

CHAPTER 10

STABLE CARBON AND NITROGEN ISOTOPE ANALYSIS OF HUMAN DIETS AT THE MITCHELL RIDGE SITE

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Stable isotope analysis has provided archaeologists with yet another tool to examine prehistoric subsistence patterns. Unlike plant macro-fossil and faunal studies which can only indirectly measure potential dietary inputs at the population level, stable isotope analysis measures the nutritional inputs actually assimilated by an individual over a lifetime. The premise of the method, at its most general, is "you are what you eat" (DeNiro and Epstein 1978, 1981). Plants at the bottom of the foodweb have different modes of photosynthesis and mechanisms for fixing nitrogen which result in measurable differences in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values. These differences are then passed up the foodchain and incorporated into consumer tissues with only slight, predictable, isotopic enrichment known as fractionation. In archaeological reconstructions of human diet, bone collagen is the tissue of choice for analysis owing to its stability in depositional environments over long time frames (Armstrong et al. 1983), and because of its slow isotopic turnover which permits long-term measures of diet (Stenhouse and Baxter 1979; Krueger and Sullivan 1984).

In this study $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values for 12 humans and three economic vertebrate species from 41GV66 are reported and discussed in several contexts. The initial purpose of the analysis is to reconstruct the paleodiet at 41GV66, and to determine if there is any variation through time in relation to changing cultural ecology of the post-2000 BP Galveston Bay area. The dietary pattern from 41GV66 will be compared with other isotopically determined dietary patterns from adjacent regions in the context of their ecological settings and subsistence patterns. Of further interest is the potential for stable isotope analysis to be combined with bioarchaeological characteristics at the site to determine changes in population structure.

Background to Archaeological Stable Isotope Studies in Coastal Regions

Current knowledge indicates that in many coastal environments both carbon and nitrogen stable isotope values of human bone collagen can be used to estimate the relative proportions of marine and terrestrial foods in long-term human diets (Schoeninger et al. 1983). Carbon isotope values in marine foodwebs are enriched with respect to those in most terrestrial systems. This phenomenon is related to the use of bicarbonate as the carbon source in oceanic photosynthesis, which is more enriched in ^{13}C than atmospheric CO_2 utilized in terrestrial photosynthesis (Boutton 1991). Since most terrestrial and marine plants use the C_3 photosynthetic pathway, except for some 20 families that use the C_4 pathway, and that these differences in isotopic range are consistent between the two ecosystem types, the degree of dependence of prehistoric humans on each photosynthetic pathway can be assessed via stable isotope analysis.

A complicating factor in isotopic reconstruction of coastal human diets is the presence of C_4 and CAM plant species in the terrestrial portion of the foodweb. Those types of plants, such as maize, millet, various grasses, and *Opuntia*, have $\delta^{13}\text{C}$ values that are on average 14‰ more enriched than the vast majority of plants which utilize the C_3 photosynthetic pathway (Smith and Epstein 1971; O'Leary, 1988; Tieszen and Boutton 1989).

The $\delta^{13}\text{C}$ values of marine resources consumed by humans commonly fall midway between the averages for C_3 and C_4 plants due to bicarbonate ^{13}C enrichment and a more evident stepwise trophic enrichment than in terrestrial systems. The presence of C_4 species in a foodweb can lead to an over-estimation of the marine dietary component. The most successful applications of the stable isotope technique have primarily been in temperate and humid coastal regions that are generally absent of C_4 native species, and temporally prior to the introduction C_4 cultigens. Representative studies are from Mesolithic Denmark (Tauber 1981), the Canadian Pacific coast (Chisholm et al. 1982), the Bahamas

(Keegan and DeNiro 1988), Japan (Roksandic et al. 1988), and (in a novel approach using dogs because of a dearth of human remains) in British and Danish sites (Noe-Nygaard 1988; Brock and Noe-Nygaard 1990).

Nitrogen isotope values, much like carbon isotopes, are also enriched in marine environments (Wada 1980). Dissolved nitrate in seawater used by phytoplankton and macrophytes is more enriched with ^{15}N than the atmospheric N_2 and soil nitrate, which accounts for the initial observed enrichment in $\delta^{15}\text{N}$ values (Wada et al. 1975). In addition, marine ecosystems commonly have a greater number of intermediate trophic steps than terrestrial ecosystems (Schoeninger and DeNiro 1984; Macko 1981). Nitrogen isotopes are enriched by approximately +2.5-3.0‰ for every trophic level, with some studies finding even greater step-wise increases (cf. Schwarcz and Schoeninger 1991).

