 M sodium hydroxide (NaOH) for twenty minutes to remove any humic contaminants. The samples were then

solubilized in 0.1 N HCl at 90°C, filtered, and evaporated in a drying oven to isolate the collagen, which was then sealed in small tin capsules and combusted into CO<sub>2</sub> and N<sub>2</sub> gases in an automated elemental analyser (Costech ECS 4010) connected to a continuous-flow isotope ratio mass spectrometer (CF-IRMS Finnegan Delta Plus XP). 7. Each bone sample was washed in distilled water, dried, and crushed into a powder using a mortar and pestle. The powdered samples were then soaked in a 2.5% bleach solution for three days, rinsed with distilled water, soaked in a buffered acetic acid solution for 24 hours, then rinsed again and left to dry. Approximately 1.5 mg of each sample was placed in an Isocarb with a standard and reacted with 100% phosphoric acid at 90°C. The resulting CO<sub>2</sub> gas was analyzed on a Fison's Optima dual inlet IRMS.

8. Each bone sample was washed in distilled water, dried, crushed into a fine powder using a mortar and pestle, and passed through a #200 mesh sieve. Approximately 2 mg of the remaining powder was mixed together with 200 mg of potassium bromide, and the mixture was compressed at 15,000 psi into small pellets. These were then scanned using a Bomen M100 FTIR spectrometer to obtain absorbance spectra. The crystallinity index (CI) of each sample was calculated using the formula  $CI = (A_{565} + A_{605}) / A_{595}$  (Wright and Schwarcz 1996).
9. The C-14 dates were generated by Beta-Analytic, Inc. (Miami, Florida) using standard AMS analysis. Results were analysed employing the calibration dataset INTcal 98, in use in 2004 (see *Radiocarbon* 40(3):1041-1083), and using a terrestrial calibration curve.

## References Cited:

- Altena, E.  
2007 The Burials of the SAN 1 Site at Manzanilla, Eastern Trinidad. In *Proceedings of the 21st International Congress for Caribbean Archaeology* (Trinidad. 2005), edited by B. Reid, H. Petitjean, and A. Curet, pp. 306-314. University of the West Indies, St. Augustine, Trinidad.
- Ambrose, S.H.  
1993 Isotopic Analysis of Paleodiets: Methodological and Interpretive Considerations. In *Investigations of Ancient Human Tissue Chemical Analyses in Anthropology*, edited by M. K. Sanford, pp. 59-130.

Gordon and Breach Science Publishers, Langhorne, PA.

Ambrose, S.H. and L. Norr

1993 Experimental Evidence for the Relationship of the Carbon Isotope Ratios of Whole Diet and Dietary Protein to Those of Bone Collagen and Carbonate. In *Prehistoric Human Bone: Archaeology at the Molecular Level*, edited by J. B. Lambert and G. Grupe, pp. 1-37. Springer-Verlag, New York.

Ambrose, S.H., B.M. Butler, D.B. Hanson, R.L.

Hunter-Anderson, and H.W. Krueger

1997 Stable Isotopic Analysis of Human Diet in the Marianas Archipelago, Western Pacific. *American Journal of Physical Anthropology* 104(3): 343-361.

Baetsen, S.

2003 *The Burials of the Manzanilla (SAN 1) Site, Trinidad and Tobago: An Analysis of Burial Ritual on Native Amerindian Skeletal Remains Excavated During an Inventory Excavation on the Manzanilla 1 Site, Trinidad*. Unpublished M.Sc. thesis, Faculty of Archaeology, Leiden University, Leiden, The Netherlands.

Berman, M.J. and D.M. Pearsall

2008 At the Crossroads: Starch Grain and Phytolith Analyses in Lucayan Prehistory. *Latin American Antiquity* 19(2):181-203.

Boomert, A.

1983 The Saladoid Occupation of Wonotobo Falls, Western Surinam. In *Proceedings of the Ninth International Congress for the Study of Precolumbian Cultures of the Lesser Antilles*, pp. 97-120. Santo Domingo, Dominican Republic.

2000 *Trinidad, Tobago, and the Lower Orinoco Interaction Sphere: An Archaeological/Ethnohistorical Study*. Cairi Publications, Alkmaar, The Netherlands.

Boomert, A., M.C. Dorst, C.L. Hofman, M.L.P.

Hoogland, D.C. Nieweg, and A. Vredenburg

1997 Preliminary Report on an Archaeological Investigation of the Manzanilla Site 1, Trinidad. Manuscript, Faculty of Archaeology, Leiden University, Leiden, The Netherlands.

