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Carbon and Nitrogen Stable Isotopic Signatures of Human Dietary Change in the Georgia Bight

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ABSTRACT Measurement of carbon and nitrogen stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) in samples of human bone collagen (n = 93) from a temporal series of four prehistoric (early preagricultural, late preagricultural, early agricultural, late agricultural) and two historic (early contact, late contact) periods from the Georgia Bight, a continental embayment on the southeastern U.S. Atlantic coast, reveals a general temporal trend for less negative $\delta^{13}C$ values and less positive $\delta^{15}N$ values. This trend reflects a concomitant decrease in emphasis on marine resources and increased reliance on C_4-based resources, especially maize. This dietary reorientation is most apparent for the early agricultural sample (AD 1150–1300), coinciding with the Mississippian florescence in the eastern United States. There is, however, a shift toward the use of C_3 (non-maize) foods during the last prehistoric period (AD 1300–1450), which is likely related to environmental stress and social disruption. A heavier use of maize and terrestrial resources in general after the establishment of mission centers on barrier islands is indicated. A reduced dietary breadth during the mission period may have contributed to the extinction of these populations in the eighteenth century.

Approaches to dietary reconstruction using stable isotope ratios of carbon and nitrogen in bone organic residues (called collagen in this article) from archaeological human bone have made it possible to reconstruct key components of subsistence economy and nutritional ecology in earlier societies (Schwarcz and Schoeninger, 1991). The organic fraction of bone does not undergo isotopic exchange, which limits post-depositional diagenetic effects (DeNiro, 1985; Bada et al., 1989). In eastern North America, the use of stable isotope ratios has facilitated an increase in knowledge of the appearance, spread, and degree of consumption of maize in native populations (summarized in Ambrose, 1987; Smith, 1989). Maize played a key role in the transformation of simple, band-level egalitarian societies into an array of complex chiefdoms during the last five hundred years or so prior to European contact (Smith, 1989). At the same time, maize is strongly implicated as a principal factor leading to a deterioration in human health in a number of geo-

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graphical settings (see Cohen and Armelagos, 1984).

In an earlier study (Schoeninger et al., 1990), we utilized carbon and nitrogen isotope ratios to track major subsistence changes in order to provide a context for understanding health and behavioral adaptation in native populations occupying the mid-section of the Georgia Bight, a large continental embayment extending from Cape Hatteras, North Carolina, to Cape Canaveral, Florida (Frey and Howard, 1986; Reitz, 1988). Physiographically, the Georgia Bight is dominated by a series of barrier and marsh islands that lie in front of an extensive estuarine system. In relation to potential food resources, the region is one of the richest, most diverse settings in the world, and it is certainly the most productive on the eastern Atlantic seaboard, especially with regard to the tremendous wealth of wild plants and animals available from inshore waters (estuaries and beaches) and surrounding areas (Reitz, 1988). Our combined use of carbon and nitrogen stable isotopes demonstrated a heavy focus on these resources prior to the twelfth century AD, which was followed by a concomitant reduction in use of marine resources and appearance of maize prior to the establishment of Spanish missions in the late sixteenth century. In addition, we were able to show that use of marine resources continued to decline and use of maize continued to increase during the early mission period.

In the present investigation, we extend the scope of the earlier study by incorporating additional samples of skeletal individuals from three temporal groups, including prehistoric hunter-gatherers and late prehistoric populations from coastal Georgia and a late contact era population from coastal northern Florida (Fig. 1). These added samples, combined with those from the aforementioned study, make the present investigation one of the most extensively documented, regionally-based dietary analyses utilizing an isotopic approach.

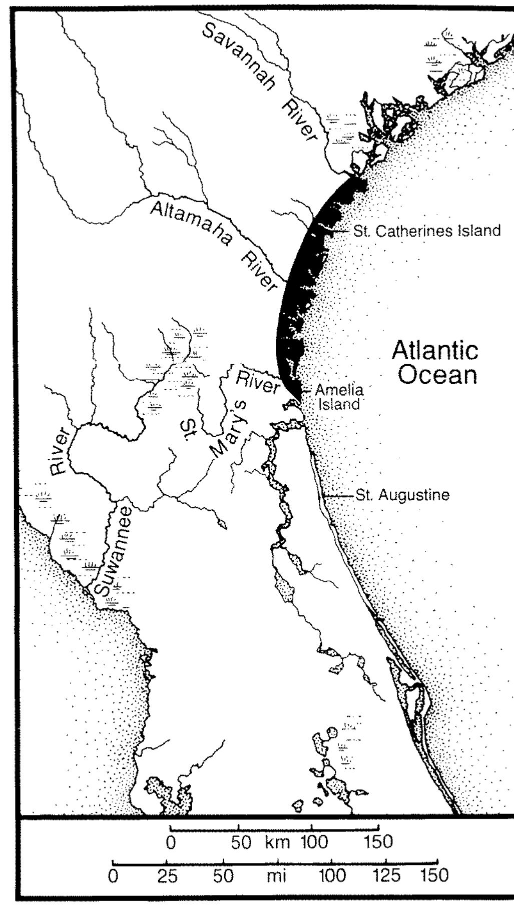

Fig. 1. Map showing study area (shaded) in the Georgia Bight. The Deptford and Irene sites are located at the mouth of the Savannah River; Santa Catalina de Guale de Santa Maria is located on Amelia Island; all other sites are located on St. Catherines Island. During the mission period, the region was one of the provinces of *La Florida*, which includes coastal Georgia and northern Florida (from Larsen et al., 1991; copyright © 1991; reprinted by permission of Wiley-Liss, a division of John Wiley and Sons, Inc.).

THE SKELETAL SAMPLES AND THEIR BIOCULTURAL CONTEXT

The skeletal samples used for the study are listed in Table 1. For purposes of analysis, we have distributed them into a temporal sequence of six periods, including early preagricultural, late preagricultural, early agricultural, late agricultural, early contact, and late contact. The early preagricultural sample consists of remains from five archaeological sites from local periods (sensu DePratter, 1979, 1984) on the Georgia coast known as the Refuge (1100–400 BC), Deptford (400 BC–AD 500), and Wilmington (AD 500–1000) periods. These local periods constitute the respective Early, Middle, and

TABLE 1. Archaeological context for Georgia and Florida coastal stable isotope data

Site	Archaeological phase(s)	N (=93)	References
Early preagricultural (1000 BC–AD 1000)			
McLeod Mound	Refuge-Deptford	4	Thomas and Larsen, 1979; Larsen, 1982
Seaside Mound II	Refuge-Deptford	2	Thomas and Larsen, 1979; Larsen, 1982
Cunningham Mound C	Deptford-Wilmington	1	Thomas and Larsen, 1979; Larsen, 1982
Cunningham Mound D	Deptford-Wilmington	1	Thomas and Larsen, 1979; Larsen, 1982
Deptford site	Deptford-Wilmington	10	Thomas and Larsen, 1979; Larsen, 1982
Late preagricultural (AD 1000–1150)			
Johns Mound	St. Catherines	10	Larsen and Thomas, 1982; Larsen, 1982
Marys Mound	St. Catherines	2	Larsen and Thomas, 1982; Larsen, 1982
Early agricultural (AD 1150–1300)			
Irene (Burial Mound)	Savannah I-III	9	Caldwell and McCann, 1941; Hulse, 1941; Larsen, 1982; Anderson, 1990a
Late agricultural (AD 1300–1450)			
Irene (Mortuary)	Irene I	11	Caldwell and McCann, 1941; Hulse, 1941; Larsen, 1982; Anderson, 1990a
Early contact (AD 1608–1680)			
Santa Catalina (St. Catherines Island)	Altamaha	22	Thomas, 1987; Larsen, 1990; Larsen et al., 1990
Late contact (AD 1686–1702)			
Santa Catalina (Amelia Island)	Altamaha	21	Saunders, 1988; Larsen, 1991

