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Frontiers of Contact: Bioarchaeology of Spanish Florida

Clark Spencer Larsen,[1,13] Mark C. Griffin,[2] Dale L. Hutchinson,[3] Vivian E. Noble,[4] Lynette Norr,[5] Robert F. Pastor,[6] Christopher B. Ruff,[7] Katherine F. Russell,[8] Margaret J. Schoeninger,[9] Michael Schultz,[10] Scott W. Simpson,[11] and Mark F. Teaford[12]

The arrival of Europeans in the New World had profound and long-lasting results for the native peoples. The record for the impact of this fundamental change in culture, society, and biology of Native Americans is well documented historically. This paper reviews the biological impact of the arrival of Europeans on native populations via the study of pre- and postcontact skeletal remains in Spanish Florida, the region today represented by coastal Georgia and northern Florida. The postcontact skeletal series, mostly drawn

[1] Department of Anthropology, The Ohio State University, Columbus, Ohio.
[2] Department of Anthropology, San Francisco State University, San Francisco, California.
[3] Department of Anthropology, East Carolina University, Greenville, North Carolina.
[4] Department of Cell and Molecular Biology, Northwestern University Medical School, Chicago, Illinois.
[5] Department of Anthropology, University of Florida, Gainesville, Florida.
[6] Department of Archaeological Sciences, University of Bradford, Richmond Road, Bradford, West Yorkshire BD7 1DP, United Kingdom.
[7] Department of Cell Biology and Anatomy, Johns Hopkins University School of Medicine, 725 North Wolfe Street, Baltimore, Maryland.
[8] Department of Biology, University of Massachusetts—Dartmouth, North Dartmouth, Massachusetts.
[9] Department of Anthropology, University of California, San Diego, California.
[10] Zentrum Anatomie, University of Göttingen, Kreuzbergring 36, D-37075, Göttingen, Germany.
[11] Department of Anatomy, School of Medicine, Case Western Reserve University, Cleveland, Ohio.
[12] Department of Cell Biology and Anatomy, Johns Hopkins University School of Medicine, 725 North Wolfe Street, Baltimore, Maryland.
[13] To whom correspondence should be addressed at Department of Anthropology, The Ohio State University, Columbus, Ohio 43210-1364.

from Roman Catholic mission sites, are among the most comprehensive in the Americas, providing a compelling picture of adaptation and stress in this setting. Study of paleopathology, dental and skeletal indicators of physiological stress, stable isotope (carbon and nitrogen) analysis, tooth microwear, and skeletal morphology (cross-sectional geometry) reveals major alterations in quality of life and lifestyle. The bioarchaeological record indicates a general deterioration in health, declining dietary diversity and nutritional quality, and increasing workload in the contact period. The impact of contact in Spanish Florida appears to have been more dramatic in comparison with other regions, which likely reflects the different nature of contact relations in this setting versus other areas (e.g., New England, New France). The bioarchaeological record represents an important information source for understanding the dynamics of biocultural change resulting from colonization and conquest.

KEY WORDS: paleopathology; physiological stress; stable isotopes; microwear; biomechanics.

INTRODUCTION

Christopher Columbus's landfall in the Bahamas in 1492 set into motion an extraordinary series of events that profoundly affected the lives and lifestyles of native peoples throughout the Americas. The first thing that comes to mind when considering the biological impact of contact on native peoples by Europeans in the colonial period is the suite of horrific diseases brought from the Old World to the New and the resulting depopulation and demographic collapse across the Western Hemisphere (e.g., Cook, 1998; Crosby, 1986; Reff, 1991; see Larsen, 1994). The large and growing literature on the biological impact of contact pertains mostly to these diseases (e.g., smallpox, measles, cholera, influenza, and malaria) and their demographic consequences, largely to the exclusion of other factors that collectively inform our understanding of human biology in the post-Columbian world. The singular focus on European-introduced disease reinforces the commonly held misperception that pre-Columbian people lived in a kind of paradise before Europeans, having suffered no disease, malnutrition, or demanding labor. Dobyns (1983, p. 34) remarked, for example, that

> Before the invasion of peoples of the New World by pathogens that evolved among inhabitants of the Old World, Native Americans lived in a relatively disease-free environment . . . (They) suffered no smallpox, no measles, no chickenpox, no influenza, no typhus, no typhoid or parathyroid fever, no diphtheria, no cholera, no bubonic plague, no scarlet fever, no whooping cough, and no malaria.

Contrary to the assertion that native peoples lived in a disease-free (or nearly so) environment prior to the arrival of Europeans, abundant paleopathological evidence shows that native populations throughout the Americas lived in a world whereby infectious disease and poor health were not uncommon (Larsen, 1994; Ubelaker, 2000; Verano and Ubelaker, 1992). Moreover, native nutrition was not always adequate and workloads were oftentimes demanding (Baker and Kealhofer, 1996; Larsen, 1994; Larsen and Milner, 1994; various authors in Verano and Ubelaker, 1992).

Why is it important to know that native New World peoples did not live in an idyllic setting that was ruined by Europeans when they arrived on the scene more than five centuries ago? Two reasons stand out: First, the misperceptions about health and well-being of pre-Columbian peoples establish an incorrect context for understanding the impact of European colonization on Native Americans. The growing record indicates that life for native populations did not simply go from good to bad. Nor is it likely that the arrival of Europeans occasioned a pandemic of smallpox in the early 1500s, resulting in immediate population collapse (see also Thornton, 1997). To be sure, whole populations went extinct and entire regions were depopulated of their native inhabitants soon following initial contact by Europeans (or later, by Euroamericans). The picture of the postcontact biological world is much more complex than that simply diseases arrived and Native Americans went extinct.

Second, the narrow focus in the historical and anthropological scholarship on the topics of disease, dying, and death in the colonial period overshadows other important areas that need to be considered when evaluating human biology. These areas include, but are not limited to, the impact of population relocation and aggregation, changing patterns of work and physical activity and labor exploitation, and shifts in diet and nutrition. All of these areas were components of the post-Columbian biological world of Native Americans.

This article examines the record of contact via bioarchaeology. Bioarchaeology developed out of osteology and skeletal biology in the 1970s and 1980s. It originated as a descriptive science with the goal of documenting geographic and temporal distribution of disease, and developed into one with an evolutionary and ecological framework that has concern for the process by which people become morbid or dead and for other issues such as lifestyle and behavior. The field is also focused on the archaeological context of human remains, with a deep knowledge of the community or population with regard to settlement patterns, material culture, plant and animal remains, and life history. Thus, although the discipline deals with the study of human remains from archaeological settings, it has matured into something newer and more informative about the human past. Here, we make the case that bioarchaeology presents an important means for developing a more comprehensive and more informed understanding of the impact of the arrival of Europeans on the health and lifeways of native New World populations.

The human skeleton is a highly sensitive indicator of life experiences (Larsen, 1997). In this regard, bones and teeth provide a retrospective record of growth and development and adulthood, providing key insight into diet and nutrition, disease, lifestyle, and activity. In the last couple of decades, bioarchaeologists have studied skeletal remains from a range of settings in the Western Hemisphere dating to the colonial period (Baker and Kealhofer, 1996; Larsen and Milner, 1994; and Miller *et al.*, 1999b; e.g., various authors in Verano and Ubelaker, 1992). One of the most comprehensive data sets for the study of the consequences of contact for Native American health and well-being is from the region named La Florida by Juan Ponce de León in 1513. First envisioned by Spain as involving control over much of eastern North America, ultimately the boundaries demarcating Spanish-controlled Florida versus other regions controlled by competing European powers (especially France and Great Britain) were drawn to include the modern state of Florida and coastal Georgia (Fig. 1).

During the nearly two centuries of the Spanish colonial period (1565–1763), there were dramatic transformations in the culture, society, and biology of native populations. Several explorations occurred prior to the colonial period, which likely had consequences for those native groups who were encountered (see Milanich, 1995; Worth, 2001). Historical records indicate that the de Soto expedition of 1539–1543, for example, engaged in violent confrontations with native groups in the American Southeast at various times and places (e.g., Varner and Varner, 1980; see Hutchinson, 1996). The more profound and long-lasting influence on the native peoples were the Roman Catholic missions established throughout the region, beginning in about 1587 and lasting until 1706 (Milanich, 1995; Thomas, 1987; Worth, 1998, 2001). During this time, the missions served as the primary loci for assimilating native societies into the larger colonial system of Spanish Florida. Many thousands of Native Americans became full and active participants in the colonial society and economy and all of its manifestations (e.g., labor supply).

Realizing the potential of the study of skeletal remains from the mission settings for developing a broader understanding of the biology of the contact period, Larsen began the La Florida Bioarchaeology Project in 1982. The project commenced with the study of skeletal remains from the seventeenth-century Santa Catalina de Guale from St. Catherines Island, Georgia (Larsen, 1990). Santa Catalina served as the primary settlement and mission outpost for the Guale, the dominant tribe on the north Georgia coast. The region occupied by the Guale was one of the first to be colonized by Europeans north of Mexico (Jones, 1978), thus making it an ideal place for investigating the biological consequences of contact. Moreover, an

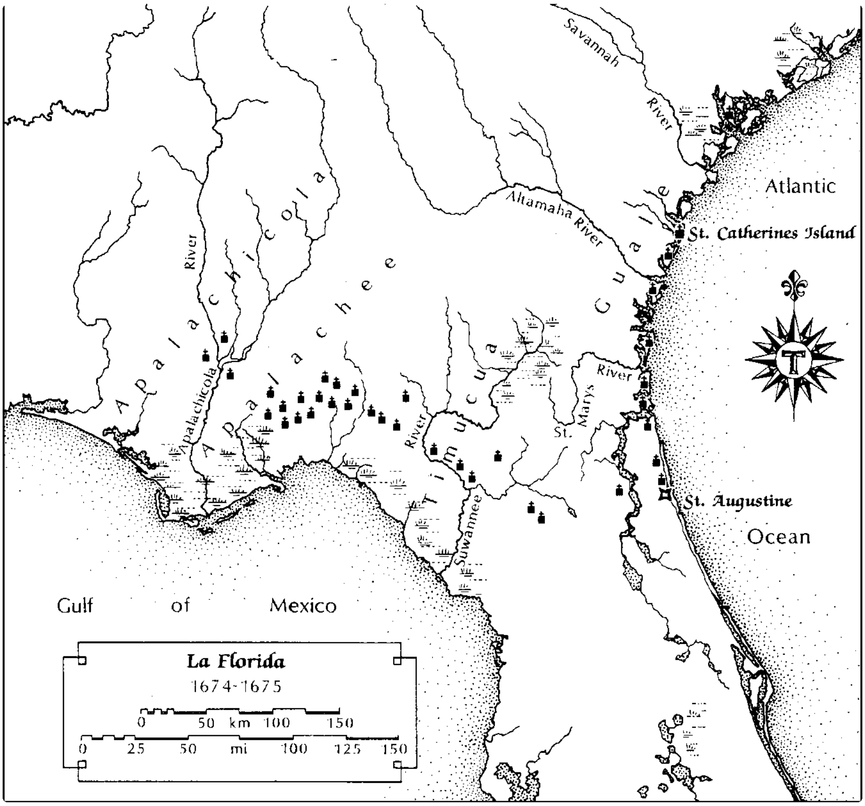

Fig. 1. Spanish Florida in the 1670s showing locations of major tribes and mission (crosses) (adapted from Thomas, 1987; reproduced with permission).

extensive precontact sample of human remains had been studied previously, providing a comparative context from which to assess the impact of contact and missionization (see Larsen, 1981, 1982, 1984). The second phase of the project entailed the study of skeletons representing the descendents of the Santa Catalina mission population that had resettled on Amelia Island, Florida, following the abandonment of St. Catherines Island in 1680 (Larsen *et al.*, 1990, 1992a, 2001). The final phase of the project was broadened to study the very sizeable sample of precontact and contact era skeletons from other areas of the Spanish colony, including those representing the Timucua and Yamasee of northeastern Florida and the Apalachee of the Florida panhandle (Larsen, 2000a,b, 2001; this study).