Buhay, W.M., Y. Chinique de Armas, R. Rodriguez Suárez, C. Arredondo, D.G. Smith, S.D. Armstrong, and M. Roksandic

2012 A Preliminary Carbon and Nitrogen Isotopic Investigation of Bone Collagen from Skeletal Remains Uncovered from a Pre-Columbian Burial Site, Matanzas Province, Cuba. *Applied Geochemistry* (available on-line 4 September 2012).

Chisholm, B. S., D. E. Nelson, and H. P. Schwarcz

1982 Stable Carbon Isotope Ratios as a Measure of Marine versus Terrestrial Protein in Ancient Diets. *Science* 216: 1131-1132.

Chisholm, B. S., D. E. Nelson, K. Hobson, H. P.

Schwarcz, and M. Knyf

1983 Carbon Isotope Measurement Techniques for Bone Collagen: Notes for the Archaeologist. *Journal of Archaeological Science* 10:355-360.

De Boer, W.

1975 Archaeological Evidence for Manioc Cultivation: A Cautionary Note. *American Antiquity* 40:419-433.

de France, S. D., W. F. Keegan, and L. A. Newsom

1996 The Archaeobotanical, Bone Isotope, and Zooarchaeological Records from Caribbean Sites in Comparative Perspective. In *Case Studies in Environmental Archaeology*, edited by E. J. Reitz, L. A. Newsom, and S. J. Scudder, pp. 289-304. Plenum, London.

Deines, P. 1980. The Isotopic Composition of

Reduced Organic Carbon. In *Handbook of Environmental Isotope Geochemistry*, edited by P. Fritz and J. C. Fontes, pp. 329-406. Elsevier, Amsterdam.

DeNiro, M. J.

1985 Postmortem Preservation and Alteration of *in vivo* Bone Collagen Isotope Ratios in Relation to Palaeodietary Reconstruction. *Nature* 317:806-809.

DeNiro, M. J.