Late Woodland occupations of this region. The late preagricultural sample is comprised of specimens from two mortuary localities dating to the St. Catherines period (AD 1000–1150), which is the transitional phase between the Woodland and the following Mississippian periods. Human populations living during the Refuge through St. Catherines periods are characterized as non-sedentary fisher-hunter-gatherers extracting resources from both marine and terrestrial contexts.

The early agricultural and late agricultural periods are represented by human remains from two cultural components of the Irene site at the mouth of the Savannah River on the north Georgia coast. The former is from the "Burial Mound," a Savannah period (AD 1150–1300) sample, and the latter is from the "Mortuary," an Irene period (AD 1300–1450) sample. The Irene site is the dominant Mississippian period occupation in the Georgia Bight.

Increasing cultural complexity and appearance of some form of chiefdom level of social organization characterizes the post-AD 1150 populations. However, changes in mortuary practices and interment patterns, shift from temple mound construction to council house construction, and other key developments taking place in the Irene period (ca. AD 1300) indicate a transition towards a more egalitarian form of social organization that likely resulted from the destabilizing effects of increasing environmental stress (e.g., reduced rainfall, increased warfare) (Anderson, 1990a,b). Moreover, following the Irene period, the region encompassing the mouth of the Savannah River—including the Irene site—was entirely abandoned by native populations. Archaeological evidence indicates that this abandonment was related to social developments and stress factors (Anderson, 1990a). The region was resettled by native populations by the time of initial European contact in the early sixteenth century. Other areas of the Georgia coast appear not to have been abandoned prior to the arrival of Europeans.

The early contact period—known locally as the Altamaha period—is represented by skeletal samples recovered from a Spanish mission (Santa Catalina de Guale) cemetery on St. Catherines Island, Georgia (AD 1608–1680), and the late contact period (also Altamaha) is represented by samples from the descendent population from Amelia Island, Florida (Santa Catalina de Guale de Santa Maria; AD 1680–1702). Ethnohistoric and archaeological evidence indicates that native populations occupying these missions were maize agriculturalists incorporating at least some wild plants (e.g., acorn, hickory) and animals (especially deer) into their diets. Moreover, these populations were subject to elevated stress loads, owing to the introduction of Old World pathogens (e.g., smallpox, measles), periods of food shortages, warfare, excessive work loads, soil depletion, and other stressors (Larsen, 1990; Larsen et al., 1990).

At the time of the first documented European contact in the early sixteenth century, the area from which these skeletal samples were derived was known as Guale, which is also the name of the tribe that occupied it (Jones, 1978). For most of prehistory, populations living in the area were dependent upon wild plants and animals from both terrestrial and marine contexts. Analysis of archaeological faunal remains indicates, however, that marine resources, especially fish and shellfish, provided most dietary protein (Reitz, 1988). During the twelfth century (or at least by the Savannah period), botanical evidence as well as the appearance of large, nucleated habitation sites, indicates the adoption of maize agriculture in addition to these resources (Larsen, 1982; Reitz, 1988). These changes are consistent with the appearance of chiefdoms of the Mississippian period in the eastern U.S. in general (Griffin, 1967; Steponaitis, 1986; Smith, 1986, 1989) and in this region in particular (Larsen, 1982; Anderson, 1990a,b). Based on archaeological (botanical) evidence alone, the relative importance of maize versus marine or other sources of food in native diets is unclear (Reitz, 1988).

Historic accounts of the Spanish mission centers suggest that maize played an increasingly important role in the diet during this period, not only for provisioning native populations occupying mission centers, but also for support of Europeans living in the region and for export to St. Augustine, the capital of Spanish Florida (Larsen et al., 1990). Indeed, elevated dental caries prevalence in contact native populations in the region points to high levels of maize consumption (Larsen et al., 1991).

METHODS

Dietary reconstruction

For this study, we determine stable carbon isotope ratios ($^{13}C/^{12}C$) as represented by delta (δ) values in parts per thousand (read as "per mil," or ‰). These values are determined by the comparison of the sample isotope ratio with a standard (based on a marine limestone, Peedee belemnite [PDB]), or

$$\delta^{13}C = \{[(^{13}C/^{12}C)_{sample}] \div [(^{13}C/^{12}C)_{standard}] - 1\} \times 1{,}000‰$$

The $\delta^{13}C$ values have been utilized by various researchers in order to distinguish two major dietary groups. First, these values distinguish C_4 plants (tropical grasses such as maize) and their consumers from C_3 plants (most leafy plants) and their consumers due to different photosynthetic pathways and the marked differences in the amount of ^{13}C incorporated into their tissues. Maize is enriched in the ^{13}C stable isotope relative to C_3 plants, and because of this distinction, $\delta^{13}C$ values have proven useful in tracking its introduction and extent of use in non-coastal areas of the New World (e.g., Vogel and van der Merwe, 1977; van der Merwe and Vogel, 1978; van der Merwe et al., 1981; Bender et al., 1981; van der Merwe, 1982; Schoeninger et al., 1983; Bumsted, 1984; Farnsworth et al., 1984; Schwarcz et al., 1985; Lynott et al., 1986; Buikstra et al., 1987, 1988; White, 1988; White and Schwarcz, 1989; Spielmann et al., 1990; Rose et al., 1991; Matson and Chisholm, 1991; Buikstra and Milner, 1991). In a similar vein, $\delta^{13}C$ values have indicated the probable presence of C_4 domesticates (e.g., millet) in Iron Age Europe (Murray and Schoeninger, 1988).

Second, $\delta^{13}C$ values provide information on the use of marine foods. Marine fishes and mammals have $\delta^{13}C$ values that are less negative by about 6‰) compared to animals that feed on C_3-based foods and values that are more negative (by about 7‰) than animals that feed on C_4-based foods (Schoeninger and DeNiro, 1984; Schoeninger et al., 1983). That is, marine animals yield $\delta^{13}C$ values that are between C_3- and C_4-based food chains. Thus, where C_4 plants are not consumed, $\delta^{13}C$ values provide insight into the consumption of marine foods by human populations (e.g., Tauber, 1981; Chisholm et al., 1982; Schoeninger et al., 1983; Sealy, 1986; Sealy and van der Merwe, 1986; Sealy et al., 1987; Walker and DeNiro, 1986; Walker et al., 1989; Keegan and DeNiro, 1988). In the Georgia Bight, human populations during both later prehistory and the contact period were known to have consumed both maize and marine foods. Thus, given the overlap in signatures of $\delta^{13}C$ values in consumers of marine and C_4-based foods (or animals that consumed C_4 foods), it is not possible to rely exclusively on $\delta^{13}C$ values for monitoring the introduction or degree of reliance on maize in this region.