In an important way, our bioarchaeological investigation was greatly enhanced by collaboration not only involving the group of physical anthropologists represented as authors of this paper, but also by the historians, ethnohistorians, and archaeologists working on the common goal of understanding the social, cultural, political, and economic dynamics of the Spanish Florida colony (and see Gannon, 1992). This interdisciplinary approach was instrumental in helping to document and interpret the rich record of prehistory and history in this region.

CONTEXT FOR BIOARCHAEOLOGICAL INTERPRETATION IN SPANISH FLORIDA

In no other region in the Americas is the combined archaeology and history of contact between Europeans and Native Americans so well documented as it is in Spanish Florida. During the last 20 years or so, the study of a large body of ethnohistory and archaeology has resulted in the development of a comprehensive picture of native lifeways, societies, cultures, and technologies in the contact era in Spanish Florida (e.g., Bushnell, 1994; Gannon, 1992; Hann, 1988, 1990; Hann and McEwan, 1998; Jones, 1978; Jones *et al.*, 1991; Larsen, 1990; Milanich, 1995, 1999; Saunders, 2000; Thomas, 1987, 1990; Weisman, 1992; Worth, 1995, 1998; various authors in McEwan, 1993).

A central research focus in the region has been the study of human biology, especially with relation to health, well-being, and lifestyle. Underlying this approach is the importance of diet and nutrition. For this region, the elements of native diets have been identified via paleoethnobotany and zooarchaeology (Reitz, 1988, 1990, 1993, 1999; Reitz and Scarry, 1985; Ruhl, 1990; Scarry, 1993; Scarry and Reitz, 1990). This record reveals that prior to Europeans and the establishment of missions, native diets were diverse and were based on various species of wild plants and animals, exclusively in some regions, and domesticated plants, to a large degree, in other areas. Coastal populations consumed relatively more marine foods than noncoastal populations. Throughout the region, the animal-based portion of diet continued to be highly variable in the contact era, presenting a picture of continuity rather than change (Reitz, 1999). Maize played an important role in later prehistoric societies in coastal Georgia and in the dominant Mississippian center at Lake Jackson in the Florida panhandle. Maize was not present in the diets of native populations elsewhere in the region (and see Hutchinson *et al.*, 1998; Larsen, 2001; Larsen *et al.*, 2001). For these and most other native societies in the southeastern United States, maize and other staples were boiled into soft mushes, soups, and stews (Hally, 1986). These preparation techniques also have implications for tooth use and the masticatory apparatus in general.

Wherever missions or other European-controlled settlements were established, the archaeological and historical records indicate a shift in some key aspects of diet, especially involving an increased dependence on maize in the Guale and Apalachee provinces and the adoption of this plant in the Timucua province. These changes undoubtedly reflect the increased production of food crops in the colonial economic system of Spanish Florida and elsewhere in New Spain (Worth, 2001).

The increased focus on maize in some areas and outright adoption of the plant in other areas in the contact period have important consequences for health status and well-being. Maize is a carbohydrate with an appreciable amount of sugar, thereby contributing to dental disease (e.g., dental caries; Larsen *et al.*, 1991). Maize contains phytate, a substance that prevents absorption of iron (Lynch, 1997). Overdependence on maize also leads to growth disruption owing to the poor quality of its protein.

Another important lifestyle change to come about during the mission period was the practice of *congregación*, or concentration of population into a limited number of villages, oftentimes associated with a mission (Worth, 1998, 2001). An important outcome of population resettlement and concentration is the establishment of conditions conducive to the maintenance and spread of infectious disease. Owing to increased population concentration, the missions became reservoirs for epidemic diseases, resulting in increased mortality, decreased fertility, and ultimately, population decline. Over seventeenth century, more than half a dozen epidemics swept through the region, resulting in the deaths of thousands (see accounts in Hann, 1986, 1988; Worth, 1998). In addition, the poor sanitary conditions of settled communities would have created conditions for more localized soft tissue infections (such as from *Staphylococcus*) that spread to adjacent bone.

In the Spanish colony, the increased production of food (especially maize) in the various mission settings resulted in an increased workload and alterations in physical activity in general. Historical sources document the practice of *repartimiento,* the highly exploitative draft-labor system practiced in La Florida and throughout other regions of the Americas controlled by Spain (see Hann, 1988; Weber, 1992; Worth, 2001). *Repartimiento* involved heavy physical labor, including agricultural labor, travel, and carrying of heavy burdens (pack animals were not present in the region until the late mission period), and construction (Hann, 1988; Milanich, 1999; Worth, 1998).

Other factors that contributed to declining quality of life included conflict with other native groups allied with British interests to the north, retaliation from Spanish authorities following revolts, piracy and slave raiding, and conflict with tribes (Worth, 1995, 1998). Clearly, the combination of a variety of factors contributed to declining conditions in Spanish Florida.

THE MORTUARY RECORD

The skeletal remains, the focus of this study, are represented in an extensive mortuary record for this region of North America. Prior to the arrival of Europeans, native mortuary practices were highly diverse, ranging from simple interments in village middens to multiple burials in multistage mounds (e.g., Caldwell and McCann, 1941; Jones, 1859; Larsen, n.d; Larsen and Thomas, 1986; Moore, 1897; Thomas and Larsen, 1979). The replacement of native beliefs with Christianity, especially with regard to the treatment of deceased, had a remarkable and long-lasting impact on mortuary practices of native peoples. Early in the founding of missions, traditional modes of burial (e.g., mound burial) were replaced with European-style interment in or near churches. Typically, deceased were placed in shallow pits, with remains extended and supine, arms flexed, and the hands on the chest or abdomen (Larsen, 1990, 1993). Following standard burial protocol, no grave inclusions were placed with the deceased. An important exception was the Santa Catalina de Guale mission on St. Catherines Island, where artifact associations with individual interments were numerous (e.g., majolica plates, mirrors, crucifixes, and glass beads in the thousands; see Larsen, 1990; Thomas, 1987, 1990, 1993). To a lesser extent, the San Luis de Apalachee mission cemetery in Leon County, Florida, also contained a significant material culture (Hann and McEwan, 1998).

For purposes of analysis, we divide the skeletal samples into two major geographic regions corresponding to the present boundary between the modern states of Georgia and Florida. We have done this because the Georgia populations were largely coastal (broadly defined to include adjacent estuaries and the mainland) whereas some of the Florida populations were coastal and some were terrestrial, with little association with the coastal setting. In addition to these broad geographic divisions, we divide the samples into a series of periods—early prehistoric, late prehistoric, early mission, and late mission. Both Georgia and Florida have early and late prehistoric periods, which roughly correspond with the foraging to farming transition that took place in this region (earlier populations were foragers, most later population were farmers). For Georgia, there is an early mission period, but no late mission period. In Florida, however, there is both an early and late mission period. Thus, where possible, the samples are divided into a total of seven geographical/temporal periods: (1) Georgia early prehistoric (400 B.C.–A.D. 1000); (2) Georgia late prehistoric (A.D. 1000–1450); (3) Florida early prehistoric (A.D. 0–1000); (4) Florida late prehistoric (plus protohistoric) (A.D. 1000–1550); (5) Georgia early mission (A.D. 1600–1680); (6) Florida early mission (A.D. 1600–1680); (7) Florida late mission (A.D. 1680–1700) (Table I).

Table I. Spanish Florida Mortuary Localities and Cultural Associations[a]

Site	Location	Cultural association
Georgia early prehistoric (400 B.C.–A.D. 1000)		
Deptford	Inland	Guale
Indian Kings Tomb	Inland	Guale
Cedar Grove Mound A	Inland	Guale
Cedar Grove Mound B	Inland	Guale
Cedar Grove Mound C	Inland	Guale
Walthour (CH 11)	Coastal	Guale
McLeod Mound	Coastal	Guale
Seaside Mound I	Coastal	Guale
Seaside Mound II	Coastal	Guale
Cunningham Mound C	Coastal	Guale
Cunningham Mound D	Coastal	Guale
Cunningham Mound E	Coastal	Guale
South New Ground Mound	Coastal	Guale
Evelyn Plantation	Inland	Guale
Sea Island Mound	Coastal	Guale/Mocama
Airport	Coastal	Guale/Mocama
Cannons Point	Coastal	Guale/Mocama
Charlie King Mound	Coastal	Guale/Mocama
Florida early prehistoric (A.D. 0–1000)		
Melton Mounds	Inland	Timucua
McKeithen Mounds	Inland	Timucua
Cross Creek Mound	Inland	Timucua
Wacahoota Mound	Inland	Timucua
Henderson Mound	Inland	Timucua
Mayport Mound	Coastal	Timucua
Georgia late prehistoric/protohistoric (A.D. 1000–1550)		
Irene Burial Mound	Inland	Guale
Irene Large Mound	Inland	Guale
Irene Mortuary	Inland	Guale
Deptford Mound	Inland	Guale
Red Knoll	Inland	Guale
Skidaway Mitigation 3	Coastal	Guale
Groves Creek	Coastal	Guale
Johns Mound	Coastal	Guale
Marys Mound	Coastal	Guale
Southend Mound I	Coastal	Guale
Southend Mound II	Coastal	Guale
North End Mound	Coastal	Guale/Mocama
Low Mound, Shell Bluff	Coastal	Guale/Mocama
Townsend Mound	Coastal	Guale
Norman Mound	Coastal	Guale
Lewis Creek	Inland	Guale/Mocama
Seven Mile Bend	Inland	Guale
Little Pine Island	Coastal	Guale
Red Bird Creek	Coastal	Guale/Mocama
Oatland Mound	Coastal	Guale/Mocama
Kent Mound	Coastal	Guale/Mocama
Martinez Test B	Coastal	Guale/Mocama
Indian Field	Coastal	Guale/Mocama
Taylor Mound	Coastal	Guale/Mocama

(Continued)

Table I. (Continued)

Site	Location	Cultural association
Couper Field	Coastal	Guale/Mocama
Lake Jackson	Inland	Apalachee
Florida late prehistoric/protohistoric (A.D. 1000–1600)		
Waddells Pond	Inland	Apalachee
Leslie Mound	Inland	Timucua
Tatham Mound	Inland	Tocobaga
Goodman Mound	Coastal	Timucua
Browne Mound	Coastal	Timucua
Holy Spirit Church	Coastal	Timucua
Georgia early mission (A.D. 1600–1680)		
Pine Harbor	Coastal	Guale
Santa Catalina de Guale	Coastal	Guale
Florida early mission (A.D. 1600–1680)		
Ossuary at Santa Catalina	Coastal	Timucua
Santa Maria de Yamasee	Coastal	Yamasee
San Martín de Timucua	Inland	Timucua
San Pedro de Patale	Inland	Apalachee
Florida late mission (A.D. 1680–1700)		
San Luis de Apalachee	Inland	Apalachee
Santa Catalina de Amelia	Coastal	Guale

[a] See Larsen (1982, 1993, 2001) for additional details on mortuary sites. Date brackets for temporal periods are general.