1987 Stable Isotopy and Archaeology. *American Scientist* 75: 182-191.

DeNiro, M. J. and S. Epstein

1978 Influence of Diet on the Distribution of Carbon Isotopes in Animals. *Geochimica et Cosmochimica Acta* 42:495-506.

1981 Influence of Diet on the Distribution of

- Nitrogen Isotopes in Animals. *Geochimica et Cosmochimica Acta* 45:341-351.
- Dorst, M. C.  
 2000 Manzanilla 1: An Archaeological Survey of a Pre-Columbian Site on Trinidad (Spatial Patterning, Ceramics, Lithics, and Faunal Remains). Unpublished M.Sc. thesis, Faculty of Archaeology, Leiden University, Leiden, The Netherlands. .  
 2007 The SAN-1 Site at Manzanilla: Creating a Site-Scale Pottery Classification at a Multi-Component Ceramic Age Site in Trinidad. In *Proceedings of the 21<sup>st</sup> International Congress for Caribbean Archaeology* (Trinidad, 2005), edited by B. Reid, H. Petitjean, and A. Curet, pp. 328-337. University of the West Indies, St. Augustine, Trinidad.  
 2008 The Pre-Columbian SAN-1 Site, Manzanilla, Trinidad: Preliminary Research Report (Fieldwork October 2007). Manuscript, on file, National Archaeological Committee of Trinidad and Tobago, Port-of-Spain, Trinidad.  
 Dorst, M. C., D. C. Nieweg, and S. Baetsen  
 2001 Archaeological Investigations on the Pre-Columbian Manzanilla 1 (SAN 1) Site: Phase H, Inventory Excavations on a Vacant Space (September, 2001). Manuscript, on file, Department of History, University of the West Indies, St. Augustine, Trinidad.
- Dorst, M. C., D. C. Nieweg, and S. Baetsen  
 2003 Manzanilla 1 (SAN 1): An Excavation of an Amerindian Habitation Area (September, 2001). Manuscript, on file, Department of History, University of the West Indies, St. Augustine, Trinidad.
- Dorst, M. C., D. C. Nieweg, and E. Altena  
 2004 Manzanilla 1 (SAN 1): An Excavation of an Amerindian Habitation Area (June, 2003 Fieldwork Report). Manuscript, on file, Department of History, University of the West Indies, St. Augustine, Trinidad.
- Froehle, A.W., C.M. Kellner, and M.J. Schoeninger  
 2012 Multivariate Carbon and Nitrogen Stable Isotope Model for the Reconstruction of Prehistoric Human Diet. *American Journal of Physical Anthropology* 147: 352-369.
- Grouard, S.  
 1998 Manzanilla- Trinidad: Premier Aperçu sur les Vertébrés. Manuscript, on file, Musée National d'Histoire Naturelle, Paris.
- Harris, P. O' B.  
 1978 Revised Chronological Framework for Ceramic Trinidad and Tobago. In *Proceedings of the Seventh International Congress for the Study of Precolumbian Cultures of the Lesser Antilles* (1977), pp. 47-63. Caracas, Venezuela.  
 1985 A Comparison of Three Bontour Period Sites, Trinidad. In *Proceedings of the 10th International Congress for the Study of Precolumbian Cultures of the Lesser Antilles* (1983), pp. 265-283. Fort of France, Martinique.  
 Hofman, C. L., A. Delpuech, and M. L. P. Hoogland  
 1999 Excavations at the Site of Anse à la Gourde, Guadeloupe: Stratigraphy, Ceramic Chronology, and Structures. In *Proceedings of the 18th International Congress for Caribbean Archaeology, Volume 2*, pp. 162-172. Grenada.
- Jansen, R. and M. C. Dorst  
 2007 Spatial Patterning and Structures of a Multi-Component Ceramic Age Site in Trinidad. In *Proceedings of the 21<sup>st</sup> International Congress for Caribbean Archaeology* (Trinidad, 2005), edited by B. Reid, H. Petitjean, and A. Curet, pp. 315-327. University of the West Indies, St. Augustine, Trinidad.
- Keegan, W.F.  
 1985 *Dynamic Horticulturalists: Population Expansion in the Prehistoric Bahamas*. Unpublished Ph.D. dissertation, Department of Anthropology, University of California, Los Angeles.
- Keegan, W. F. and M. J. DeNiro  
 1988 Stable Carbon- and Nitrogen-isotope Ratios of Bone Collagen Used to Study Coral-reef and Terrestrial Components of Prehistoric Bahamian Diet. *American Antiquity* 53(2):320-336.
- Kellner, C.M. and M.J. Schoeninger  
 2007 A Simple Carbon Isotope Model for Reconstructing Prehistoric Human Diet. *American Journal of Physical Anthropology* 133:1112-1127.
- Krueger, H. W. and C. H. Sullivan  
 1984 Models for Carbon Isotope Fractionation between Diet and Bone. In *Stable Isotopes in Nutrition*, American Chemical Society Symposium Series 258, edited by J. R. Turnlund and P. E. Johnson, pp. 205-