Three situations create further difficulties for paleodiet interpretation of $\delta^{15}\text{N}$ from bone collagen. The first two relate to terrestrial ecosystems, while the third is found in coral reef systems. In terrestrial environments legumes (members of the Leguminosae and Rhamnaceae), have the ability to fix nitrogen from the air ($\delta^{15}\text{N} = 0\text{‰}$), where other non-fixing plants acquire more isotopically positive N_2 from soil nitrates. This gives nitrogen fixing plants and their consumers lower $\delta^{15}\text{N}$ values, and can skew the ca. +2.5-3.0‰ trophic enrichment. Secondly, in arid regions several animal species have adapted biochemical processes of water conservation that allow them to excrete ^{15}N -depleted urea. This process creates a protein sparing effect and generates a pool of available nitrogen enriched in ^{15}N for tissue growth and maintenance (Sealy et al. 1987; Ambrose 1991 and references within). This produces enriched bone collagen $\delta^{15}\text{N}$ values that can exceed the normal step-wise trophic enrichment for these species, and their consumers. In coral reef, seagrass meadow, and salt marsh marine environments it has been found that $\delta^{15}\text{N}$ values are less positive than in the open ocean due to higher rates of nitrogen fixation (Capone and Carpenter 1982; Keegan and DeNiro 1988).

Applications using $\delta^{15}\text{N}$ values, or $\delta^{15}\text{N}$ in conjunction with $\delta^{13}\text{C}$ values for identifying marine components in human paleodiet have been made for the California coast Walker and DeNiro (1986), and on Nantucket Island by Medaglia et al. (1990).

Isotopic Subsistence Ecology of the Upper Texas Coast

From the evidence for subsistence practices and regional ecology presented earlier in this report, as well as from isotopic data from the modern environment, it is possible to provide a reasonably accurate estimate of the carbon and nitrogen isotope ranges for the prehistoric foodweb. Archaeological and ethnographic evidence suggest that the hunter-gatherer groups that occupied 41GV66 drew their subsistence from several types of environments during their annual rounds.

Terrestrial Environments

There are scant data available for the isotopic ranges of terrestrial flora and fauna in the Upper Texas Coast either for modern or prehistoric times. Given the 120+ cm of annual precipitation in this region, the flora resembles that of the Mississippi valley to the east, more than the remainder of Texas to the west (Dice 1934). Few, if any, native C_4 and CAM plants should be present in the modern or past foodwebs. Thus the terrestrial flora, comprised of C_3 plants, can be expected to have an average $\delta^{13}\text{C}$ of -26.0‰ and consumers would have bone collagen around -21.0‰ (Table 10.1). This reflects the +5‰ fractionation between food and mammal collagen, which also holds for humans (Krueger and Sullivan 1984; Krueger 1985). Muscle tissue $\delta^{13}\text{C}$ values average 2.3‰ more negative than bone collagen in the same animal (Vogel 1978).

Stable nitrogen isotope values for terrestrial ecosystems in this area should be low. Plants in arid and saline environments commonly have the highest $\delta^{15}\text{N}$ values (Heaton et al. 1986), while those in moist and forested environments have the lowest (Heaton 1987). Since the intra-specific $\delta^{15}\text{N}$ values of a plant will vary with environmental type and the $\delta^{15}\text{N}$ value of the soil nitrates, and since we have no isotope data for modern species in this region, it is only possible to speculate that the $\delta^{15}\text{N}$ range for terrestrial non-fixing plants will be toward the low end of +2-10‰ (Letolle 1980; Hoefs 1987). Nitrogen fixing plants (legumes) have $\delta^{15}\text{N}$ values at or near 0‰ (Table 10.1). Bone collagen values of consumers are isotopically enriched along each trophic step. A number of studies have shown that there is a step-wise trophic

enrichment of +2.5-3.0‰ for $\delta^{15}\text{N}$ values within both marine and terrestrial ecosystems (Wada 1980; Minagawa and Wada 1984; Schoeninger and DeNiro 1984; Schoeninger 1989, Hobson and Welch, 1992). In a study from Hays County in Central Texas, bone collagen from Late Prehistoric on, pronghorn, and white-tailed deer had mean $\delta^{15}\text{N}$ values of +4.8‰, +4.3‰ and +3.5‰, respectively (Huebner 1992). As the latter two species consume significant amounts of legumes, the data suggest that plant biomass $\delta^{15}\text{N}$ in that area of Texas should average around +2.0‰. The muscle tissue of an animal is enriched by an average of 1.7‰ relative to the $\delta^{15}\text{N}$ value of the bone collagen.

Riverine resources, those found in brackish swamps and the lower reaches of the river valleys and bay heads, have $\delta^{13}\text{C}$ values similar to those of terrestrial ecosystems (Fry and Sherr 1984). A limited number of bone collagen $\delta^{15}\text{N}$ values from prehistoric riverine fish suggests a +10.0‰ average (Katzenberg 1989; Huebner, unpublished data). Freshwater mussel and clam meat has an average $\delta^{15}\text{N}$ of +12.0‰ (Huebner, unpublished data).