HEALTH AND LIFESTYLE

There were two major shifts in lifeway in this setting, including (1) the shift from a subsistence economy based exclusively on foraging to one based at least in part on farming prior to European contact, and (2) the arrival of Europeans and establishment of Roman Catholic missions among native populations. An important outcome of the establishment of missions was the intensification of agricultural production in some settings (e.g., Guale, Apalachee) and the shift from foraging to farming where it had not occurred before European contact (e.g., Timucua).

This article addresses two key questions: (1) How did diet change and what are the implications for nutrition, health, and resource acquisition for native populations living in the region both before and after European contact? (2) How did lifestyle—physical activity, workload, and behavior—in general change, and what are the implications for health and well-being over the time span? In this paper, we address these questions via the examination of specific data sets. These data sets include stable isotope analysis, dental caries, and dental microwear for dietary reconstruction and various skeletal and dental stress indicators for health implications of dietary change

(Question 1) and osteoarthritis and skeletal structural adaptation for lifestyle (Question 2).

Ideally, the data sets would be uniformly represented for all temporal periods and all locations. However, the topics addressed in this study have a variable history. Dietary reconstruction and biomechanical analysis have been addressed by us for most of the 20-year history of the La Florida Bioarchaeology Project. As a result, these data sets are especially complete. On the other hand, we have only recently begun to study microscopic indications of tooth use and physiological stress. Thus, these data sets are necessarily more restricted in their scope. In addition, skeletal preservation is highly variable across Spanish Florida. The biomechanical analysis requires well-preserved long bones (humeri and femora). As a rule, well-preserved long bones are only available for the Atlantic coastal Georgia and Florida samples (mostly Guale, Timucua, and Yamasee). The lack of well-preserved long bones in the Apalachee setting prevents this type of study for those populations. We employed a multifactorial aging methodology, which involved age estimation by independent criteria (e.g., dental wear, auricular surface) (Lovejoy *et al.*, 1985). This required relatively good preservation of skeletons, thereby limiting demographic analysis to the Atlantic coastal groups. On the other hand, the generally better preservation of teeth throughout the region enhances our understanding of physiological stress as represented in the dentition. A more thorough discussion of the samples, specific analyses completed, and limitations of the data set overall are presented elsewhere (Larsen, 2001).

Health in Spanish Florida: Dietary Reconstruction and Nutritional Inference

Fundamental to a person's health are the foods they eat (the diet) and the nutrients these foods provide (the nutrition). We can never be certain of what the nutritional quality of diet was like for native peoples before and after European contact. However, several lines of evidence (in addition to zooarchaeological and paleoethnobotanical sources) provide key information for reconstructing and interpreting foodways that inform our understanding of nutrition. They include bone chemistry (stable isotope ratios), oral health (dental caries), and tooth use (dental microwear).

Stable Isotope Ratios

Analysis of stable isotope ratios of carbon and nitrogen makes possible the tracking of major dietary shifts and drawing inferences about nutrition.

Field and laboratory animal studies show that ratios of stable isotopes of carbon and nitrogen found in their tissues reflect the ratios of the foods they eat (see review in Schoeninger, 1995). Thus, humans should also retain these signatures in their tissues, including bones. $^{13}C/^{12}C$ ratios (expressed as $\delta^{13}C$ values expressed as parts per thousand, or "per mil" [‰], in relation to an international standard, Pee Dee Belemnite [PDB]) depend on the photosynthetic pathway of the particular kind of plant. In Spanish Florida, the two key plants were either C_3 or C_4, depending on how they extract carbon from atmospheric carbon dioxide during photosynthesis. Most plants consumed by native populations in Spanish Florida were C_3, which results in a relatively negative stable isotope ratio. Maize, the only major economically important C_4 plant, has a relatively less negative stable isotope ratio.

Nitrogen isotope variation provides an important means of distinguishing terrestrial from marine food consumption. Because of the differences in the manner in which nitrogen is used in these contrasting ecosystems, marine organisms tend to have more positive stable nitrogen isotope ratios ($^{15}N/^{14}N$, or $\delta^{15}N$ values expressed in per mil [‰], in relation to an international standard, Ambient Inhalable Reservoir [AIR]) than terrestrial organisms. These differences, as with stable carbon isotope ratios, are reflected in the animal and human consumers and their bone tissues. Because of the strong overlap in the stable carbon isotope ratios for maize and marine organisms (both are less negative than an exclusive or predominant C_4 diet), bivariate plots of stable isotope ratios of both carbon and nitrogen are used (Schoeninger *et al.*, 1990).

Analysis of temporal and geographic variation in stable isotope ratios from bone collagen in Georgia and Florida has shown important patterns of variation in food use in precontact and contact era populations (Hutchinson *et al.*, 1998, 2000; Larsen *et al.*, 1992b, 2001; Schoeninger *et al.*, 1990). Comparisons of early and late prehistoric average isotope values for Georgia reveals a shift from more negative to less negative stable carbon isotope ratios and a more positive to less positive stable nitrogen isotope ratios. For the inland populations having little access to marine foods, the $\delta^{13}C$ values increase on average from −16.0‰ to −15.1‰, and $\delta^{15}N$ values decrease from 11.1‰ to 10.2‰. For coastal populations, the ratios shift from more negative to less negative for carbon (−15.1‰ to −13.4‰), without any appreciable change in $\delta^{15}N$ values (12.8‰ to 12.6‰). These findings indicate a shift from a nonmaize to a maize diet in late prehistory.

Like the Georgia coastal setting, a number of inland (terrestrial) sites in late prehistoric Florida show a clear shift in average $\delta^{13}C$ values, from −15.9‰ (Henderson Mound) in the early prehistoric period to −13.7‰ (Waddells Pond, Lake Jackson) in the late prehistoric period. The $\delta^{15}N$ values show virtually no change over time in the terrestrial setting. For the late prehistoric Florida coastal setting, however, the values are highly negative (−16.1‰), indicating no contribution of maize to diet. These findings show that the only major contribution of maize in prehistoric Florida is associated with the Mississippian Fort Walton Culture (represented by Lake Jackson), the late prehistoric ancestors of the Apalachee Indians in the contact period. All other settings in Florida show no change in diet (i.e., no adoption of maize) prior to European contact (although see Magoon *et al.*, in press).

The analysis of stable isotope values shows clear temporal trends in comparison of late prehistoric Georgia and Florida with the later mission populations (Fig. 2). All mission settings—regardless of location in the colony—have less negative $\delta^{13}C$ values and less positive $\delta^{15}N$ values both as a group and in comparison with prehistoric populations from their respective regions. Moreover, the $\delta^{13}C$ values are statistically indistinguishable when comparing mission samples from coastal Georgia (−11.5‰), coastal Florida (−11.8‰), and inland Florida (−12.4‰) (t test; $p \leq 0.05$). The only difference among the mission samples is the somewhat less positive $\delta^{15}N$ values from inland Florida missions (8.6‰) than from the coastal Florida (10.2‰) and Georgia missions (9.4‰), which almost certainly reflects the greater access to marine foods in the coastal setting than in the terrestrial setting. Moreover, comparison of isotopic values across the region shows a general pattern of shift from foraging to maize farming in some regions (i.e., Timucua) or maize intensification in other areas (i.e., Guale, Apalachee). In an important way, there was a general increase in use of maize, a decrease in use of marine foods, and an increasing similarity of diet across the region in the mission period. In general, the isotopic analysis shows that for coastal populations marine foods were always present in native diets (and see Ezzo *et al.*, 1995), albeit to a reduced degree in the contact period. The broader implication of this dietary reconstruction from stable isotope analysis is that diet became less variable in the contact populations in comparison to the precontact populations. Moreover, the high degree of variation observed prior to contact narrows significantly, resulting in a general homogenization of diet across the large region of Spanish Florida during the mission period (and see Hutchinson *et al.*, 1998; Larsen *et al.*, 2001). This reduction in the diversity of the resource portfolio was clearly detrimental to the health and well-being of the native populations living in the region.

Dental Caries

Dental caries is a disease process characterized by focal demineralization of dental hard tissues (especially enamel and dentine) by organic acids

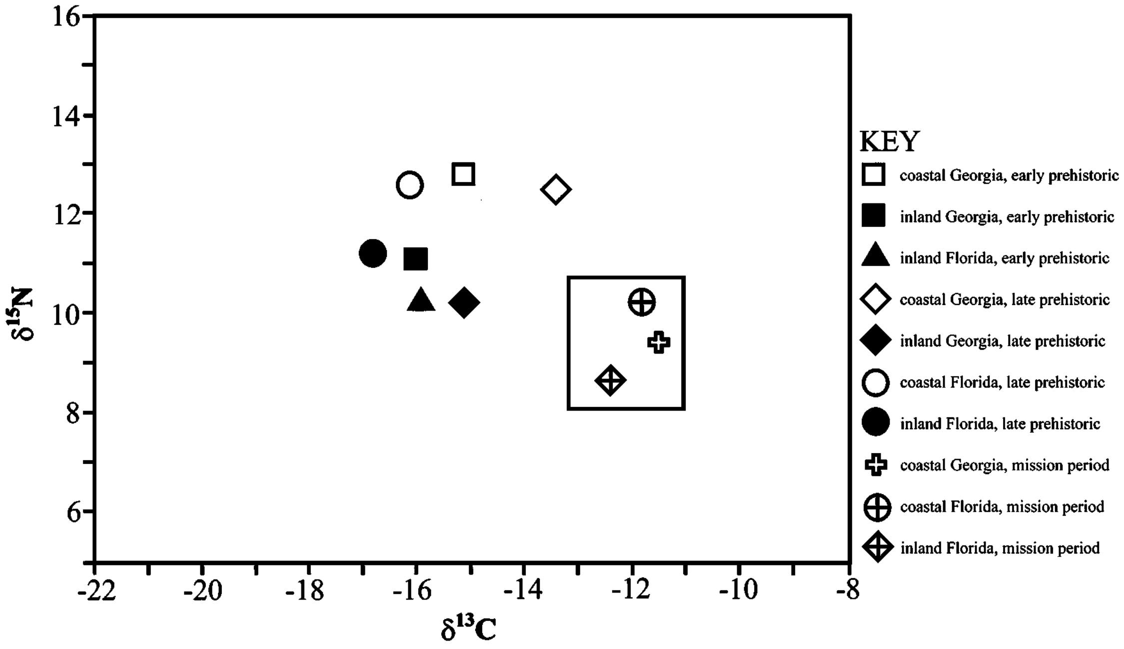

Fig. 2. Bivariate plot of $\delta^{15}N$ and $\delta^{13}C$ average values (in ‰) from Georgia and Florida prehistoric and contact era samples. Each symbol represents the average value of a specific subset. Note the direction of change: the mission period populations have less positive $\delta^{15}N$ values and less negative $\delta^{13}C$ values, representing decreasing focus on marine resources and increasing focus on maize in diet (illustration by Christopher Rodning).