However, when nitrogen and carbon ratios are used concurrently, it is possible to identify key components of diet, particularly in populations using maize (the only documented dietary C_4 plant in the region) and marine resources. Like carbon, nitrogen stable isotope ratios ($^{15}N/^{14}N$) identified from collagen samples have been demonstrated to reflect dietary ratios (DeNiro and Epstein, 1981). Similarly, the values are expressed in relation to a standard (atmospheric nitrogen, or Ambient Inhalable Reservoir [AIR]) as delta (δ) values in parts per mil (‰):

$$\delta^{15}N = \{[(^{15}N/^{14}N)_{sample}] \div [(^{15}N/^{14}N)_{standard}] - 1\} \times 1{,}000‰$$

Schoeninger and DeNiro (1984) have provided evidence that in many regions of the world $\delta^{15}N$ values in terrestrial plants and animals are about 10‰ less positive than marine plants and animals. Thus, they conclude that it is possible to determine with some precision the relative contribution of marine foods in human populations in many circumstances (cf. Schoeninger et al., 1983; Walker and DeNiro, 1986; Walker et al., 1989; Ericson et al., 1989). A sample of modern terrestrial and marine fauna collected from a Georgia coastal barrier island (St. Catherines Island) was analyzed for $\delta^{15}N$ values. These values demonstrated differences between marine and terrestrial foods (Schoeninger et al., 1990). Therefore, if it can be shown that $\delta^{15}N$ values become less positive (reflecting increased utilization of terrestrial foods) at the same time that $\delta^{13}C$ values become less negative, then it can be inferred that maize likely took on a more important role in diet (Fig. 2; see also discussion in Schoeninger et al., 1990).

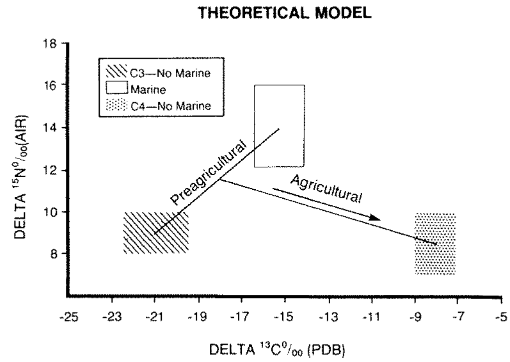

Fig. 2 Graph showing theoretical values for three diets plotting $\delta^{15}N$ and $\delta^{13}C$ in human bone collagen from the Georgia Bight. The boxes are intended to show the general dietary tendencies and not to delineate clear separations between diets (from Schoeninger et al., 1991; reprinted by permission of the American Museum of Natural History).

Collagen analysis

Bone collagen was removed from archaeological bone samples (mostly ribs) and analyzed following procedures detailed elsewhere (Schoeninger et al., 1990). Only specimens yielding organic residues in excess of 5% of the original bone weight (modern bone contains about 25% of dry weight [Boskey and Posner, 1984]) and with atomic carbon:nitrogen ratios between 2.7 and 3.6 were included in the study. It has been argued that values deviating from these ranges do not reflect biological values and thus are not true indicators of dietary isotope ratios (Schoeninger and DeNiro, 1982; DeNiro, 1985; Schoeninger et al., 1989; Bada et al., 1989). Several samples in the present analysis yielded C:N ratios that were slightly above (.1–.2) the ideal C:N ratios. However, because these few outlyer C:N ratios were close to acceptable values, we chose to use them in the study. Moreover, exclusion of them did not affect the results. In total, 93 samples yielding both $\delta^{13}C$ and $\delta^{15}N$ values conforming or closely conforming to these parameters were used for documenting dietary changes in the Georgia Bight.

Two laboratories were involved in the analysis of bone collagen samples. All prehistoric specimens (early preagricultural, late preagricultural, early agricultural, late agricultural) were prepared and analyzed under the direction of N.J.v.d.M. at the University of Cape Town, and the samples from mission period archaeological sites (early contact, late contact) on St. Catherines Island and Amelia island were prepared and analyzed by M.J.S. at Harvard University. In order to demonstrate compatibility of analysis involving different researchers and laboratories, bone samples from a single Georgia coastal archaeological site (Deptford) were independently analyzed by Schoeninger at the University of California, Los Angeles, and by van der Merwe at the University of Cape Town. The carbon and nitrogen isotope ratio values determined by the two labs are statistically indistinguishable (Schoeninger et al., 1990: Table 6-2). In addition, bone samples from another study (Schoeninger et al., 1983) and several standards were analyzed concurrently at U.C.L.A. and Harvard. These results are also very similar (Schoeninger et al., 1990). We conclude, therefore, that the $\delta^{13}C$ and $\delta^{15}N$ values produced by these labs are directly comparable.

RESULTS

Carbon and nitrogen stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) are presented for each individual in Table 2 and summary statistics by site are presented in Table 3. One individual, a skeleton recovered from Santa Catalina de Guale on St. Catherines Island is a juvenile (specimen MS 2876, eight years). All other individuals are adults, and they are represented by approximately equal numbers of females and males. It is possible that any temporal changes in isotope ratios revealed by our analysis may be influenced by sex differences in diet or sex-based physiological differences in fractionation of isotopes. Regarding the latter interpretation, findings from at least one study have strongly suggested that there are no physiological differences between sexes (Lovell et al., 1986; and see Schwarcz and Schoeninger, 1991). Additionally, statistical treatment of female and male mean values in the present investigation (see Table 4 and 5 for sites and periods, respectively) reveals no differences between sexes within sites or periods in either carbon or nitrogen stable isotope ratios (t-test: $P > 0.05$). Therefore, we conclude that temporal differences discussed below reflect true dietary changes.

Summary statistics for the six periods (sexes combined) are presented in Table 6 ($\delta^{13}C$, $\delta^{15}N$), and the means of stable isotope ratios are graphically presented in Figure 3 ($\delta^{13}C$) and Figure 4 ($\delta^{15}N$). Examination of these data reveals that the late preagricultural period carbon isotope ratios are less negative than the early preagricultural period ratios, with the range of values being much narrower in the former. Given that the early preagricultural period encompasses a time range of some 2,000 years and the late preagricultural period spans only about 150 years, the discrepancy in ranges of isotope ratios probably reflects a greater breadth of foods exploited in relation to a longer period of time in the early preagricultural period than in the late preagricultural period. The nitrogen isotope ratios are also more positive in the late preagricultural period, suggesting a greater reliance on marine foods in the later period. The relatively less positive mean $\delta^{15}N$ value in the early preagricultural group may reflect, however, the presence of generally less positive values from the Deptford site, which is located several miles up the Savannah River from the coast. This factor alone may indicate consumption of more terrestrial foods than in the late preagricultural period populations, which are represented by samples from a barrier island (St. Catherines Island) only. Indeed, the mean $\delta^{15}N$ value for the Deptford site is the lowest in the five early preagricultural period sites (see Table 3).