220. American Chemical Society, Washington, DC.
- Laffoon, J.E. and B.R. de Vos  
2011 Diverse Origins, Similar Diets: An Integrated Isotopic Perspective from Anse à la Gourde, Guadeloupe. In *Communities in Contact*, edited by C.L. Hofman and A.v. Duijvenbode, pp. 187-203. Sidestone Press, Leiden.
- Larsen, C. S., M. J. Schoeninger, N. J. van der Merwe, K. M. Moore, and J. A. Lee-Thorp  
1992 Carbon and Nitrogen Stable Isotopic Signatures of Human Dietary Change in the Georgia Bight. *American Journal of Physical Anthropology* 89:197-214.
- Lee-Thorp, J. A. and N. J. van der Merwe  
1987 Carbon Isotope Analysis of Fossil Bone Apatite. *South African Journal of Science* 83:343-351.
- Lee-Thorp, J.A., J.C. Sealy, N.J. van der Merwe  
1989 Stable Carbon Isotope Ratio Differences between Bone Collagen and Bone Apatite, and Their Relationship to Diet. *Journal of Archaeological Science* 16:585-599.
- Longin, R.  
1971 New Method for Collagen Extraction for Radiocarbon Dating. *Nature* 230:241-242.
- Lubell, D., M. Jackes, H. P. Schwarcz, M. Knyf, and C. Meiklejohn  
1994 The Mesolithic-Neolithic Transition in Portugal: Isotopic and Dental Evidence of Diet. *Journal of Archaeological Science* 21:201-216.
- Manolagas, S.  
2000 Birth and Death of Bone Cells: Basic Regulatory Mechanisms and Implications for the Pathogenesis and Treatment of Osteoporosis. *Endocrine Reviews* 21:115-137.
- Mickleburgh, H.L. and J.R. Pagan-Jimenez  
2012 New Insights into the Consumption of Maize and Other Plant Foods in the Pre-Columbian Caribbean from Starch Grains Trapped in Human Dental Calculus. *Journal of Archaeological Science* 39(7): 2468-2478.
- Newsom, L.A.  
2008 Caribbean Paleoethnobotany: Present Status and New Horizons. In *Crossing the Borders: New Methods and Techniques in the Study of Archaeological Materials from the Caribbean*, edited by C.L. Hofman, M.L.P. Hoogland, and A.L. van Gijn, pp. 173-194. University of Alabama Press, Tuscaloosa.
- Newsom, L. A. and K. A. Deagan  
1994 *Zea mays* in the West Indies: The Archaeological and Early Historic Record. In *Corn and Culture in the Prehistoric New World*, edited by S. Johannessen and C. A. Hastorf, pp. 203-217. Westview Press, Boulder.
- Newsom, L.A. and E. S. Wing  
2004 *On Land and Sea: Native American Uses of Biological Resources in the West Indies*. University of Alabama Press, Tuscaloosa.
- Nieweg, D. C.  
2000 *Shells in Archaeology (Archaeological Shell on Trinidad and Guadeloupe: Two Case Studies)*. Unpublished M.Sc. thesis, Faculty of Archaeology, Leiden University, Leiden, The Netherlands.
- Nieweg, D. C. and M. C. Dorst  
2001 The Manzanilla 1 (SAN 1) Site, Trinidad. In *Proceedings of the 19th International Congress of Caribbean Archaeology*, Volume 1, edited by L. Alofs and R.A.C. F. Dijkhoff, pp. 173-185. Archaeological Museum of Aruba Publication No. 9, Aruba.
- Norr, L.  
1995 Interpreting Dietary Maize from Bone Stable Isotopes in the American Tropics: The State of the Art. In *Archaeology in the Lowland American Tropics: Current Analytical Methods and Recent Applications*, edited by P. W. Stahl, pp. 198-223. Cambridge University Press, Cambridge.
- 2002 Bone Isotopic Analysis and Prehistoric Diet at the Tutu Site. In *The Tutu Archaeological Village Site: A Multidisciplinary Case Study in Human Adaptation*, edited by E. Righter, pp. 263-273. Routledge, London.
- Oviedo y Valdes, G. F. de  
1959 *Natural History of the West Indies*, translated by S. A. Stoudemire. University of North Carolina, Studies in Romance Languages and Literatures, No. 32. University of North Carolina Press, Chapel Hill.

Passey, B.H., T.F. Robinson, L.K. Ayliffe, T.E. Cerling, M. Sponheimer, M.D. Dearing, B.L. Roeder, J.R. Ehleringer

2005 Carbon Isotope Fractionation between Diet, Breath CO<sub>2</sub>, and Bioapatite in Different Mammals. *Journal of Archaeological Science* 32: 1459-1470.

Pearsall, D. M.

2002 Analysis of Charred Botanical Remains from the Tutu Site. In *Tutu Archaeological Village Site: A Multidisciplinary Case Study in Human Adaptation*, edited by E. Righter, pp. 109-134. Routledge, Taylor & Francis Group, New York.

Rand, A.J., Healy, P.F., and Awe, J.J.

2013 Stable Isotopic Evidence of Ancient Maya Diet at Caledonia, Cayo District, Belize. *International Journal of Osteoarchaeology* (published on-line; doi: 10.1002/oa.2308).

Righter, E.

2002 Post Hole Patterns: Structures, Chronology, and Spatial Distribution at the Tutu Site. In *Tutu Archaeological Village Site. A Multidisciplinary Case Study in Human Adaptation*, edited by E. Righter, pp. 284-341. Routledge, Taylor & Francis Group, New York.

Righter, E., K. S. Wild, and E. R. Lundberg

2004 Late Ceramic Age Developments in the Virgins Archipelago: The Puerto Rican Connection. In *Late Ceramic Age Societies in the Eastern Caribbean*, edited by A. Delpuech and C. L. Hofman, pp. 101-118. BAR International Series #1273. Paris Monographs in American Archaeology #14. Archaeopress, Oxford.

Rodriguez Suarez, R. and J.R. Pagan

2008 The *Buren* in Precolonial Cuban Archaeology. In *Crossing the Borders: New Methods and Techniques in the Study of Archaeological Materials from the Caribbean*, edited by C.L. Hofman, M.L.P. Hoogland, and A.L. van Gjin, pp. 159-169. University of Alabama Press, Tuscaloosa.

Rouse, I.