Marine Environments

There is a considerable amount of stable carbon isotope data available for the marine populations and foodwebs of the Gulf of Mexico (Fry et al. 1984). Unfortunately, the bulk of the data were collected from communities outside the barrier islands. Isotopic evidence indicates that there are two marine ecosystem types for carbon isotope flow. These are based on the main primary producers, either sea grass or phytoplankton (Table 10.1). In systems where seagrass detritus forms the base of foodwebs fish had $\delta^{13}\text{C}$ ratios that were significantly different (+3.3 to 5.1‰) from those for phytoplankton based systems (Fry and Parker 1979). Those investigators also noted a +1‰ shift in $\delta^{13}\text{C}$ per trophic level. The $\delta^{13}\text{C}$ values listed in Table 10.1 reflect the measured meat values; theoretically, collagen values are +3.3‰ relative to meat values in the same animal. This factor is based on the mean $\Delta\delta^{13}\text{C}$ between these two types of tissues in 15 modern Bahamian fish reported by Keegan and DeNiro (1988).

The flow of stable nitrogen isotopes in the Gulf of Mexico also relates to the primary production. Sea grass environment have lower $\delta^{15}\text{N}$ values than open water habitats. Meat from brown shrimp harvested in seagrass meadows had $\delta^{15}\text{N}$ values of +8.2‰, which is 5.7‰ lower than for those caught in the open ocean (Macko 1981: Table 7, Fry 1983). From San Antonio Bay, the average $\delta^{15}\text{N}$ ratios of pinfish muscle, in open water, were +13.6‰, while the average for the same species in the seagrass meadow was +10.2‰ (Pat Parker, personal communication). Since there is insufficient nitrogen isotope data for individual species used for human subsistence along the prehistoric Gulf Coast, a crude average for each has to be used in the mixing model (Table 10.1). Stable nitrogen isotope value for muscle tissue is 1.7‰ more enriched than bone collagen (Keegan and DeNiro 1988: Table 3).

Materials and Methods

An abundance of human skeletal and faunal remains usable for stable carbon and nitrogen isotope analysis were recovered from 41GV66. However, only a small number of faunal samples were selected for study, so that research could concentrate on the available human skeletal population. The faunal samples represent three of the most abundant species recovered from the site. Each is representative of an environment exploited by the occupants of 41GV66: deer, a terrestrial mammal; gar, an estuarine top-level carnivore, and drum, a bay/lagoon mid-level carnivore. All of these samples were selected from the Late Prehistoric occupation stratum (Zone 2) from the 1992 excavations.

Twelve individuals were sampled from the non-cremated adult human population recovered from the site during the 1970s excavations and from the 1992 work carried out by Coastal Archaeological Research, Inc. This represents a 31 percent sample of the non-cremated mortuary population. Sampling strategy dictated that the sample universe meet a number of minimum requirements. The initial decision was to sample the full temporal range present at the site (Table 10.2). Within this group, we then selected for sex (7M/5F) and dental wear-patterns as identified by the Powell. Samples 10 and 11 (Fea. 64-1 and 64-2) were chosen because of the anomalous nature of the grave pit, as documented during excavation. The preparation and analysis of samples was performed at Geochron Laboratories, Cambridge, Massachusetts. Bone samples were cleaned manually, then in Alconox, and later given an overnight bath in 1N acetic acid until all reaction with carbonates ceased. Samples were then neutralized,

Table 10.1. Average stable isotope values for mixing model.

<u>Terrestrial</u>		
Group	$\delta^{13}\text{C}\text{‰PDB}$	$\delta^{15}\text{N}\text{‰AIR}$
C ₃ plants	-26.0	+2-3
C ₄ plants	-12.0	+2-3
C ₃ consumer, bone collagen	-21.0	Diet +3
Legumes	--	0.0
<u>Marine</u>		
Group	$\delta^{13}\text{C}\text{‰PDB}$	$\delta^{15}\text{N}\text{‰AIR}$
Bivalves, muscle		
sea grass	-15.0	+8.0
open water	-19.0	+14.0
Shrimp, Crab, whole		
sea grass	-13.0	+8.0
open water	-16.0	+14.0
Fish, meat		
sea grass	-12.0	+10.0
open water	-18.0	+15.0
<u>Riverine</u>		
Group	$\delta^{13}\text{C}\text{‰PDB}$	$\delta^{15}\text{N}\text{‰AIR}$
Fish, bone collagen	-21.0	+10.0
Mussels & Crab, meat	-24.0	+12.0

mechanically crushed to a 1mm powder and again placed in 1N acetic acid until no further reaction was observed, to insure removal of all extraneous carbonates. Next, one gram of bone powder was demineralized in 1N HCl, and the collagen fraction separated by decantation and filtration. The sample was kept acidic by the addition of a small amount of HCl and was dissolved by boiling. The resulting hot broth was filtered through fine fiberglass and the filtrate evaporated and transferred to teflon crucibles, where it was dried in an oven at 70 °C to form a crystalline gelatin.