The early agricultural period shows less negative $\delta^{13}C$ values and less positive $\delta^{15}N$ values than the preceding late preagricultural period. These temporal trends combined suggest an increasing focus on terrestrial plants (maize) and animals coupled with a decreasing reliance on marine foods. These trends are consistent with findings reported from other U.S. localities. For example, the $\delta^{13}C$ mean value is well within the range of values summarized by Ambrose (1987: see Fig. 4-2) for eastern North America. It is important to note, however, that the reduction in $\delta^{15}N$ values in the early agricul-

TABLE 2. Stable isotope and individual data from Georgia and Florida coastal archaeological sties

Lab No.	Site	Skeleton	Sex[1]	Age	$\delta^{13}C$‰ (PDB)	$\delta^{15}N$‰ (AIR)
Early preagricultural						
UCT 389	McLeod Mound	13	F	21	−17.1	13.1
UCT 391	McLeod Mound	15	F	15	−18.6	12.9
UCT 392	McLeod Mound	16	F	30	−13.8	12.6
UCT 393	McLeod Mound	17	F	36	−13.6	12.4
UCT 388	Seaside Md. II	14	F	Adult	−13.4	13.2
UCT 386	Seaside Md. II	11	M	Adult	−13.8	10.6
UCT 394	Cunningham Md. C	1	F	Adult	−16.0	14.4
UCT 396	Cunningham Md. D	2	M	Adult	−13.9	12.9
UCT 334	Deptford	4A	F	Adult	−13.4	11.3
UCT 335	Deptford	4B	F	Adult	−14.5	11.3
UCT 382	Deptford	8A	F	45	−18.6	10.7
UCT 337	Deptford	13	F	25	−17.5	9.6
UCT 339	Deptford	17	F	Adult	−16.7	11.6
UCT 341	Deptford	22	F	Adult	−16.0	11.8
UCT 340	Deptford	18A	M	37	−15.6	12.9
UCT 342	Deptford	28	M	Adult	−16.8	12.0
UCT 343	Deptford	29A	M	21	−17.1	9.6
UCT 344	Deptford	40	M	23	−12.6	10.4
Late preagricultural						
UCT 374	Johns Mound	26	I	45	−13.7	12.3
UCT 370	Johns Mound	36	I	Adult	−14.1	13.0
UCT 377	Johns Mound	16	F	50	−14.6	13.3
UCT 376	Johns Mound	18	F	36	−13.9	13.6
UCT 375	Johns Mound	37	F	40	−14.4	12.7
UCT 379	Johns Mound	14	M	Adult	−13.4	13.1
UCT 372	Johns Mound	1	M	21	−14.2	11.6
UCT 371	Johns Mound	11A	M	45	−14.2	13.3
UCT 378	Johns Mound	47	M	45	−14.3	13.5
UCT 373	Johns Mound	B	M	33	−14.2	12.9
UCT 380	Marys Mound	1	F	Adult	−14.3	11.8
UCT 381	Marys Mound	5	F	25	−14.7	12.9
Early agricultural						
UCT 349	Irene Bu. Md.	2A	F	22	−14.0	9.6
UCT 352	Irene Bu. Md.	7	F	19	−10.8	9.5
UCT 355	Irene Bu. Md.	12	F	37	−16.4	10.1
UCT 356	Irene Bu. Md.	14	F	36	−13.9	11.2
UCT 358	Irene Bu. Md.	72	F	Adult	−11.5	13.3
UCT 350	Irene Bu. Md.	3	M	Adult	−13.3	10.4
UCT 351	Irene Bu. Md.	4B	M	24	−10.0	10.6
UCT 353	Irene Bu. Md.	5	M	19	−12.4	10.5
UCT 357	Irene Bu. Md.	16	M	Adult	−14.4	10.8
Late agricultural						
UCT 363	Irene Mortuary	74	F	33	−14.5	9.7
UCT 366	Irene Mortuary	108	F	31	−17.0	9.6
UCT 368	Irene Mortuary	110	F	Adult	−15.6	10.0
UCT 369	Irene Mortuary	111	F	22	−17.2	9.6
UCT 359	Irene Mortuary	8A	M	23	−17.4	10.7
UCT 360	Irene Mortuary	64	M	16	−16.8	9.2
UCT 361	Irene Mortuary	69B	M	21	−17.9	8.7
UCT 362	Irene Mortuary	70	M	47	−17.0	10.4
UCT 364	Irene Mortuary	75	M	Adult	−13.7	10.2
UCT 365	Irene Mortuary	107	M	37	−17.7	9.9
UCT 367	Irene Mortuary	109	M	45	−17.9	10.2
Early contact						
MS 2862	Santa Catalina	160	I	25	−12.9	9.9
MS 2871	Santa Catalina	219	I	Adult	−11.0	8.9
MS 2876	Santa Catalina	235	I	8	−10.6	10.0
MS 2859	Santa Catalina	na[2]	I	Adult	−12.6	9.6
MS 2835	Santa Catalina	9	F	44	−9.6	7.4
MS 2838	Santa Catalina	22	F	45	−12.4	9.6
MS 2844	Santa Catalina	58	F	20	−12.0	9.5
MS 2832	Santa Catalina	60	F	43	−14.3	9.5
MS 2848	Santa Catalina	64	F	35	−11.8	9.9
MS 2850	Santa Catalina	88	F	22	−11.0	9.7
MS 2851	Santa Catalina	98	F	28	−11.2	8.9
MS 2857	Santa Catalina	99	F	36	−12.1	9.0
MS 2865	Santa Catalina	123	F	26	−11.2	10.2

(*Continued*)

TABLE 2. Stable isotope and individual data from Georgia and Florida coastal archaeological sties (Continued)

Lab No.	Site	Skeleton	Sex[1]	Age	$\delta^{13}C$‰ (PDB)	$\delta^{15}N$‰ (AIR)
MS 2879	Santa Catalina	276	F	20	−11.3	9.4
MS 2836	Santa Catalina	18	M	43	−11.7	9.6
MS 2839	Santa Catalina	39	M	39	−11.6	10.4
MS 2840	Santa Catalina	41	M	37	−11.0	9.8
MS 2841	Santa Catalina	46	M	29	−10.4	8.5
MS 2849	Santa Catalina	74	M	36	−9.7	7.5
MS 2861	Santa Catalina	107	M	25	−10.8	10.8
MS 2865	Santa Catalina	169	M	39	−11.6	9.3
MS 2877	Santa Catalina	294	M	38	−11.4	9.8
Late contact						
MS 3248	Santa Catalina	1	F	34	−11.1	10.9
MS 3250	Santa Catalina	7	F	60	−11.3	10.1
MS 2834	Santa Catalina	19	F	52	−12.1	8.8
MS 3252	Santa Catalina	20	F	25	−11.8	10.5
MS 3254	Santa Catalina	30	F	39	−11.1	9.6
MS 3256	Santa Catalina	36	F	37	−11.3	9.4
MS 3258	Santa Catalina	50A	F	45	−12.2	10.3
MS 3272	Santa Catalina	60	F	39	−12.2	9.6
MS 3274	Santa Catalina	66	F	19	−12.5	8.3
MS 3277	Santa Catalina	88	F	51	−12.6	10.1
MS 3278	Santa Catalina	91	F	45	−12.1	9.7
MS 3249	Santa Catalina	6C	M	46	−10.2	11.0
MS 2832	Santa Catalina	11	M	37	−12.4	9.8
MS 3251	Santa Catalina	15	M	39	−11.3	10.1
MS 3255	Santa Catalina	34A	M	46	−10.9	9.8
MS 3257	Santa Catalina	45	M	27	−10.0	8.6
MS 3271	Santa Catalina	59B	M	20	−11.4	10.3
MS 3273	Santa Catalina	65	M	29	−10.4	10.2
MS 3275	Santa Catalina	73	M	42	−10.5	8.8
MS 3276	Santa Catalina	78	M	25	−12.5	11.6
MS 3279	Santa Catalina	95B	M	42	−12.5	10.9