Fig. 3. Carious lesion on mandibular right first molar (photograph by Donald Ortner).

produced by bacterial fermentation of dietary carbohydrates, especially sugars. The carious lesions (cavities) resulting from this process range in size from tiny opacities or barely visible pits to total crown (and sometimes root) destruction (Fig. 3). Because of the presence of sugar in maize, it is cariogenic. In eastern North America, populations that were involved in an agricultural economy generally have more than 7% of teeth affected (Larsen *et al.*, 1991).

We have analyzed the dental samples from coastal Georgia and Florida Guale and the Apalachee from San Luis de Talimali. Temporal comparisons show a general increase in dental caries prevalence, first with the adoption of maize prior to contact and then a large increase in the late mission period (Table II). We regard these increases as reflecting the adoption and increased focus on maize. It is possible that the pronounced increase in the late mission period (Santa Catalina de Guale, Amelia Island) was due to the importation of sugar to the Florida colony. However, we could find no mention of sugar imports in the historic records. Therefore, we regard the role of sugar—aside from its association with maize—as likely minimal or nonexistent.

Interestingly, the frequency of dental caries in the San Luis mission was quite low compared to other samples (less than 5%). Zooarchaeological analysis indicates the significant presence of domesticated sources of animal protein, including cattle and pigs at San Luis (Reitz, 1993). Protein has cariostatic properties (Rowe, 1982), and the presence of these protein sources may have promoted better dental health at San Luis than in other missions.

Table II. Dental Caries[a]

	GEP	GLP	GEM	FLM	Significant change[b]
Total[c]	1.2 (2479)	9.6 (5984)	7.6 (4466)	19.6 (1548)	GEP/GLP, GLP/GEM, GEM/FLM
Males	0.3 (638)	8.3 (1931)	14.9 (441)	21.4 (754)	GEP/GLP, GLP/GEM, GEM/FLM
Females	1.1 (1034)	12.8 (2405)	11.0 (598)	21.1 (606)	GEP/GLP, GEM/FLM

Note. GEP: Georgia early prehistoric; GLP: Georgia late prehistoric; GEM: Georgia early mission; FLM: Florida late mission. Values are percent of teeth affected with at least one carious lesion, with *n* in parentheses; *n*: total number of teeth examined (carious + noncarious teeth).

[a] Adapted from Larsen *et al.* (2002).

[b] Statistically significant change (chi-square; $p \leq .05$, two-tailed).

[c] Total: juveniles, unsexed adults, adult females, adult males (see also Larsen, 1983b).

The dental caries prevalences are not equally distributed in the samples that we have studied. In particular, caries frequencies in late prehistoric Georgia are higher for females than for males (12.8 vs. 8.3%) (Larsen, 1983; Larsen *et al.*, 2001). We interpret this sex difference as reflecting a greater consumption of maize in women than in men prior to European contact, perhaps reflecting the increased role that women played in food preparation (and consumption) in comparison with men. The greater prevalence in females than in males does not hold true for the early or late mission Guale. In the former, males have higher caries prevalence than females (14.9 vs. 11.0%), and in the latter, females and males are about equal in caries prevalence (21.1 vs. 21.4%). The similarity between females and males in the late mission setting may reflect similarity in diet as agriculture became more intensified. This conclusion is consistent with similar values of carbon and nitrogen isotope ratios between females and males in these populations (Hutchinson *et al.*, 1998; Larsen *et al.*, 1992b, 2001). Moreover, the increased focus on maize clearly had a negative impact on dental health.

Dental Microwear

Microwear of tooth surfaces offers important insight into patterns of tooth use and dietary adaptation. Microwear analysis is based on the study of scratches and pits laid down on tooth surfaces during the life of the individual (Teaford, 1991; Teaford *et al.*, 2001) (Fig. 4). Experimental laboratory and field research on animals shows that certain diets can result in characteristic patterns of microwear. Animals that eat foods that are hard and abrasive tend to have more and larger pits on their molars, whereas animals with fine abrasives in their diets tend to have scratches on their molars. This has also been documented experimentally in humans (Teaford and Lytle, 1996).

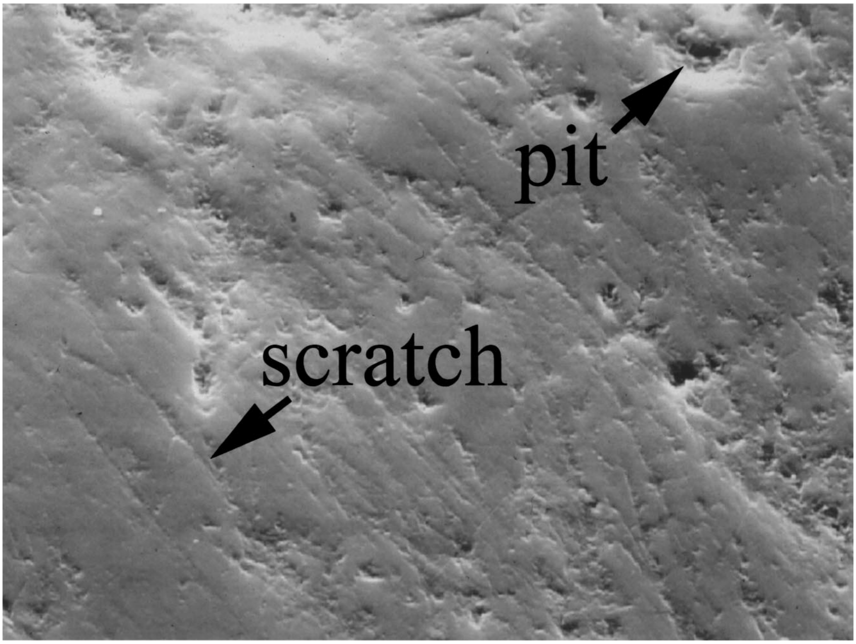

Fig. 4. Microwear on maxillary first molar showing features (pits and scratches) analyzed (micrograph by Mark Teaford).

For the relatively few studies completed on archaeological human remains, there is a high degree of variation in microwear (see Larsen, 1997; Teaford *et al.*, 2001).

For this study, we examined the occlusal (chewing) surfaces of a large sample of maxillary central incisors (I1) and maxillary first molars (M1). Cast impressions were made of the occlusal surfaces, and the impressions examined via scanning electron microscopy at approximately 500× (Teaford *et al.*, 2001). Several key patterns emerge from the analysis of the microwear. First, much of the variation seen across the region reflects whether the population lived in a coastal or a terrestrial setting. That is, irrespective of time period or dietary adaptation (as revealed in the isotopic analysis), the teeth from terrestrial settings have more and smaller microwear features than do teeth from coastal settings (Table III). These differences likely reflect differences in soil composition and the fortuitous incorporation of the different soils into the foods eaten. Thus, the bulk of the differences appear to be related to habitat and not dietary adaptation.

Second, molars from prehistoric contexts show more homogeneous patterns of microwear, especially in the expression of scratches, than from

Table III. Molar Microwear for Coastal and Inland Sites (Florida and Georgia Combined)[a]

Period	*n*	Pit width[b]	Scratch width[b]	Scratch orient.[c] (*r*)	% Pits
Coastal ($n = 52$)	215 (11)	2.65[d] (0.11)	1.00[e] (0.03)	0.498 (0.02)	46.9 (1.4)
Inland ($n = 40$)	352[f] (20)	2.04 (0.07)	0.86 (0.03)	0.509 (0.03)	45.9 (1.3)

Note. Values are mean and SE, with the latter in parentheses.

[a] Adapted from Teaford *et al.* (2001).

[b] Measurements in microns.

[c] Scratch orient.: Orientation vector length for scratches (*r* is a measure of the homogeneity of scratch orientation; see Ungar, 1994); higher values indicate more homogeneous scratch orientation.

[d] Coastal significantly greater than inland ($p < .000$).

[e] Coastal significantly greater than inland ($p < .002$).

[f] Inland significantly greater than coastal ($p < .000$).

mission contexts. We interpret this difference to reflect the tougher consistency of foods eaten prior to contact, which reflects a more homogeneous use of the molars in food processing, than in the mission or other agricultural settings, which show heterogeneous orientation of scratches (Teaford *et al.*, 2001).

Lastly, mission Indians display fewer microwear features for some settings. For example, in the Guale sequence from the Atlantic coast, the number of features declines in the mission Indians from St. Catherines and Amelia Islands (Teaford, 1991). This change most likely reflects the adoption of the practice of boiling of staples into soft mushes and soups (see also Hally, 1986). This increased emphasis on soft foods would also have promoted cariogenesis, owing to the propensity of soft foods to contribute to the buildup of plaque and increased caries activity.

Health and Stress

Stress—physiological disruption resulting from impoverished environmental circumstances—is central to the study of health and well-being in human populations (Goodman *et al.*, 1988). Stress has very specific consequences for a population, such as functional impairment, diminished work capacity, reduction in reproductive potential, and marginal development of cognitive abilities. Biological anthropologists use a variety of indicators of stress (Fig. 5). For this study, we report here on growth disruption (defects in enamel), iron status (porotic hyperostosis and cribra orbitalia), infectious disease (specific and nonspecific skeletal lesions), and demographic inference (fertility and growth rates).