Approximately 20 mg of bone gelatin, along with excess CuO, were then placed in a pyrex tube, evacuated, sealed with a torch, and held in an oven at 500 °C overnight. Complete combustion results in CO₂, N₂ and H₂O which are then cryogenically separated to provide the carbon and nitrogen gas for analysis.

Analysis of CO₂ for $\delta^{13}\text{C}$ and N₂ for $\delta^{15}\text{N}$ were performed on a Micromass 903 triple collecting mass spectrometer. Overall precision for individual analyses was $\pm 0.2\text{‰}$ for both carbon and nitrogen. Results are expressed in ‰ as δ values where

$$\delta^{13}\text{C} (\text{‰}) = \left[\frac{(^{13}\text{C}/^{12}\text{C})_{\text{sample}}}{(^{13}\text{C}/^{12}\text{C})_{\text{standard}}} - 1 \right] \times 1000$$

$$\delta^{15}\text{N} (\text{‰}) = \left[\frac{(^{15}\text{N}/^{14}\text{N})_{\text{sample}}}{(^{15}\text{N}/^{14}\text{N})_{\text{standard}}} - 1 \right] \times 1000$$

Reported values are given relative to the PDB and AIR standards for carbon and nitrogen, respectively.

Results

The $\delta^{13}\text{C}_o$ and $\delta^{15}\text{N}_o$ values for the 41GV66 bone samples are given in Tables 3a and 3b. The values within parentheses in Table 3a represent the estimated $\delta^{13}\text{C}_m$ and $\delta^{15}\text{N}_m$ value for the meat of the indicated animals. In Table 3b the parenthetic number is the estimated overall dietary isotope value.

Faunal Remains

The three faunal samples display the isotopic diversity expected between terrestrial and marine species. The two fish samples, when converted to meat values, have $\delta^{13}\text{C}_m$ ratios midway between the modern averages for fish feeding in seagrass meadows and those feeding in open water. This pattern is common in several species which spend their juvenile years in the protective sea meadows, then move into open water later in life. The deer $\delta^{13}\text{C}$ values are within the expected range for a pure C_3 consumer.

The $\delta^{15}\text{N}_m$ values of the archaeological fish are lower than modern averages (modern + 15-17‰). For a top-level estuarine lagoonal carnivore, the gar has a lower than expected $\delta^{15}\text{N}$ value, however it is consistent with the $\delta^{13}\text{C}$ value. The $\delta^{15}\text{N}_m$ value from the deer sample is, as expected, relatively low at 4.1‰. Since deer consume several legume species, which lower tissue $\delta^{15}\text{N}$ values, their isotopic values may underestimate the average plant biomass $\delta^{15}\text{N}$ ratio (Huebner 1992). Prehistoric deer and pronghorn from Central Texas had lower $\delta^{15}\text{N}_o$ than bison from the Mustang Branch site, suggesting that the grass-dominated bison diet, generally free of N_2 -fixing species, is a better estimate at ca. +3‰ of overall plant $\delta^{15}\text{N}$.

Human Remains

The human $\delta^{13}\text{C}_o$ values varied from -16.2 to -10.4‰, with a mean of -13.2 ± 2.01 ‰. After accounting for fractionation between dietary assimilation and bone collagen, the average $\delta^{13}\text{C}_d$ is estimated at -18.2‰. This value is consistent with the archaeological and ethnohistorical context, and is indicative of a diet that consisted of both terrestrial and marine components.

Temporal differences are present in the human isotope data from 41GV66. Arranged chronologically, there is a trend for $\delta^{13}\text{C}$ values to become 2 to 3‰ more negative (more C_3 -like) from the earliest to the latest burials (Figure 10.1). Two groups are identified based on the $\delta^{13}\text{C}_o$ values, and, in part, on the basis of ^{14}C assays. The more positive Group 1 contains the earliest five burials (Feature 25 and 1970s Burials 5, 20, 7 and 12; the exception being Feature 62-2, which is Early Historic), while the less positive Group 2 is comprised mainly of later burials (Features 30 and 61, which are Protohistoric, Features 63, 64-1 and 64-4, which are Early Historic; the exception is Feature 87, which is Final Late Prehistoric). The chronological distinction between the two groups is not hard and fast, since Feature 62-2 in Group 1 is Early Historic and Feature 87 in Group 2 is Final Late Prehistoric as opposed to Protohistoric or Early Historic. However, Student's *t* test ($T = 6.238$, $df = 9$) does show that the means of the two groups are significantly different at the .001 level (2-tailed test).

Differences in dental-wear patterns correlate best with individual age in years and, to a more limited degree, with the $\delta^{13}\text{C}$ values. The pattern of extreme wear in two early individuals and minor wear in the two late individuals from Feature 64 suggests that minor wear may correlate with less positive $\delta^{13}\text{C}_d$ values. Along with other considerations such as differences in skeletal morphology *and/or* mortuary ritual in the Feature 64 individuals, the $\delta^{13}\text{C}_d$ evidence suggests that these folks and the female from

Table 10.2. Particulars of analyzed samples in ascending chronological order.