[1] F = female, M = male, I = indeterminate.
[2] na = isolated skeletal element not associated with a burial.

tural period is not so large as to imply that no marine foods were exploited by native populations during this time. Rather, marine foods likely continued to play a role in precontact diets during the Savannah period, a finding that is supported by analysis of food remains recovered from archaeological habitation sites (Reitz, 1988, 1990).

As shown in Figure 3, the average $\delta^{13}C$ value in the late agricultural period shows a striking reversal of the trend of less negative values in the previous period. That is, the average $\delta^{13}C$ value is considerably more negative, even more so than in either the early or late preagricultural periods. This shift is not due to the presence of one or two strongly negative individuals. Rather, delta values of seven of the 11 specimens analyzed were either equal to or less than −17‰ (Table 2). The continued reduction in $\delta^{15}N$ values, however, indicates a continued decrease in reliance on marine foods. It seems most likely, therefore, that during the immediately preceding period in this area of the Georgia coast (Irene period), consumption of C_4-based plants and animals decreased in favor of a greater reliance on C_3-based plants and their consumers.

The early contact period sample shows a return to less negative $\delta^{13}C$ values, more than what was observed for the early agricultural period. This reversal is accompanied by a continued trend (although statistically insignificant) of less positive $\delta^{15}N$ values, suggesting a renewed focus on C_4 foods and reduced reliance on marine foods. The late contact period carbon and nitrogen delta values are very similar to the early contact period values. Unlike some of the other between-period comparisons (Table 6), the differences between the early and late contact periods in both carbon and nitrogen are not statistically significant (*t*-test: $P > 0.05$). Therefore, the dietary differences that are determined by comparisons of carbon and nitrogen stable isotopes between

TABLE 3. Carbon and nitrogen stable isotope summary statistics by site

		$\delta^{13}C$‰ (PDB)				$\delta^{15}N$‰ (AIR)			
Site	N	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.
Early preagricultural									
McLeod Mound	4	−18.6	−13.6	−15.8	2.5	12.4	13.1	12.8	0.3
Seaside Md. II	2	−13.8	−13.4	−13.6	0.3	10.6	13.2	11.9	1.8
Cunningham Md. C	1	−16.0	−16.0	−16.0	—	14.4	14.4	14.4	—
Cunningham Md. D	1	−13.9	−13.9	−13.9	—	12.9	12.9	12.9	—
Deptford	10	−18.6	−12.6	−15.9	1.9	9.6	12.9	11.1	1.1
Late preagricultural									
Johns Mound	10	−14.6	−13.4	−14.1	0.4	11.6	13.6	12.9	0.6
Marys Mound	2	−14.7	−14.3	−14.5	0.3	11.8	12.9	12.4	0.8
Early agricultural									
Irene (Burial Mound)	9	−16.4	−10.0	−13.0	2.0	9.5	13.3	10.7	1.1
Late agricultural									
Irene (Mortuary)	11	−17.9	−13.7	−16.6	1.4	8.7	10.7	9.8	0.6
Early contact									
Santa Catalina (St. Catherines Island)	22	−14.3	−9.6	−11.5	1.0	7.4	10.8	9.4	0.8
Late contact									
Santa Catalina (Amelia Island)	21	−12.6	−10.0	−11.5	0.8	8.3	11.6	9.9	0.8

TABLE 4. Carbon and nitrogen stable isotope summary statistics by site and by sex

			$\delta^{13}C$‰ PDB)				$\delta^{15}N$‰ (AIR)			
Site	Sex	N	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.
Early preagricultural										
McLeod Md.	F	4	−18.6	−13.6	−15.8	2.5	12.4	13.1	12.8	0.3
	M	—	—	—	—	—	—	—	—	—
Seaside Md. II	F	1	−13.4	−13.4	−13.4	—	13.2	13.2	13.2	—
	M	1	−13.8	−13.8	−13.8	—	10.6	10.6	10.6	—
Cunn. Md. C	F	1	−16.0	−16.0	−16.0	—	14.4	14.4	14.4	
	M	—	—	—	—	—	—	—	—	—
Cunn. Md. D	F	—	—	—	—	—	—	—	—	—
	M	1	−13.9	−13.9	−13.9	—	12.9	12.9	12.9	—
Deptford	F	6	−18.6	−13.4	−16.1	1.9	9.6	11.8	11.1	0.8
	M	4	−17.1	−12.6	−15.5	2.1	9.6	12.9	11.2	1.5
Late preagricultural										
Johns Md.	F	3	−14.6	−13.4	−14.3	0.4	12.7	13.6	13.2	0.5
	M	5	−14.3	−13.4	−14.1	0.4	11.6	13.5	12.9	0.8
Marys Md.	F	2	−14.7	−14.3	−14.5	0.3	11.8	12.9	12.4	0.8
	M	—	—	—	—	—	—	—	—	—
Early agricultural										
Irene (Bu. Md.)	F	5	−16.4	−10.8	−13.3	2.2	9.5	13.3	10.7	1.6
	M	4	−14.4	−10.0	−12.5	1.9	10.4	10.8	10.6	0.2
Late agricultural										
Irene (Mortuary)	F	4	−17.2	−14.5	−16.1	1.3	9.6	10.0	9.7	0.2
	M	7	−17.9	−13.7	−16.9	1.5	8.7	10.7	9.9	0.7
Early contact										
Santa Cat. (St. Cath.)	F	10	−14.3	−9.6	−11.7	1.2	7.4	10.2	9.3	0.8
	M	8	−11.7	−9.7	−11.0	0.7	7.5	10.8	9.5	1.1
Late contact										
Santa Cat. (Amelia)	F	11	−12.6	−11.1	−11.9	0.6	8.3	10.9	9.8	0.8
	M	10	−12.5	−10.0	−11.2	1.0	8.6	11.6	10.1	0.9

the two human populations inhabiting the St. Catherines Island and Amelia Island missions appear to be minimal. Nevertheless, the $\delta^{15}N$ values in the late contact period are somewhat more positive than the early contact period, reflecting perhaps, a slight increase in consumption of marine resources. In addition, there appears to be a greater range in $\delta^{13}C$ values in the early contact sample relative to the late contact sample. Although this may represent a greater range in dietary breadth in the ear-