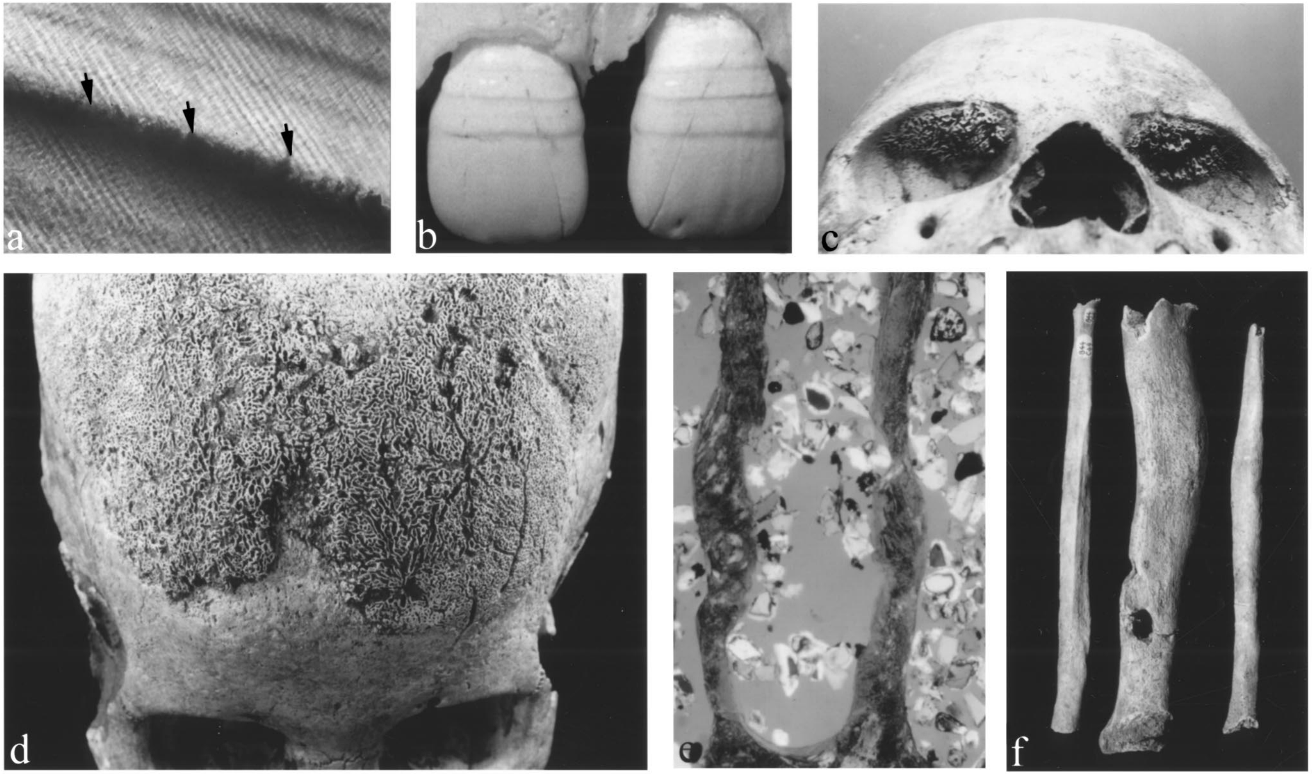

Fig. 5. Health indicators: (a) pathological Retzius line; (b) hypoplasia; (c) cribra orbitalia; (d) porotic hyperostosis; (e) histological section of porotic hyperostosis; (f) periosteal reaction of right tibia and left and right fibulae (photographs by Scott Simpson, Barry Stark, Mark Griffin, Michael Schultz).

Physiological Stress: Microdefects of Enamel

Teeth are highly sensitive indicators of growth disruption, especially with regard to developmental timing of defects in enamel that arise from a range of environmental insults, such as infectious disease or malnutrition. Enamel microdefects called pathological Retzius lines (or Wilson bands) offer important perspective on stress in this regard (Rose, 1977; Wright, 1990). In longitudinal sections of teeth, Retzius lines are visible microscopically as brown lines radiating from the junction between the dentin and enamel to the external surface of the tooth. Each of these lines represents an event involving deposition of enamel matrix on a growth front. Adjacent Retzius lines are separated by about 1 week of enamel growth (Dean, 1987; FitzGerald, 1998). Owing to the periodicity of enamel development, timing of enamel maturation can be tracked with a high degree of precision.

Disruption of enamel development results in irregular or otherwise thick or dark Retzius lines (Marks, 1992; Rose, 1977; Simpson, 2001). The factors that produce the pathological lines are not clearly understood, but they have been associated with a range of stressors, such as vitamin deficiencies, childbirth, toxemia during pregnancy, various viral and bacterial infections, crowding, hypoxia, and dehydration associated with infantile diarrhea (see Simpson, 1999, 2001). Pathological lines represent very short stress events, probably in the range of hours to less than 4 days, indicating a brief and acute metabolic disruption (Simpson, 2001). As regards the reduced quality of life for mission Indians, the study of Retzius lines should provide insight into health before and after contact.

For this part of the study, we analyzed a sample of permanent mandibular canines from prehistoric and mission period Florida (Simpson, 1999, 2001). Tooth thin sections were prepared for microscopic analysis and examined with standard light microscopy (100×–1,000×) and scanning electron microscopy (less than 5,000×). This analysis revealed that about two-thirds (68%) of the total sample of 143 teeth had at least one pathological Retzius line, with an average of 1.6 lines per tooth. There is an increase in pathological lines per individual from 1.8 to 2.6 from the early to late prehistoric periods. On the other hand, the frequency of affected individuals declined sharply from 67 to 36%. This indicates that fewer people experienced acute stressors causing the lines, but those who were so affected had more of them.

The earliest contact sample from the region is from an ossuary sample of comingled skeletons adjacent to the Santa Catalina mission on Amelia Island (Larsen, 1993; Simmons *et al.*, 1989). The sample appears to pre-date the mission period owing to the fact that the remains were not interred following Christian practice. The sample showed only 54% of teeth with pathological lines and an affliction rate of 0.9 lines per individual, which is among the lowest in the entire series.

Comparison of the early and late mission samples with the late prehistoric period revealed some important changes in pathological line frequency. The early and late mission samples have a high frequency of pathological lines (83 and 82%, respectively), indicating a marked increase in comparison with the protohistoric ossuary and the late prehistoric period. Moreover, the rates of affliction per individual are also elevated (2.5 and 2.9 pathological lines, respectively). In contrast to the prehistoric and early mission teeth, the pathological lines are present in cuspal enamel, indicating that stresses occurred earlier in life in the late mission period in comparison with the earlier periods. Thus, stress was at its highest and earliest levels in the late mission period, the time just prior to the abandonment of the region by the Spanish and the tribes. This pattern is similar to the temporal changes seen in other indicators of morbidity, such as enamel macrodefects, porotic hyperostosis, and nonspecific infection (see later).

Because the pathological Retzius lines are nonspecific in origin, it is not possible to identify their causes in the prehistoric or mission individuals. However, we can identify general factors that may have been involved, especially in comparing the mission Indians with their prehistoric predecessors. One common health problem in many traditional societies, especially those living in relatively poor living circumstances that are analogous to the La Florida missions, is disease that produce diarrhea in the first 2 years of life (Gordon *et al.*, 1963). Infantile diarrhea is especially problematic because of the associated rapid systemic dehydration in susceptible juveniles. As a result of these crucial fluid losses, normal cellular homeostasis is jeopardized. There is then a rapid movement of fluids from the intracellular spaces, leading to cell dysfunction, including those cells (ameloblasts) that produce enamel. In the unsanitary conditions of missions, the shift from maternal nutrition (milk) to weanling diets would have introduced pathogens to young infants, contributing to elevated frequency of infantile diarrhea.

Physiological Stress: Macrodefects of Enamel

Physiological disruption is also visible macroscopically as surface features characterized by deficiency in enamel thickness. These deficiencies, called hypoplasia, are most commonly visible on the crown surface as linear furrows or pits. Like the microscopic pathological Retzius lines, hypoplasia is a nonspecific indicator of stress, having been associated in clinical and experimental settings with a range of diseases, malnutrition, or both (Cutress and Suckling, 1982).

For this study, we have documented the pattern and prevalence of linear enamel hypoplasias from early and late prehistoric and early and late mission samples from Georgia and Florida (Hutchinson and Larsen, 1988, 1990, 2001). The documentation of these enamel defects in the permanent maxillary and mandibular incisors and canines revealed that in both Georgia and Florida, the percent of individuals affected by at least one hypoplasia is greatest in the earliest and latest groups that represent the two broad regions. However, for all periods, there are more individuals affected by enamel defects in Georgia than in Florida (Table IV). For Florida, where data are available for pathological Retzius lines, the frequency pattern is similar with regard to relatively elevated prevalence in the late mission period. Researchers have found that frequency or pattern of microdefects and macrodefects do not coincide necessarily, owing to different factors that cause them (see Simpson, 2001). Thus, these differences are not unexpected, especially given the somewhat different lifeways and commitment to agriculture in comparing Georgia and Florida native populations. Importantly, both microdefects and macrodefects are relatively high in the late mission period in Florida in comparison with other subsets of the study. Given the elevated stress levels due to the variety of factors impacting native populations in the missions, we believe that the increase in both microdefects (accentuated Retzius lines) and macrodefects (hypoplasias) reflect the deteriorating conditions, including poorer nutrition, population concentration, and elevated disease prevalence.

Table IV. Individuals with Hypoplasia[a]

EP	LP	EM	LM	Total
		Georgia		
(*n* = 98)[b]	(*n* = 183)	(*n* = 229)	—	(*n* = 510)
88 (86)[c]	86 (157)	88 (202)	—	445
		Florida		
(*n* = 21)	(*n* = 40)	(*n* = 118)	(*n* = 83)	(*n* = 262)
76 (16)	58 (23)	50 (57)	59 (49)	145
		Difference[d]		
(*n* = 119)	(*n* = 223)	(*n* = 347)		(*n* = 689)
−12 (102)	−28 (180)	−38 (259)	—	541

Note. EP: early prehistoric; LP: late prehistoric; EM: early mission; LM: late mission.

[a] Adapted from Hutchinson and Larsen (2001).

[b] Number of individuals represented by at least one tooth in the dentition.

[c] Values are percent of individuals affected by at least one enamel hypoplasia, with *n* in parentheses; *n* = number of individuals affected by at least one enamel hypoplasia.

[d] Difference = Florida − Georgia.

Iron Status and Chronic Anemia

Other pathological modifications arising from physiological stress are indicated in the flat bones of the cranial vault and the eye orbits. Pathological features called porotic hyperostosis when the cranial vault is affected and cribra orbitalia when the eye orbits are affected have been studied in populations around the world (see Larsen, 1997). These features are typically seen as porous, sieve-like lesions that are oftentimes linked to iron deficiency anemia (e.g., Stodder, 1994; Wright and Chew, 1999). Other investigators have shown, however, that these features are also caused by inflammatory processes, infection, hemorrhage (bleeding) associated with vitamin C and D deficiencies, and other diseases (see Schultz *et al.*, 2001). Nevertheless, iron deficiency is an important cause of these pathological features. In this regard, iron deficiency results in an increased production of red blood cells (which takes place in the cranial bones), and the cranial expansion and porosity that is so typical of both porotic hyperostosis and cribra orbitalia are the expected outcome.