1947 Prehistory of Trinidad in Relation to Adjacent Areas. *Man (Old Series)* 47 (103):93-98.

1992 *The Tainos: Rise and Fall of the People Who Greeted Columbus*. Yale University Press, New Haven.

Sauer, C. O.

1966 *The Early Spanish Main*. University of California Press, Berkeley.

1969 Oceanic Islands and Biogeographic Theory: A Review. *The Geographical Review* 59(4):582-593.

Schoeninger, M.J.

2010 Diet Reconstruction and Ecology using Stable Isotope Ratios. In *A Companion to Biological Anthropology*, edited by C.S. Larsen, pp. 445-464. Chichester: Wiley-Blackwell.

Schwarcz, H. P.

2000 Some Biochemical Aspects of Carbon Isotopic Paleodiet Studies. In *Biogeochemical Approaches to Paleodietary Analysis*, edited by S. H. Ambrose and M. A. Katzenberg, pp. 189-210. Kluwer Academic/Plenum Publishers, New York.

Schwarcz, H. P., J. Melbye, M. A. Katzenberg, and M. Knyf

1985 Stable Isotopes in Human Skeletons of Southern Ontario: Reconstructing Palaeodiet. *Journal of Archaeological Science* 12:187-206.

Schwarcz, H. P. and M. J. Schoeninger

1991 Stable Isotope Analyses in Human Nutritional Ecology. *Yearbook of Physical Anthropology* 34: 283-321.

Smith, B. and S. Epstein

1971 Two Categories of <sup>13</sup>C/<sup>12</sup>C Ratios of Higher Plants. *Plant Physiology* 47: 380-384.

Stokes, A. K.

1998 *A Biogeographic Survey of Prehistoric Human Diet in the West Indies Using Stable Isotopes*. Unpublished Ph.D. dissertation, Department of Anthropology, University of Florida, Gainesville.

2005 Ceramic-Age Dietary Patterns in Puerto Rico: Stable Isotopes and Island Biogeography. In *Ancient Borinquen: Archaeology and Ethnohistory of Native Puerto Rico*, edited by P.E. Siegel, pp. 185-201. The University of Alabama Press, Tuscaloosa.

van der Merwe, N.J. and J.C. Vogel

1978 <sup>13</sup>C Content of Human Collagen as a

Measure of Prehistoric Diet in Woodland North America. *Nature* 276: 815-816.

van Klinken, G. J.  
1991 *Dating and Dietary Reconstruction by Isotopic Analysis of Amino Acids in Fossil Bone Collagen-With Special Reference to the Caribbean*. Publication of the Foundation for Scientific Research in the Caribbean Region, No. 128. Amsterdam.

Varney, T.  
2003 *Reconstructing Diet and Tracing Life Histories in Colonial Populations of the Northeast Caribbean Using Stable Carbon and Nitrogen Isotopes*. Unpublished Ph.D. dissertation, Department of Archaeology, University of Calgary, Calgary, Alberta.

Versteeg, A. H. and K. Schinkel  
1992 *Archaeology of St. Eustatius: The Golden Rock Site*. St. Eustatius Historical Foundation Publication No. 2, and Foundation for Scientific Research in the Caribbean Region Publication No. 131. Amsterdam.

White, C. D.  
1994 Dietary Dental Pathology and Cultural Change in the Maya. In *Strength in Diversity*, edited by D. A. Herring and L. Chan, pp. 279-302. Canadian Scholar's Press, Toronto.

Wright, L. E. and H. P. Schwarcz  
1996 Infrared and Isotopic Evidence for Diagenesis of Bone Apatite at Dos Pilas, Guatemala: Paleodietary Implications. *Journal of Archaeological Science* 23:933-944.

## Author Information

Paul F. Healy  
Department of Anthropology  
Trent University  
2140 East Bank Drive  
Life & Health Sciences, DNA Building, Module "C"  
2<sup>nd</sup> Floor, Office: C207  
Peterborough, ON Canada K9J 7B8  
([phealy@trentu.ca](mailto:phealy@trentu.ca))

Anne Keenleyside  
Department of Anthropology  
Trent University  
2140 East Bank Drive  
Life & Health Sciences, DNA Building, Module "C"  
2<sup>nd</sup> Floor, Office: C207  
Peterborough, ON Canada K9J 7B8  
([annekeenleyside@trentu.ca](mailto:annekeenleyside@trentu.ca))

Marc C. Dorst  
Leiden University  
Grevenstraat 18  
2312 VJ  
Leiden, The Netherlands  
([marcdorst@hotmail.com](mailto:marcdorst@hotmail.com))