TABLE 5. Carbon and nitrogen stable isotope summary statistics by period and by sex[1]

			$\delta^{13}C$‰ (PDB)				$\delta^{15}N$‰ (AIR)			
Period[1]	Sex	N	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.
Early preag.	F	12	−18.6	−13.4	−15.8	2.0	9.6	14.4	12.1	1.3
	M	6	−17.1	−12.6	−15.0	1.8	9.6	12.9	11.4	1.4
Late preag.	F	5	−14.7	−13.9	−14.4	0.3	11.8	13.6	12.9	0.7
	M	5	−14.3	−13.4	−14.1	0.4	11.6	13.5	12.9	0.8
Early ag.	F	5	−16.4	−10.8	−13.3	2.2	9.5	13.3	10.7	1.6
	M	4	−14.4	−10.0	−12.5	1.9	10.4	10.8	10.6	0.2
Late ag.	F	4	−17.2	−14.5	−16.1	1.3	9.6	10.0	9.7	0.2
	M	7	−17.9	−13.7	−16.9	1.5	8.7	10.7	9.9	0.7
Early contact	F	10	−14.3	−9.6	−11.7	1.2	7.5	10.2	9.3	0.8
	M	8	−11.7	−9.7	−11.0	0.7	7.5	10.8	9.5	1.1
Late contact	F	11	−12.6	−11.1	−11.9	0.6	8.3	10.9	9.8	0.8
	M	10	−12.5	−10.0	−11.2	1.0	8.6	11.6	10.1	0.9

[1]Early preag. = McLeod Mound, Seaside Mound II, Cunningham Mound C, Cunningham Mound D, Deptford site. Late preag. = Johns Mound, Marys Mound. Early ag. = Irene site (Burial Mound). Late ag. = Irene site (Mortuary). Early contact = Santa Catalina de Guale (St. Catherines Island). Late contact = Santa Catalina de Guale de Santa Maria (Amelia Island).

TABLE 6. Carbon and nitrogen stable isotope summary statistics by period

		$\delta^{13}C$‰ (PDB)				$\delta^{15}N$‰ (AIR)			
Period[1]	N	Min.	Max.	Mean[2]	S.D.	Min.	Max.	Mean[2]	S.D.
Early preag.	18	−18.6	−12.6	−15..5	1.9	9.6	14.4	11.9	1.3
Late preag.	12	−14.7	−13.4	*−14.2*	0.4	11.6	13.6	*12.8*	0.6
Early ag.	9	−16.4	−10.0	−12.9	2.0	9.5	13.3	*10.7*	1.1
Late ag.	11	−17.9	−13.7	*−16.6*	1.4	8.7	10.7	*9.8*	0.6
Early contact	22	−14.3	−9.6	*−11.5*	1.0	7.4	10.8	9.4	0.8
Late contact	21	−12.6	−10.0	−11.5	0.8	8.3	11.6	9.9	0.8

[1]Early preag. = McLeod Mound, Seaside Mound II, Cunningham Mound C, Cunningham Mound D, Deptford site. Late preag. = Johns Mound, Marys Mound. Early ag. = Irene site (Burial Mound). Late ag. = Irene site (Mortuary). Early contact = Santa Catalina de Guale (St. Catherines Island). Late contact = Santa Catalina de Guale de Santa Maria (Amelia Island).
[2]Mean values in italics indicates statistically significant difference with the previous period (t-test: $P < 0.05$).

lier period, it more likely reflects a greater length of time represented by the death assemblage in the early contact period relative to the late contact period (i.e., ca. 70 years vs. ca. 20 years in the St. Catherines Island and Amelia Island populations, respectively).

DISCUSSION

Comparison of stable isotope composition in human collagen from archaeological sites in Georgia Bight provides compelling evidence for alterations in subsistence economies of native populations throughout prehistory and into the contact period. Taken as a whole, the early and late preagricultural populations had subsistence economies that were highly focussed on marine resources. However, some of the individuals in the early preagricultural period have $\delta^{13}C$ values that reflect average diets that were strongly terrestrial in orientation. In the Deptford site sample, a number of individuals approach values that would be expected from consumption of C_3 foods, both plant (e.g., acorns, hickory nuts) and animals con-

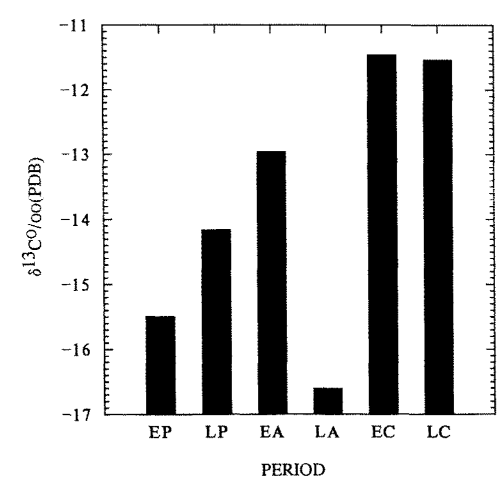

Fig. 3. Bar graph of mean values of $\delta^{13}C$ from earliest to latest periods (EP = early preagricultural; LP = late preagricultural; EA = early agricultural; LA = late agricultural; EC = early contact; LC = late contact).

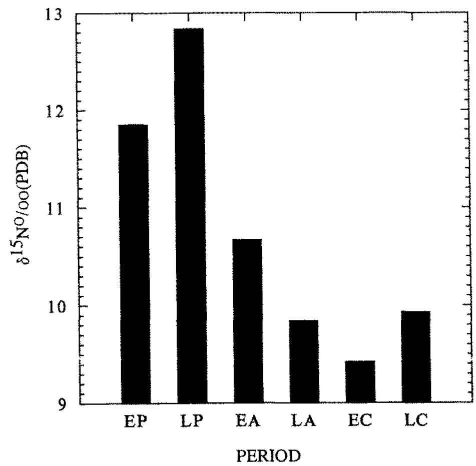

Fig. 4. Bar graph of mean values of $\delta^{15}N$ from earliest to latest periods (EP = early preagricultural; LP = late preagricultural; EA = early agricultural; LA = late agricultural; EC = early contact; LC = late contact).

suming them (e.g., deer). This penchant for terrestrial foods may reflect the fact that the site is located on the Savannah River several miles from the coast. Thus, the population represented by these samples would be expected to have obtained a somewhat greater percentage of terrestrial plants and animals on average for dietary consumption. Two individuals from St. Catherines Island have $\delta^{13}C$ values that indicate significant emphasis on terrestrial foods (−17.1‰, −18.6‰), despite their immediate proximity to marine environments.

The differences observed by us in comparing the early agricultural period with the late preagricultural period are consistent with findings reported from other eastern U.S. settings (Ambrose, 1987; Smith, 1989). Namely, increasingly positive $\delta^{13}C$ values are best explained by the adoption and increased utilization of maize, the only major C_4 plant of economic importance in the region. This increase could be due to an emphasis on marine foods in the early agricultural period. However, the accompanying reduction in $\delta^{15}N$ values indicates that an increase in marine food consumption is highly unlikely. Therefore, maize partially replaced marine foods in addition to C_3 plants and animals that feed on C_3 plants (e.g., deer).