For prehistoric and mission period Guale, Yamasee, and Timucua, there is a distinctive temporal pattern of change in frequency in porotic hyperostosis/cribra orbitalia (Table V). Unlike a number of settings where there are increases in frequency in late prehistoric populations, such as the American Southwest, we found no temporal changes prior to European contact. For both the early and late prehistoric periods, the prevalence of porotic hyperostosis and cribra orbitalia was well under 10% (Larsen and Sering, 2000; Schultz *et al.*, 2001). The low frequency can be attributed to the adequate

Table V. Cribra Orbitalia and Porotic Hyperostosis[a]

	GEP	GLP	GFEM	FLM	Significant change[b]
Cribra orbitalia					
Total[c]	5.7 (104)	3.1 (287)	14.0 (121)	22.9 (70)	None
Juvenile[d]	38.5 (13)	6.1 (33)	21.7 (23)	73.3 (15)	GEP/GLP, GLP/GEM
Porotic hyperostosis					
Total	0.0 (113)	3.3 (308)	15.8 (133)	21.1 (90)	None
Juvenile	0.0 (13)	0.0 (33)	20.0 (25)	50.0 (18)	GEM/FLM

Note. GEP: Georgia early prehistoric; GLP: Georgia late prehistoric; GFEM: Georgia and Florida early mission; FLM: Florida late mission. Values are percent of orbits/vaults affected, with *n* in parentheses; *n*: total number of orbits/vaults examined (pathological + nonpathological).

[a] Adapted from Larsen and Sering (2000) and Schultz *et al.* (2001).

[b] Statistically significant change (chi-square; $p \leq .05$, two-tailed).

[c] Total: juveniles, unsexed adults, adult females, adult males combined.

[d] Juvenile: individuals less than 10 years.

intake of iron via marine food resources by native populations prior to European contact. The abundant prehistoric shell middens, associated with both early and late prehistoric sites, suggest that seafood was very important in diet, as is also indicated by the stable nitrogen isotope analysis (as shown previously). Clinical evidence indicates that when maize (a food that decreases iron bioavailability) is simultaneously eaten with seafood, iron status is greatly improved (Layrisse *et al.*, 1968). Thus, maize consumed with seafood is much better nutritionally than maize alone. We suggest that the strong presence of seafood in native diets allayed the nutritional shortfalls of maize.

In contrast to the prehistoric period, there is a remarkable increase in frequency of porotic hyperostosis and cribra orbitalia in the contact era, both with respect to the early and late mission samples. The most profound increases are for juveniles (individuals less than 16 years of age). In the late mission juveniles from Amelia Island, Florida, 73.3% had cribra orbitalia and 50.0% had porotic hyperostosis. We believe that two factors contributed to these increases in the mission period. First, there was an increased focus on maize and a decreased focus on marine foods. Second, and probably of greater consequence, was the shift in living circumstances in the mission setting involving closer, more crowded habitation, poorer hygiene, and especially consumption of contaminated water. Mission inhabitants acquired at least some water from a shallow well constructed at Santa Catalina on St. Catherines Island (Thomas, 1987). Shallow wells of this sort can easily become contaminated by parasites in these sorts of subtropical environments. Parasitic infection of humans could promote iron losses, and hence, iron deficiency anemia (see Larsen and Sering, 2000; Schultz *et al.*, 2001).

To diagnose with more precision the cause of porotic hyperostosis and cribra orbitalia, two crania for the early mission site of Santa Maria de Yamasee and two crania from the ossuary near Santa Catalina (Amelia Island) were examined by radiography, and light and scanning electron microscopy (Schultz *et al.*, 2001). This analysis involved the preparation of thin sections of porotic hyperostosis and cribra orbitalia to compare pathological changes with clinically documented cases of iron deficiency and other factors that cause these features (see Schultz, 1988). This analysis revealed a number of changes that are typically associated with iron deficiency anemia. For example, in a 9–12-year-old child from Santa Maria de Yamasee (Amelia Island, Florida), there is extensive porotic hyperostosis involving much of the top of the cranium (Fig. 5(d)). Microscopic examination shows new bone formation that is built of parallel, relatively long and gracile bone trabeculae (Fig. 5(e)). These trabeculae are expanded, reflecting enlargement of red blood marrow due to increased production of red blood cells. This feature is characteristic of chronic anemia. Similarly, two of the other three skulls show changes that are characteristic of chronic anemia. Although only a few crania have been subjected to microscopic analysis, it nevertheless suggests that at least some of the increased frequency of porotic hyperostosis and cribra orbitalia is linked to anemia in this setting.

Infectious Disease: Specific and Nonspecific

One of the best historically documented health problems in the contact era in Spanish Florida—like most of the rest of the Americas—is the introduction and rapid spread of Old World pathogens, especially those causing smallpox and measles. Indeed, during the mission period, epidemics accounted for many deaths (see Hann, 1986, 1988; Larsen, 1990, 2001; Worth, 1998). These acute infectious diseases are expressed only rarely in osteological remains, primarily because the human host dies long before osseous changes have time to develop. Chronic infectious disease, however, should be present in these populations and should mark changes in quality of life and living circumstances in prehistoric and mission settings of Spanish Florida.

Pathology representing specific infectious diseases—especially tuberculosis and treponematosis—has been documented in the region. Pathological changes consistent with these two diseases have been identified mostly from the Irene Mound site, a large late prehistoric (Mississippian) ceremonial and habitation center on the north Georgia coast (Powell, 1990, 2000) and other settings in the region (Hutchinson *et al.*, in preparation).

Nonspecific skeletal lesions called periosteal reactions have been systematically studied in the region. Periosteal reactions can appear minimally as vascular tracks and slight inflammation on bone surfaces to extensive bone involvement with pronounced inflammatory response. The lesions can be caused by a variety of circumstances that result in trauma to the periosteum. However, the net result is typically new bone formation and remodeling. Bioarchaeologists associate these changes with infection (see Larsen, 1997), but even minor trauma—such as a blow to the tibia resulting from a fall or being kicked on the shin—can cause periosteal reactions (Eyre-Brook, 1984; Simpson, 1985).

Temporal comparisons for early and late prehistoric Georgia, early mission Georgia, and late mission Florida (Atlantic coast) show a general increase in prevalence for the tibia (Table VI). Other skeletal elements also show increases in frequency of periosteal reactions, but the increases are most pronounced for the tibia (Larsen *et al.*, in press; Moore, 1993). The

Table VI. Tibial Periosteal Reactions[a]

	GEP	GLP	OSS	GFEM	FLM	Significant change[b]
Total[c]	9.5 (126)	19.8 (331)	44.7 (76)	15.4 (26)	59.3 (96)	GEP/GLP, GLP/ OSS, GEM/FLMC
Male[d]	9.3 (32)	23.6 (93)	—	23.1 (13)	70.0 (36)	GEP/GLP, GEM/FLM
Female[d]	4.3 (47)	24.1 (133)	—	14.3 (7)	65.7 (35)	GEP/GLP, GEM/FLM

Note. GEP: Georgia early prehistoric; GLP: Georgia late prehistoric; GFEM: Georgia and Florida early mission; OSS: Ossuary at Santa Catalina de Guale (Amelia Island); FLM: Late mission. Values are percent of tibiae/elements affected, with *n* in parentheses; *n*: total number of tibiae/elements examined (pathological + nonpathological).

[a] Adapted from Larsen *et al.* (in press) and Schmidt (1993).

[b] Statistically significant change (chi-square: $p \leq .05$, two-tailed).

[c] Total: juveniles, unsexed adults, adult females, adult males.

[d] Male: adult males; Female: adult females.

increase in frequency of periosteal reactions is relatively moderate in the comparison of early and late prehistoric periods (from 9.5 to 19.8%). This is followed by a slight decline in the early mission Georgia and Florida (to 15.4 and 14.1%, respectively) and a substantial increase in the protohistoric ossuary at Santa Catalina (Amelia Island; to 44.7%) and in the late mission period (to 59.3%).

The moderate increase in periosteal reactions prior to the arrival of Europeans is similar to changes documented in other New World settings where populations became larger and more sedentary, which is associated with the shift from foraging to partial or intensive farming (Larsen, 1995). To account for the declining quality of living conditions in mission settings, we regard the very marked increase in periosteal reactions in the late mission Florida sample as resulting from infection rather than from traumatic injury or other factors that cause periosteal reactions.

In summary, the evidence described here indicates a consistent picture of increased morbidity that began before the arrival of Europeans. To be sure, there is variation across this large landscape in pathology. However, that variation is to be expected in what must have been a highly dynamic setting.

Demographic Consequences of Stress: Fertility and Population Decline

The increase in morbidity documented here would have had certain implications for demographic patterns, especially mortality and fertility. In regard to fertility, study of traditional societies in Africa and elsewhere reveal a close relationship between resources and birthrate. Among the Turkana pastoralists (Ngisonyoka) of East Africa, for example, Leslie *et al.* (1999) have shown that under conditions of reduced food availability during seasonal droughts, number of births decrease; conversely, during periods of increased food availability, birthrates increase. Their findings point to a close link between environmental perturbations, fertility reduction, and decline of population size.

The age distributions for the La Florida skeletal samples are presented as number (D_x) and percentage (d_x) of deaths by age class (Table VII). In some respects, there is an overall similarity in age structure between the groups. For example, with respect to mean age-at-death four of the five groups are in the early 20s. The Florida late mission sample stands out from the rest of the groups with a mean age-at-death of 29.8 years. It may be possible that the high average age-at-death is an indicator of reduced mortality in the late mission setting. However, evaluation of demographic profiles in archaeological death assemblages suggests that mean age-at-death reflects the influence of fertility and birthrate, not mortality, especially in populations that are closed to migration and have highly fluctuating growth (Johansson and Horowitz, 1986; Milner *et al.*, 1989; Sattenspiel and Harpending, 1983). In particular, population growth relating to increased birthrate will result in a larger number of younger individuals in the skeletal series, and hence, lower mean age-at-death. Conversely, population decline resulting from a decrease in number of new individuals entering a population (lower birthrate) will result in fewer younger individuals (or more older individuals), and a higher mean age-at-death. In this respect, the markedly higher mean age-at-death in the late mission sample from Florida (Santa Catalina, Amelia Island) likely reflects reduced fertility compared with earlier populations.