Sample No.	Burial	Sex	Chronological Period
2	1970s 10	M	Late Preceramic/Early Ceramic
3	1970s 12	F	Initial Late Prehistoric
4	Feature 25	M	Initial Late Prehistoric
1	1970s 7	M	Initial Late Prehistoric
12	1970s 5	F	Initial Late Prehistoric
8	Feature 87	M	Final Late Prehistoric
5	Feature 30	F	Protohistoric
7	Feature 61	F	Prothistoric
9	Feature 63	M	Early Historic
11	Feature 64-4	M	Early Historic
10	Feature 64-1	F	Early Historic
6	Feature 62-2	F	Early Historic

Feature 61 spent most of their lives in a different dietary ecology from that offered by the environs of Mitchell Ridge.

Stable nitrogen isotope values for the 41GV66 humans have a small range (1.8‰), and no temporal pattern is evident in the overall sample population (Table 10.2). There are no significant differences in $\delta^{15}\text{N}$ values between males and females, although the females have slightly lower values in both the Late Prehistoric/Protohistoric and 18th Century temporal groups. Dental-wear patterns also offer no correlations with the $\delta^{15}\text{N}$ values.

Discussion

Isotopic Dietary Reconstruction at the Mitchell Ridge Site

Prehistoric human diet in the Upper Gulf Coast derived protein from terrestrial, estuarine, and marine sources; carbohydrate from terrestrial plants; and fats from all sources. From the values given in Table 10.1, a clear dichotomy between terrestrial/estuarine and marine resources is apparent, since there is scant evidence for a terrestrial C_4 dietary input.

Carbon Isotopes

The broad range of $\delta^{13}\text{C}_a$ in the human sample from 41GV66 shows a varying amount input from

Table 10.3a. Stable Isotope values of bone collagen from faunal remains and estimated meat values.

Taxa	$\delta^{13}\text{C}$ ‰	$\delta^{15}\text{N}$ ‰
Sciaenids	-11.9 (-15.2)	+9.9 (+11.6)
Gar	-11.3 (-14.6)	+6.6 (+8.3)
Deer	-20.7 (-23.7)	+2.4 (+4.1)

Table 10.3b. Stable isotope values of bone collagen from human remains and estimated dietary values.

Sample No.	$\delta^{13}\text{C}$ ‰	$\delta^{15}\text{N}$ ‰
1	-10.4 (-15.4)	+10.8 (+8.3)
2	-11.4 (-16.4)	+10.6 (+8.1)
3	-11.0 (-16.0)	+10.2 (+7.7)
4	-12.1 (-17.1)	+10.2 (+7.7)
5	-14.7 (-19.7)	+10.6 (+8.1)
6	-11.7 (-16.7)	+11.3 (+8.8)
7	-15.7 (-20.9)	+9.8 (+7.3)
8	-13.7 (-18.7)	+9.5 (+7.0)
9	-13.6 (-18.6)	+10.9 (8.4)
10	-16.2 (-21.2)	+9.6 (+7.1)
11	-14.6 (-19.6)	+10.8 (+8.3)
Average	13.2 +/-2.01	+10.4 +/-0.58