Other data provided from study of dental caries prevalence support this interpretation of an increase in C_4 food consumption. Comparison of pre-Savannah period dentitions with late prehistoric dentitions from the Georgia coast shows that the former has only 1.3% carious teeth (of the total number of teeth, including incisors, canines, premolars, and molars combined), and the latter has 11.4% carious teeth, which is well within the range of caries prevalence reported for other prehistoric agriculturalists in eastern North America (Larsen et al., 1991). Owing to its high sugar component, maize was the principal cariogenic food utilized by the later prehistoric populations in the Georgia Bight, and almost certainly explains the increase in prevalence of dental caries in these populations.

A marked decrease in late agricultural period $\delta^{13}C$ values (more negative) relative to the early agricultural period is obvious. This trend indicates a shift toward consumption of C_3 plants and their consumers, a finding that is consistent with the continuation of less positive $\delta^{15}N$ values, also indicating an increase in focus on terrestrial foods (Fig. 5, and compare with Fig. 2). This dietary shift would seem to be entirely contrary to the development of Mississippian societies throughout the southeastern U.S., given that one hallmark of these societies is dependence upon maize agriculture (Griffin, 1967). Anderson (1990a,b) has completed a detailed study of prehistoric lifeways, subsistence practices, and social organization of Savannah River valley Mississippian populations (including the Irene site). He demonstrates a clear pattern of appearance, expansion, and collapse of Mississippian societies in the south Atlantic Slope, a region that includes the lower Savannah River valley and north coastal Georgia. The Mississippian societies that emerged around AD 1100 expanded, but as in the case of the Irene site, declined precipitously during the early to mid-1400s. Anderson argues that the final half-century of the occupation of the Irene site and other Mississippian population centers represents a period of social decline culminating in organizational col-

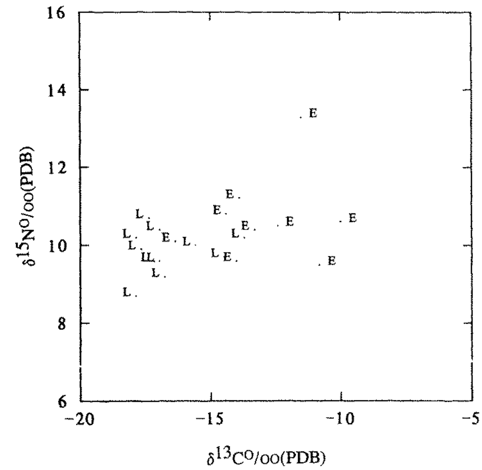

Fig. 5. Plot of early agricultural (E) and late agricultural (L) carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope values. The temporal trend suggests an increase in emphasis on non-C_4 terrestrial foods during the last prehistoric period (1300-1450) in the Georgia Bight (compare with Fig. 2).

lapse and eventually abandonment of the region. For example, he notes that during the period of time immediately preceding the abandonment of this region of the Georgia Bight, burials exhibit considerably fewer grave goods. Moreover, grave goods associated with later burials (Irene period) became much less elaborate than earlier burials (Savannah period) (Anderson, 1990a).

Although it is not entirely clear why this social transformation took place, Anderson (1990a) argues that during the fifteenth century the region experienced a general environmental deterioration, especially a reduction in local rainfall. Moreover, he indicates these rainfall decreases, if severe enough, would have resulted in a reduction in crop harvests, thereby forcing populations to utilize alternative foods, such as wild (non-C_4) plants and animals. Like many other Mississippian centers, there is an increase in population size in the Georgia Bight (see discussions in Larsen, 1982; Reitz, 1988) that would potentially place further pressures to increase food production. Thus, the dramatic change in diet during the final prehistoric occupation of the Irene site may be linked to the overall social and environmental deterioration that Anderson (1990a,b) has documented for this region.

Study of botanical remains recovered from archaeological habitation sites in the upper Savannah River valley shows a decline in use of maize and an increase in use of C_3 plants (especially acorns) during the period of time that is contemporary with the final period of occupation of the Irene site (see Moore, 1985). Anderson (1990a) argues that the increased use of nuts was necessary in order to supplement carbohydrate deficits caused by the dwindling maize yields. Because the Irene site was excavated over 50 years ago (when there was little interest in recovering archaeobotanical materials), only minimal evidence exists regarding the role of plants—either C_3-based or C_4-based—in late prehistoric diets (Larsen, 1982; Reitz, 1988). However, recently recovered botanical remains from other Mississippian period habitation sites in the region indicate a shift towards heavier use of C_3 plants during the Irene period (Moore, 1985).

This is not to say that agriculture was not practiced by late prehistoric populations in the Georgia Bight. Teeth from a number of individuals in the Irene period sample from the Irene site display carious lesions (Larsen, unpublished data; Larsen et al., 1991). Moreover, despite the meager botanical samples from late prehistoric sites, Irene period maize fragments have been found at a number of them (Larsen, 1982; Reitz, 1988).

It is conceivable that the differences between early and late agricultural period diets are not temporal changes. We speculate that the individuals interred in the Mortuary at the Irene site may be simply higher in status than individuals interred in the Burial Mound. Indeed, the Mortuary is a unique feature in the Georgia Bight and may, therefore, represent burial for a super-elite component of this Mississippian society. If these individuals are from a super-elite rank, then perhaps their diets contained less maize and more animal protein derived from non-marine sources. This scenario seems highly unlikely, however, particularly given the presence of characteristics discussed above relating to social decline and increase in environmental stress and the lack of evidence for status distinctions in the Irene period (Anderson, 1990a,b). We argue, therefore, that a simple high status-low status dichotomy cannot be invoked to explain the difference in use of maize between the Irene and Savannah periods in the Georgia Bight. Rather, temporal change in late prehistoric diets is the preferred explanation. We caution, however, that because the Mortuary and Burial Mound components of the Irene site are not contemporary (see Materials and Methods), it is extremely difficult to test competing hypotheses involving status vs. temporal models.

If consumption of maize during the later prehistoric occupation of the Georgia Bight decreased, then this implies that the degree of maize utilization in Mississippian societies was highly variable, even within the confines of this small region (cf. Buikstra and Milner, 1991). Another important implication of these findings is that changes in health status and mechanical behavior documented in this region (summarized in Larsen, 1984; Larsen et al., 1990) may be related to a complex of circumstances (e.g., increasing sedentism) not necessarily including maize production or consumption as direct causal factors.