One approach to estimating fertility and birthrates in archaeological settings is to look at the proportion of number of individuals older than30 years (D_{30+}) to number of individuals older than 5 years (D_{5+}) in the death assemblage (Buikstra *et al.*, 1986). The inverse of the proportion of D_{30+}/D_{5+} is a robust indicator of fertility in a population: the higher the proportion, the lower the fertility; conversely, the lower the proportion, the higher the fertility (see Buikstra *et al.*, 1986). The proportions in the Georgia early and late prehistoric groups are similar (.3790, .3500) and there is a slight but statistically nonsignificant reduction in the descendent early mission group on St. Catherines Island (to .2823). In the early mission Florida series (Santa Maria de Yamasee), the proportion shows a statistically significant increase to .4493, which may reflect a decline in fertility. The most marked change in the proportion is the (statistically significant) jump to .7263 in the late mission Florida sample, a value that reflects a relatively low number of young individuals and a high number of old adults. We believe that this change in the

Table VII. Age-at-Death Distribution[a]

	D_x (d_x)				
Age group	GEP	GLP	GEM	FEM	FLM
Total sample[b]					
0–4.9	15 (8.9)	36 (11.4)	22 (6.9)	14 (16.9)	19 (16.7)
5–9.9	23 (13.7)	24 (7.6)	44 (13.9)	12 (14.5)	8 (7.0)
10–14.9	10 (5.6)	15 (4.8)	22 (6.9)	4 (4.8)	4 (3.5)
15–19.9	19 (11.3)	67 (21.2)	36 (11.4)	4 (4.8)	7 (6.1)
20–24.9	24 (14.3)	56 (17.7)	58 (18.4)	11 (13.3)	1 (0.8)
25–29.9	19 (11.3)	20 (6.3)	51 (16.1)	7 (8.4)	6 (5.3)
30–34.9	15 (8.9)	24 (7.6)	33 (10.4)	4 (4.8)	5 (4.4)
35–39.9	10 (5.9)	28 (8.8)	40 (12.6)	7 (8.4)	17 (14.9)
40–44.9	12 (7.1)	24 (7.6)	8 (2.5)	15 (18.1)	20 (17.5)
45+	21 (12.5)	22 (6.9)	2 (0.6)	5 (6.0)	27 (23.7)
Total *n*	168	316	316	83	114
Mean age	23.2	22.5	21.3	23.0	29.8
D_{30+}/D_{5+}	.3790	3500	.2823	.4493	.7263
Adult males					
16.1–20	2 (5.4)	12 (14.1)	2 (7.7)	0 (0.0)	3 (7.7)
20.1–25	11 (29.7)	22 (25.9)	6 (23.1)	2 (12.5)	1 (2.6)
25.1–30	5 (13.5)	6 (7.1)	6 (23.1)	3 (18.8)	4 (10.3)
30.1–35	4 (10.8)	13 (15.3)	5 (19.2)	1 (6.3)	3 (7.7)
35.1–40	3 (8.1)	11 (12.9)	6 (23.1)	4 (25.0)	7 (18.0)
40.1–45	6 (16.2)	12 (14.1)	1 (1.2)	6 (37.5)	11 (28.2)
45.1+	6 (16.2)	9 (10.6)	0 (0.0)	0 (0.0)	10 (25.6)
Total *n*	37	85	26	16	39
Mean age	32.1	31.4	30.5	34.6	38.9
Adult females					
16.1–20	12 (21.8)	27 (24.6)	6 (15.0)	0 (0.0)	2 (4.9)
20.1–25	12 (21.8)	23 (20.9)	8 (20.0)	6 (37.5)	2 (4.9)
25.1–30	7 (12.7)	18 (16.4)	6 (15.0)	1 (6.3)	1 (2.4)
30.1–35	2 (3.6)	14 (12.7)	12 (30.0)	1 (6.3)	4 (9.8)
35.1–40	7 (12.7)	13 (11.8)	5 (12.5)	1 (6.3)	9 (22.0)
40.1–45	4 (7.3)	8 (7.3)	3 (7.5)	5 (31.3)	11 (26.8)
45.1+	11 (20.0)	7 (6.4)	1 (2.5)	2 (12.5)	12 (29.3)
Total *n*	55	110	41	16	41
Mean age	30.9	28.9	30.3	32.5	41.0

Note. GEP: Georgia early prehistoric; GLP: Georgia late prehistoric; GEM: Georgia early mission; FEM: Florida early mission; FLM: Florida late mission. D_x: number of deaths; d_x: percent of deaths.

[a] Adapted from Larsen *et al.* (in press) and Russell *et al.* (n.d.).

[b] Juveniles and sexed and unsexed adults.

proportion reflects a marked decline in birthrate during the late mission period. This conclusion is consistent with the increase in morbidity in general and with the historical accounts of population and settlement change in the contact era. With regard to the latter, during the seventeenth century there is a reduction in number of settlements and total native population size in the region (Jones, 1978). For example, from 1675 to 1686, there was a reduction from seven villages containing less than 500 individuals on the Georgia coast to virtually complete depopulation of the area north of Cumberland Island (Jones, 1978). Some of the population reduction (see also discussions in Hann, 1986, 1988; Larsen, 1990; Larsen *et al.*, 1990; Worth, 1998) can be accounted for by out-migration, but we regard other factors as more significant in explaining the change in the proportion of old to young deaths, especially the deteriorating quality of life overall coupled with epidemics that periodically swept through the region. Not only did these circumstances contribute to death, but they almost certainly caused a reduction in fertility. That said, the possibility remains that skeletons may be undernumerated in some of the age categories in these skeletal series, especially very young individuals whose skeletons may not preserve. Certainly, this is an important consideration in interpreting demographic profiles in this and other archaeological contexts.

In summary, a number of lines of evidence reveal a pattern of population decline and reduced health and quality of life in the native populations living in the Spanish colony. There are indications that reduced quality of life involving poorer nutrition, increased infection, and other negative factors began prior to the arrival of Europeans. In an important way, these factors may have predisposed these groups to reduction and population loss once Europeans arrived in the region. This analysis reveals that a variety of negative circumstances contributed to shifts in health and the ultimate decline and depopulation of the region. European-introduced infectious diseases played a large role in these declines, but the range of other factors identified in this study indicate that the population change is complex. Key to the understanding of population decline is the complex interaction between mortality and fertility (and see Thorton, 1997).

LIFESTYLE: ACTIVITY, LABOR, AND BEHAVIOR

Lifestyle—patterns of habitual activity—is a defining characteristic of human populations, and has long been a subject of anthropological interest. Skeletal biology offers an important means of contributing insight into reconstructing and interpreting lifestyle in past populations (Bridges, 1995; Brues, 1960; Larsen, 1997; Lieberman, 1997; Pearson, 2000; Ruff, 2000). As with other regions of the globe where the transition from foraging to farming took place, the fundamental changes in the manner in which food is acquired had consequences for workload and activity (see Larsen, 1995). During the mission period in La Florida, historical records indicate that the arrival of Europeans and the enforcement of new labor demands and exploitation of native populations had profound implications for lifestyle in general and work in particular. Two areas of bioarchaeological analysis allow us to extend our understanding of the impact of behavioral alterations before and after contact, namely (1) degenerative changes on articular joints (osteoarthritis) and (2) morphological alterations of long bones reflecting structural adaptations to different levels and types of physical activity. Both of these areas are important because they represent a cumulative history of the mechanical demands of day-to-day life for individuals and for the populations from which they are drawn (see Ruff, 2000; Ruff and Larsen, 2001).

Osteoarthritis

Osteoarthris (or degenerative joint disease) is an age-progressive disorder involving degenerative changes of the articular joints (Hough, 1997). The changes are characterized by apposition of bone on joint margins (marginal lipping), or less commonly, loss of bone on joint surfaces, or both (Fig. 6). The disorder is complex and involves multiple causes, including genetic predisposition and the metabolic and immunologic environment. Figuring most importantly in its etiology, however, are mechanical factors—the cumulative wear and tear on the articular joints because of physical activity (Hough, 1997).

Documentation of osteoarthritis is based on early and late prehistoric Georgia and late mission Florida (Santa Catalina de Guale, Amelia Island), representing the temporal continuum for Guale. For this study, we report osteoarthritis prevalence for the vertebrae (cervical, thoracic, and lumbar),

Fig. 6. Osteoarthritis (degenerative joint disease): (a) marginal lipping on lumbar vertebrae; (b) eburnation and articular joint surface deterioration (photographs by Mark Griffin and Barry Stark).

shoulder, hip, wrist, and hand joints. Osteoarthritis was considered present if any element of a specific joint (e.g., humerus head for the shoulder) showed either loss (or polish) of bone on the joint surface or apposition of bone on the joint margin or both.

Comparison of the three samples reveals two distinctive temporal trends in the frequency of the disorder (see Table VIII). First, there is a moderate reduction in late prehistoric Georgia relative to the early prehistoric Georgia. Second, there is a dramatic increase in osteoarthritis prevalence in the late mission period. This change is quite pronounced for some of the joints, especially for the vertebral joints. Some of this temporal variation is due to the differences in age structure of the three populations. The late prehistoric group is slightly younger than the early prehistoric group, and the late mission group is older than the late prehistoric group. However, analysis of the samples by comparison of 5-year age groups indicates that the temporal changes are real and not due to age structure alone.

Table VIII. Degenerative Joint Disease[a]

Articular joint	GEP	GLP	FLM	Significant change[b]
All adults				
Cervical	26.0 (50)	16.4 (189)	68.3 (60)	GLP/FLM
Thoracic	15.6 (32)	11.4 (175)	68.3 (60)	GLP/FLM
Lumbar	41.9 (43)	24.5 (163)	67.2 (58)	GEP/GLP, GLP/FLM
Shoulder	9.7 (113)	5.3 (207)	15.2 (66)	GLP/FLM
Hip	12.0 (108)	6.8 (206)	10.5 (67)	None
Wrist	5.9 (84)	1.1 (187)	13.2 (68)	GEP/GLP, GLP/FLM
Hand	5.0 (40)	3.0 (165)	5.9 (68)	None
Adult males				
Cervical	33.3 (18)	27.5 (80)	74.1 (27)	GLP/FLM
Thoracic	16.7 (12)	19.2 (73)	74.1 (27)	GLP/FLM
Lumbar	50.0 (14)	37.7 (69)	75.0 (28)	GLP/FLM
Shoulder	17.7 (34)	10.1 (79)	16.7 (30)	None
Hip	13.2 (38)	12.5 (80)	9.4 (32)	None
Wrist	15.4 (26)	2.7 (75)	16.1 (31)	GEP/GLP, GLP/FLM
Hand	8.3 (12)	5.8 (69)	3.3 (30)	None
Adult females				
Cervical	22.2 (27)	8.4 (95)	65.6 (32)	GLP/FLM
Thoracic	16.7 (18)	5.5 (91)	65.6 (32)	GLP/FLM
Lumbar	38.5 (26)	15.3 (85)	60.0 (30)	GEP/GLP, GLP/FLM
Shoulder	5.2 (58)	2.9 (105)	13.9 (36)	GLP/FLM
Hip	13.2 (53)	3.8 (105)	11.4 (35)	GEP/GLP
Wrist	2.3 (43)	0.0 (96)	10.8 (37)	GLP/FLM
Hand	4.0 (25)	1.2 (85)	7.9 (38)	None

Note. GEP: Georgia early prehistoric; GLP: Georgia late prehistoric; FLM: Florida late mission. Values are percent of articular joints affected, with *n* in parentheses; $n =$ total number of joints examined (pathological + nonpathological).

[a] Adapted from Larsen *et al.* (in press).

[b] Statistically significant change (chi-square; $p \leq .05$, two-tailed).

We regard the temporal decline in frequency of osteoarthritis as reflecting a reduction in workload, or at least the kind of work and activity that results in osteoarthritis. Especially interesting is the dramatic increase in osteoarthritis in the late mission period. In light of the references to demanding physical labor in the mission system for its native participants (e.g., Hann, 1988), it seems reasonable to conclude that the increase in osteoarthritis reflects the increased labor demands of the *repartimiento* draft labor system. For example, some adults males were required to make long-distance trips to various localities in the various provinces of the Spanish colony (Hann, 1988). These trips involved carrying of heavy burdens over lengthy distances, which would have resulted in increased mechanical loading of the weight-bearing and other joints. Unlike many other areas of the Americas controlled by Spain, La Florida did not have pack animals until late in the Spanish occupation of the region; thus any burden bearing was the responsibility of native individuals (Worth, 1998). Moreover, native individuals—adult men especially—were recruited for other labor projects, including construction and agricultural field labor.