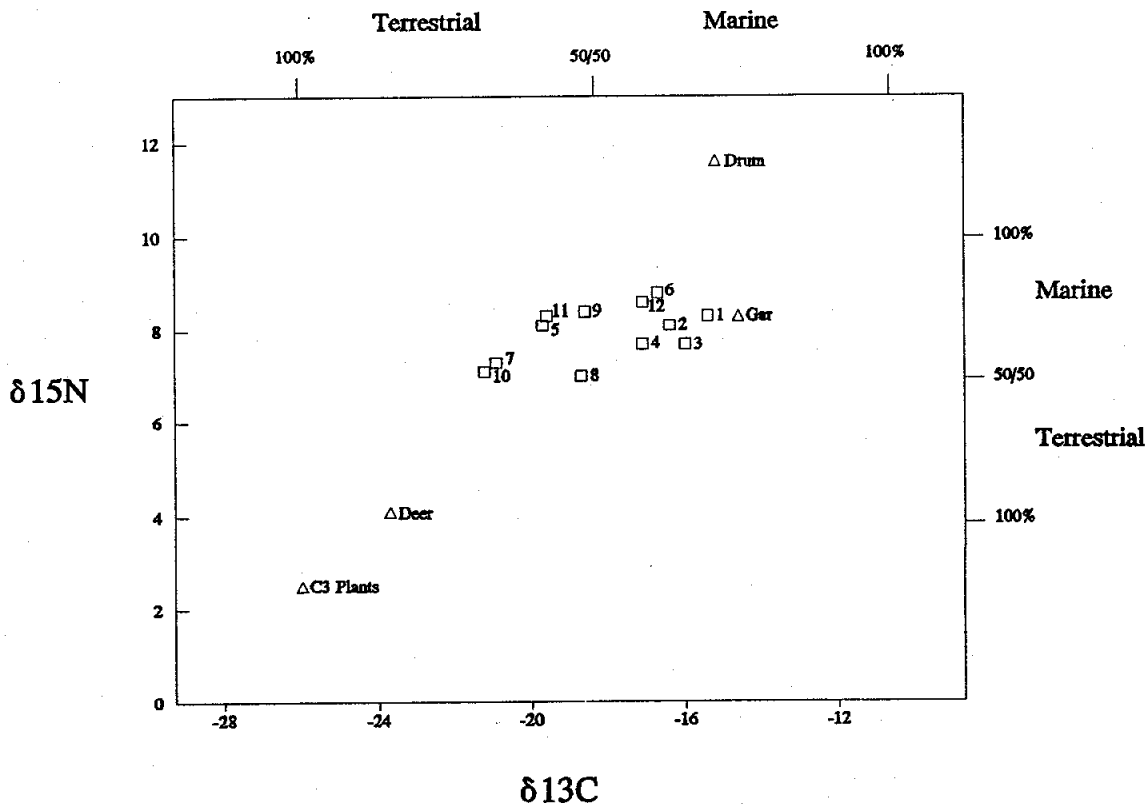


Figure 10.1. Graph showing distributions of faunal and human bone samples at Mitchell Ridge, according to stable carbon and nitrogen isotope values. Sample numbers for human bone correlate with Feature numbers as follows: #1 is 1970s Burial 7, #2 is 1970s B. 10, #3 is 1970s B. 12, #4 is Fea. 25, #5 is Fea. 30, #6 is Fea. 62-2, #7 is Fea. 61, #8 is Fea. 87, #9 is Fea. 63, #10 is Fea. 64-4, #11 is Fea. 64-1 and #12 is 1970s B. 5.

marine sources. By calculating the $\delta^{13}C_d$ values resulting from varying contributions of marine and terrestrial dietary inputs, a precursory reconstruction of human diet at 41GV66 can be obtained. For this mixing model the marine resources are given an average $\delta^{13}C$ value of -11.0‰ , and terrestrial foods are assigned an average $\delta^{13}C$ value of -26.0‰ . Ideally, a human $\delta^{13}C_d$ value of -11.0‰ suggests total reliance on marine foods, while a $\delta^{13}C_d$ value of -26.0‰ suggests total reliance on terrestrial foods (Figure 10.1). A human $\delta^{13}C_d$ value of -18.5‰ implies equal contributions from both groups. Allowing for $\pm 1.0\text{‰}$ to account for the error induced by using average $\delta^{13}C$ values, not actual isotope values from the prehistoric ecosystem, and machine error, diet at 41GV66 ranged from $77 \pm 7\%$ marine (-15.4‰), to $39 \pm 7\%$ marine (-21.2‰).

Group 1 members, which tend to represent the earlier inhabitants of the site, show a diet comprised of two thirds to three quarters marine products (Figure 10.1). The later occupants of the site show mostly show a decrease in marine resource consumption as their diets contained only half to one third marine products. There are several possible explanations for this significant shift in diet.

Environmental change manifested as rising or falling sea levels, altered salinity or hurricane modification would have been detrimental to the sea grass meadows exploited by local human populations. With the loss of the C_4 grasses from the bottom of the ecosystem the carbon isotope values of human prey species would become more C_3 -like, and most resemble those animals in their open water, offshore habitats. The loss of seagrasses would also change the species composition in the shallow water flats, and modify human exploitation patterns. Ecological changes by these means would have been primarily episodic in nature and of short durations. However, what we see in the data is an abrupt change in diet in by the time of European contact. This suggests that if ecological change were the principal cause for

dietary change, the ecological changes were pervasive and long enduring.

Dietary change might be linked to changes in resource use. Technological changes may have opened new niches for the Protohistoric-Historic people of Group 2. The greater exploitation of offshore populations of older, larger fish would cause human $\delta^{13}\text{C}$ values to become more negative. Broadening of the terrestrial/riverine econiche would also bring about the type of change seen in the human carbon isotope data if a increase in these C_3 pathway foods were at the expense of marine resources. Population growth and increased mobility could be argued for as causes for expansion of the dietary niche, in addition to technological changes.