Both contact periods—early and late—show $\delta^{13}C$ and $\delta^{15}N$ values that are generally more negative and less positive, respectively, than in the late agricultural period. The increase in reliance on maize demonstrated by these findings are consistent with both archaeological and historical documentation. Large quantities of maize remnants have been recovered from the Santa Catalina mission sites on both St. Catherines and Amelia Islands (Ruhl, 1990). Historic records point to the vital role that Indian missions played in agricultural production in particular and in fostering Spanish economic interests in the region in general. Indeed, St. Catherines Island was viewed as an important source of maize for use in the capital of Spanish Florida at St. Augustine (see Ruhl, 1990). One priest living in Guale, noted that his superior "came [away] from there very satisfied, because it is [a] people who work and sow maize and thus they have food; and they have maintained the Christians that are there with them for many days" (quoted in Larson, 1980:208).

The scope of agricultural production is reflected in Jonathan Dickinson's account made a decade and a half after the abandonment of St. Catherines Island: "We got to the place called St. Catelena, where hath been a great settlement of Indians, for the land hath been cleared for planting, for some miles distant" (Dickinson, 1975:70). Although he did not observe maize crops *per se,* the extent of agricultural lands attests to the scope of cultigen production, at least for this island, during the contact period.

Analysis of nitrogen values from agriculturalists consuming no marine foods in other geographic settings are somewhat lower than the samples from the Georgia Bight (cf. Spielmann et al., 1990; Schoeninger et al., 1990). These comparisons reveal, therefore, that although there was an increase in focus on maize, some marine resources continued to be utilized by mission Indians. Archaeologically recovered botanical and faunal evidence indicates, moreover, the use of New World and Old World terrestrial plants (Ruhl, 1990) and animals (Reitz, 1990).

The finding that there was a marked change in diet in the contact period is interesting in that it strongly suggests that the establishment of mission centers by the Spanish had a profound effect on native subsistence systems. This has similarly been reported by Spielmann and co-workers (1990) from the Southwest (Pecos Pueblo). However, unlike the Guale, populations they studied appeared to have experienced a decline in maize consumption. These differences between southeastern and southwestern North American populations may be related to different strategies employed by the Spanish in colonization and missionization efforts in these different regions, a broader consideration of which is beyond the scope of the present investigation.

In contrast to the pattern of dietary reconstruction showing a decline in maize consumption in the contact southwestern U.S. sample, our results parallel those provided by White and Schwarcz (1989) in their comparison of precontact and contact Maya from Lamanai, Belize. Like the Guale sample from the Georgia Bight, the Maya exhibit fluctuations in degree of maize consumption (based on $\delta^{13}C$ values), with a sharp reduction in maize consumption during the Terminal Classic period (AD 900–1000), followed by increases in the Post-Classic period (AD 1000–1520) that are maintained at the same level during the mission period (AD 1520–1670). Unlike the late agricultural (Irene) period in the Georgia Bight, the Terminal Classic period of the Maya is not represented by cultural decline or other evidence to suggest social or environmental decay. Rather, at least in this area of the Maya lowlands, the Terminal Classic is characterized as a period of florescence and increased building activity (White and Schwarcz, 1989). The decline in maize consumption in precontact Lamanai Maya occurred, then, under a wholly different set of circumstances than the precontact Guale. Therefore, the similarity in patterns of late prehistoric maize consumption between the Maya and Guale is mostly superficial.

SUMMARY AND CONCLUSIONS

The present investigation provides additional evidence for the value of combining carbon and nitrogen stable isotope ratios in dietary reconstruction from the Georgia Bight (Schoeninger et al., 1990) and elsewhere (Schoeninger et al., 1983; Walker and DeNiro, 1986; Sealy et al., 1987; Walker et al., 1989; Ericson et al., 1989). Stable isotope ratios for carbon and nitrogen closely fit our earlier model of dietary changes in this region (Fig. 6). With the exception of collagen samples analyzed for the late prehistoric populations from the Irene site, there is a continuous trend for less negative $\delta^{13}C$ values and less positive $\delta^{15}N$ values that reflect an increased emphasis on maize and decreased emphasis on marine foods, such as fish and shellfish.

The other conclusion to emerge from this study is that marine resources were never entirely replaced, even in mission populations that were heavily focussed on indigenous domesticated plants. The ubiquity of shellfish (oysters and clams, especially) remains in archaeological sites throughout the prehistoric and historic record, including mission localities, certainly supports this observation. Although the repertoire of plants and animals consumed by native groups does not change in Spanish Florida (see also Scarry, 1991; Reitz, 1991), our findings indicate that the proportions of some foods did—for at least Guale.

Finally, the reconstruction of subsistence in these societies provides an important context for addressing salient issues such as quality of diet, health status, and behavioral change in these populations. In concert with a host of stressors—especially epidemic diseases—we speculate that the increasingly narrow dietary base in the contact era native groups may have ultimately contributed to the extinction of these populations during the eighteenth century.

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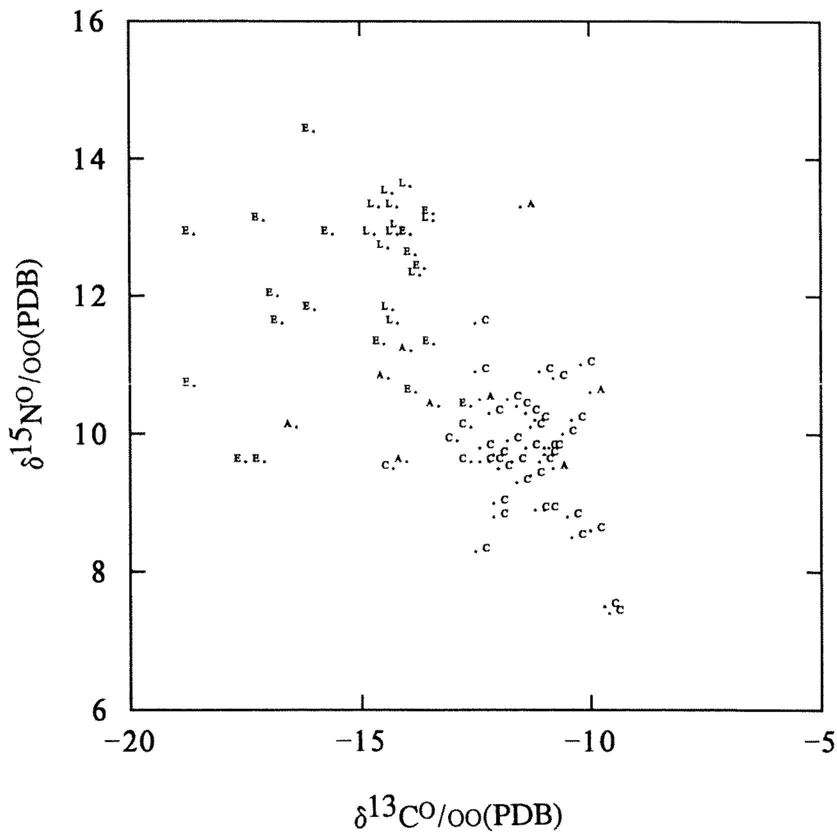

Fig. 6. Plot of Georgia Bight carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope values (excluding the late agricultural period; E = early preagricultural; L = late preagricultural; A = early agricultural; C = early contact and late contact combined). The temporal trend shows a decrease in nitrogen delta values and an increase in carbon delta values, indicating a decrease in use of marine foods coupled with an increase in emphasis on maize (compare with Fig. 2).

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