Perhaps the most likely explanation for the apparent shift in diet is related to the nature of the cultural dynamics along the Gulf coast during the period of European contact, as suggested by the fact that three of the four individuals with the most negative ^{13}C values date to the Early Historic Period (samples 7, 10 and 11). Powell (Chapter 9 has pointed to the bioarchaeological evidence for introduction of non-local individuals into the Mitchell Ridge burial population, and the ethnohistoric and archaeological evidence for influx of outsiders is summarized and discussed by Ricklis in Chapter 12. Such individuals could be expected to show lifetime dietary signatures, in terms of ^{13}C values, which in general diverge from those of prehistoric (and presumably indigenous) individuals. Ricklis suggests that, based on ethnohistoric evidence, a general Southeastern origin for such individuals is possible, and it may be relevant and significant that the average ^{13}C value for Samples 7, 10 and 11 is -15.5, within the range indicated for Caddoan maize horticulturalists in Table 10.4 (which does not necessarily imply that these individuals were Caddoan, but rather that they might have had a dietary history involving an non-coastal, horticultural adaptation).

Nitrogen Isotopes

The human $\delta^{15}\text{N}$ values are relatively uniform through time. They are also rather on the low side for a population subsisting, in part, on marine resources. Previous studies of prehistoric human diets in coastal regions have shown $\delta^{15}\text{N}_d$ values to range between +8.5 and +18.0‰ (Schoeninger et al. 1983; Schoeninger and DeNiro 1984; DeNiro 1987). The lowest range of values (8.5-13.5‰) are normally seen in populations who consume mainly marine invertebrates, while vertebrate consumers range between 10.5-18.5‰. Since the faunal record from sites in the Upper Coast indicates that humans consumed marine vertebrates in abundance, the low $\delta^{15}\text{N}_d$ range at 41GV66 (7.0-8.8‰) is not directly comparable with these studies.

The reason for the differences between 41GV66 and other analyses lies in the type of coastal environment studied. The earlier studies cited above all involved open coastlines, whereas we are dealing with a bay system protected by barrier islands. Seagrass meadows found behind the barrier islands have a high rate of nitrogen fixation, approximately 250 times greater than the open ocean, which results in low $\delta^{15}\text{N}$ values (Capone and Carpenter 1982).

Despite their low values, the $\delta^{15}\text{N}$ values of the marine component of diet for the 41GV66 population do not overlap the terrestrial portion, which means we should be able to tell the two systems apart. Using an average value of +10.0‰ from the two archaeological fish samples to represent the marine component of diet and +4.0‰ for the terrestrial portion, a preliminary reconstruction of human diet can be calculated for the sample population's $\delta^{15}\text{N}$ values. Consumption of marine products ranged from 50% (+7.0‰), to 80% (+8.8‰) of dietary intake.

Stable nitrogen isotope values found in the 41GV66 humans suggest that the prehistoric bay environments contained more expansive areas of seagrass meadow than at present, and these were heavily exploited by local populations. This would have produced lower overall $\delta^{15}\text{N}$ values such as seen in the archaeological gar sample.

Interregional Isotopic Dietary Comparisons

Stable isotopes have been used to analyze both hunter-gatherer and horticulturalist paleodiets in several of the diverse environmental zones of Texas (Table 10.4). Four of these, two coastal populations from 41GV53 and from a collection of four sites in the vicinity of Corpus Christi, and two inland coastal plain populations from Ernest Witte (41AU36) and Blue Bayou (41VT94), are particularly germane for

Table 10.4. Stable isotope values in ‰ for prehistoric Texas.

	$\delta^{13}\text{C}$ (PDB)	$\delta^{15}\text{N}$ (AIR)	Reference
MAIZE FARMERS			
<u>Antelope Creek</u>			
\bar{x} sd	-8.1 ± 0.61	9.8 ± 0.45	Levendosky '87
Range	-11.2 to -7.4	8.3 to 10.5	
<u>Caddo</u>			
\bar{x} sd	-16.3 ± 1.15	8.7 ± 0.55	Gill-King '93
Range	-17.6 to -15.2	7.6 to 9.2	
<u>Old Socorro</u>			
\bar{x} sd	-11.0 ± 1.38	10.8 ± 1.0	Evans '89
Range	-13.5 to -9.0	9.2 to 11.9	
HUNTER-GATHERERS			
<u>Bering Sink</u>			
\bar{x} sd	-15.8 ± 0.97	8.1 ± 0.85	Bement '92
Range	-17.5 to -13.7	6.9 to 9.7	
<u>Lower Pecos</u>			
\bar{x} sd	-14.0 ± 1.23	11.1 ± 2.8	Huebner '91
Range	-15.8 to -11.9	5.3 to 16.6	
<u>Corpus Christi</u>			
\bar{x} sd	-13.0 ± 1.78	10.4 ± 1.08	Huebner &
Range	-14.7 to -7.7	9.2 to 12.8	Krueger '92
<u>Ernest Witte</u>			
\bar{x} sd	-19.2 ± 0.7	--	Huebner &
Range	-20.5 to -18.4	--	Boutton '92
<u>Blue Bayou</u>			
\bar{x} sd	-18.7 ± 0.81	10.5 ± 1.04	Huebner &
Range	-20.3 to -17.8	9.1 to 11.8	Commuzzie '92
<u>Mitchell Ridge</u>			
\bar{x} sd	-13.2 ± 2.01	10.4 ± 0.58	This Study
Range	-16.2 to -10.4	9.5 to 11.3	

The separation of carbon isotope values from these inland sites and the Corpus Christi coastal sites is congruent with the 41GV66 findings. These stable isotopic patterns fit within the spatial distribution of discrete cultural patterns within their specific environmental zones, along with the archaeological findings of their respective subsistence patterns.

Inland coastal plain populations have similar $\delta^{13}\text{C}$ values, which are about 7‰ more negative than the 41GV66 human values. The inland samples are indicative of a diet comprised of 85-90% C_3 terrestrial/riverine foods, and absent of marine products. The small C_4 component of the diet is drawn from C_4 grass seed, or small herbivorous mammals which consumed C_4 grasses. Grasses with the C_4 photosynthetic pathway were the dominant species in the prehistoric central and lower coastal prairies.

Of the inland sites only 41VT94 has $\delta^{15}\text{N}$ data. With an average $\delta^{15}\text{N}$ value of +10.5‰ these values are nearly identical to those of the coastal populations. The riverine input to these diets is the suspected cause of the high $\delta^{15}\text{N}$ values relative to the low $\delta^{15}\text{N}$ values found in the seagrass ecosystems (Huebner and Comuzzie 1992).

The Corpus Christi and 41GV66 samples both have similar $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values. This suggests that the economic species have similar isotope values and the subsistence patterns are analogous, or that the isotope values vary dramatically from bay to bay and the subsistence patterns were different. Based on faunal remains from sites along the central and upper coast, the former would seem to be the case.

The $\delta^{13}\text{C}$ results from 41GV53 human samples are the only discordant $\delta^{13}\text{C}$ values for a prehistoric Texas population in relation to its local environmental zones. The $\delta^{13}\text{C}$ range of the four analyzed burial features from 41GV53 is -22.4 to -21.0‰ (Colby et al. 1992). These values are inconsistent with the subsistence patterns, and human skeletal evidence from other Texas coastal sites. The $\delta^{13}\text{C}$ values used in the 41GV53 dietary analysis were from tiny AMS ^{14}C samples which are expected to be somewhat less precise in comparison with $\delta^{13}\text{C}$ values measured from larger samples used for beta counting ^{14}C assays, or dietary $\delta^{13}\text{C}$ studies (Hines 1992:25-27). Even if these $\delta^{13}\text{C}$ values were off 3-4‰ due to incomplete combustion during sample preparation, they would still show a significant divergence from the findings from 41GV66. The average human $\delta^{13}\text{C}$ of -21.5‰ from 41GV53 indicates a diet of 100% C_3 products which seems highly unlikely given the environment of the site and its faunal collection. To have this range of depleted $\delta^{13}\text{C}$ values, the 41GV53 individuals would have to have come from non-horticultural Midwestern and the Eastern Woodlands populations; where C_4 plants were and are extremely rare, and did not contribute to hunter-gatherer diets (cf. Huebner and Boutton 1992).

The four AMS ^{14}C assays of the human remains from 41GV53 overlap the ^{14}C age of 41GV66 samples 1,4 and 8 (this excepts their potentially incorrect calibration owing to the depleted $\delta^{13}\text{C}$ value used in correction), ruling out temporal discrepancies as an explanation for dietary differences between the two site populations. Be it from sample contamination or incomplete combustion, these $\delta^{13}\text{C}$ values do not agree with the ecological setting of the site, and therefore will not be further discussed.

When the four data sets are compared they show a clear separation in $\delta^{13}\text{C}$ values between groups who lived on the coast and those that drew their subsistence from purely terrestrial sources. Conversely, the $\delta^{15}\text{N}$ values have negligible powers to discriminate between the ecosystems. While nitrogen isotopes are useful for determining dietary patterns within an ecosystem, only carbon isotopes may be employed to determine differences between these ecosystems.

The characteristics of the 41GV66 mortuary population are unique in comparison to the other sites. None of the dietary differences noted at 41GV66 are seen in the Blue Bayou, Ernest Witte, and Corpus Christi data sets. While all have a partial temporal overlap with 41GV66, none continue past the Late Prehistoric period, and none suggest the kind of population movements such as those suspected for the Historic period samples from 41GV66.

As a final note, given the unique and heterogeneous nature of the late burial population at 41GV66, stable isotope analysis may present a means of eventually identifying source populations. In a recent article Verano and DeNiro (1993) used stable carbon and nitrogen isotope analysis in conjunction with biometric measurements of the craniofacial skeleton to determine the population affinity for a mass burial in Pacatnamu, Peru. In the future, when isotope analyses are obtained for regions east of 41GV66, it may be possible to estimate the origin of Diet Group 2 from the stable isotope data in concert with the mortuary and biometrical traits present at the site.