Skeletal Structural Adaptation

Just like other living organs, the bones of a person alter their shape and structure in response to mechanical stresses associated with physical activity. Activity has a strong influence on the amount of bone development, especially in nonarticular regions of the skeleton (Ruff, 2000; Larsen, 1997). One of the breakthroughs in bioarchaeology as it relates to the reconstruction of physical activity and interpretation of structural adaptation is the application of a simple mechanical model known as beam theory. Under this model, a long bone can be modeled as a hollow beam and engineering properties determined, much in the same way that a civil or mechanical engineer analyzes the properties of materials that go into the construction of a bridge or a building. Beam theory is based on the premise that the further the materials are placed away from a central or neutral axis in a cross-section of a beam, the greater its ability to resist fracture. In this model, cross-sectional geometric properties are used to calculate the rigidity (or strength) under different kinds of loading modes (Ruff, 2000). These properties include cross-sectional area of bone and second moments of area. The former are proportional to compressive strength (ability to resist compression) and the latter are proportional to bending and torsional (twisting) strength (ability to resist bending or torsion; see Ruff, 2000; Ruff *et al.*, 1984; Ruff and Hayes, 1983; Ruff and Larsen, 2001). The model has been successfully applied to human remains from a range of

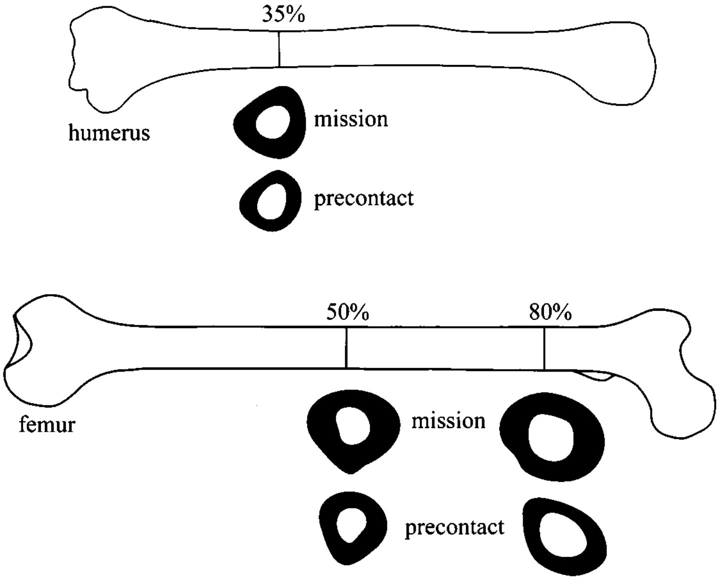

Fig. 7. Humerus (top) and femur (bottom) cross-section locations for biomechanical analysis. The sections are schematic versions showing the direction of change comparing precontact and mission Indians. Note the greater amount and outward distribution of bone in the mission period, indicating skeletal adaptation to increased workload (illustration by Christopher Ruff and Christopher Rodning).

paleontological and archaeological settings (see Bridges, 1995; Larsen, 1997; Ruff, 2000).

For this study, we analyzed a large sample of precontact and contact era femora ($n = 168$) and humeri ($n = 189$) from sites in Spanish Florida. For purposes of comparison, we use the temporal/geographic divisions described previously. However, for the early mission Florida, we subdivided the sample into early mission Yamasee and early mission Timucua. Specific cross sections that were analyzed include the femoral midshaft (50% of length from the distal end), femoral subtrochanteric (80% of length from the distal end), and humeral mid-distal (35% of length from the distal end) (Fig. 7). These specific locations have been shown to be highly informative about function and mechanical loading in the lower and upper limbs.

Bone sections were made at each of the three diaphyseal locations, the exposed surfaces photographed, and the images projected onto a digitizer screen. The outer (subperiosteal) and inner (endosteal) surfaces were manually traced with the digitizer, and cross-sectional geometric properties were automatically calculated using a modified version of the program

SLICE (Nagurka and Hayes, 1980) developed for bone analysis. For each section, three properties were analyzed: cortical area (CA), polar second moment of area (J), and the ratio of perpendicular second moments of area (I_x/I_y for femur midshaft and humerus mid-distal and $I_{\max}/I_{\min}$ for femur subtrochanteric). CA represents the amount of cortical bone in the cross section and measures the axial rigidity (resistance to compression in the long axis of the bone). J, defined as the sum of I_x and I_y, measures resistance to torsion and is a good overall indicator of bone strength. I_x/I_y is a ratio of anterior–posterior (front to back) to medial–lateral (side to side) bending strength. Higher I_x/I_y ratios (where I_x is greater than I_y) indicate that anterior–posterior bending strength is greater than medial–lateral bending strength. Ruff (1987, 2000) has observed that values greater than 1.0 are associated with mobile populations, whereas values closer to 1.0 are associated with sedentary populations (e.g., industrialized populations). $I_{\max}/I_{\min}$ is the ratio of the maximum to minimum strength, and best quantifies cross–sectional shape in the proximal (upper) femur. Because the properties described here are strongly influenced by body size, they are standardized following procedures described by Ruff (2000). Only the size-standardized properties are reported here (and see Ruff and Larsen, 2001)

Previous research by Ruff (1999) on structural adaptation in prehistoric Amerindians from the eastern Great Basin of western North America shows a clear relationship between degree of maize consumption and skeletal structural adaptation. To document potential direct links between diet and physical activity at the individual level, we examine statistically (regression analysis) the relationship between diet (as measured by $\delta^{13}C$ and $\delta^{15}N$ values) and activity (J_{STD} and I_x/I_y for femoral midshaft, J_{STD} for humeral mid-distal).

Bone Strength

The summary data for the cross-sectional geometric analysis are presented in Table IX (and see summary in Fig. 7). Comparisons of the groups reveal clear temporal trends for the prehistoric and mission Guale and the early mission Yamasee. In this regard, there is a general uniformity of $\mathrm{CA}_{\mathrm{STD}}$ among the samples, suggesting the general maintenance of bone mass throughout the sequence. In contrast, J_{STD} varies by temporal period in a patterned fashion.

Among males, the greatest values for J_{STD} are in early prehistoric Georgia. This is followed by a decline in late prehistoric Georgia and an increase to intermediate values in the early and late mission Georgia/Florida (Santa Catalina de Guale on St. Catherines and Amelia Islands). The early

Table IX. Femoral and Humeral Length' and Cross-Sectional Properties[a]

Group[b]	*n*	Length′	CA_{STD}	J_{STD}	I_x/I_y	I_{max}/I_{min}
Femur midshaft (50%)						
Combined sex						
GEP	14	412.2 (4.9)	526.2 (29.4)	468.8 (30.0)	1.261 (.046)	
GLP	45	410.4 (3.7)	497.9 (13.0)	410.4 (14.7)	1.137 (.029)	
GEM	18	412.2 (5.3)	533.8 (18.6)	459.1 (23.2)	1.085 (.061)	
FLM-G	47	406.4 (3.2)	530.0 (12.1)	493.6 (16.3)	1.045 (.033)	
FEM-Y	16	408.9 (6.6)	509.7 (15.0)	428.2 (17.5)	1.089 (.034)	
FEM-T	28	406.9 (5.1)	544.4 (14.6)	496.6 (21.3)	1.083 (.040)	
Adult males						
GEP	6	418.3 (8.8)	600.9 (24.8)	563.6 (27.2)	1.333 (.048)	
GLP	21	421.4 (4.1)	531.0 (19.4)	443.8 (22.0)	1.153 (.040)	
GEM	9	420.3 (7.9)	546.5 (31.9)	501.5 (37.1)	1.192 (.109)	
FLM-G	21	420.0 (3.9)	536.3 (13.3)	505.9 (21.0)	1.137 (.045)	
FEM-Y	8	425.9 (9.8)	519.6 (21.3)	444.2 (22.7)	1.110 (.057)	
Adult females						
GEP	8	407.6 (5.5)	470.2 (37.9)	397.8 (28.9)	1.207 (.068)	
GLP	24	400.7 (5.3)	468.8 (15.6)	381.1 (18.1)	1.122 (.042)	
GEM	9	404.1 (6.5)	521.2 (20.1)	416.7 (21.5)	0.978 (.036)	
FLM-G	23	392.1 (3.2)	523.5 (20.6)	480.7 (25.4)	0.949 (.041)	
FEM-Y	8	391.9 (3.2)	499.7 (22.0)	412.3 (27.0)	1.068 (.039)	
Femur subtrochanteric (80%)						
Combined sex						
GEP	14		516.3 (28.2)	559.6 (42.0)		2.166 (.082)
GLP	45		488.8 (11.7)	472.0 (16.2)		1.970 (.049)
GEM	18		550.0 (16.8)	547.3 (31.3)		1.713 (.060)
FLM-G	47		533.2 (11.8)	557.1 (18.1)		1.690 (.042)
FEM-Y	16		496.1 (15.2)	497.9 (20.3)		1.630 (.054)
FEM-T	28		536.4 (14.8)	570.7 (27.0)		1.701 (.047)
Adult males						
GEP	6		566.9 (28.0)	665.8 (65.3)		2.186 (.113)
GLP	21		519.0 (15.8)	502.1 (23.4)		1.863 (.053)
GEM	9		564.7 (26.5)	589.5 (45.7)		1.624 (.073)
FLM-G	24		537.9 (14.7)	570.0 (22.2)		1.623 (.048)
FEM-Y	8		511.0 (22.1)	519.6 (27.4)		1.555 (.084
Adult females						
GEP	8		478.3 (41.0)	480.0 (36.6)		2.151 (.122)
GLP	24		462.4 (15.3)	445.6 (21.4)		2.064 (.075)
GEM	9		535.3 (21.0)	505.0 (40.3)		1.802 (.090)
FLM-G	23		528.4 (19.0)	569.8 (29.5)		1.760 (.068)
FEM-Y	8		481.2 (21.0)	476.1 (29.7)		1.706 (.061)
Humerus mid-distal (35%)						
Combined sex						
GEP	15	299.5 (5.0)	705.3 (40.2)	670.6 (57.3)	1.043 (.044)	
GLP	61	312.3 (2.3)	584.6 (17.6)	487.7 (18.4)	1.056 (.014)	
GEM	19	308.3 (3.5)	617.8 (24.9)	520.0 (42.1)	1.107 (.034)	
FLM-G	48	306.2 (2.1)	615.3 (17.8)	576.6 (25.0)	1.087 (.020)	
FEM-Y	19	304.2 (4.5)	542.0 (24.9)	475.6 (27.7)	1.111 (.028)	
FEM-T	27	307.6 (3.4)	569.3 (16.3)	501.5 (19.7)	1.080 (.027)	
Adult males						
GEP	8	309.2 (6.3)	736.3 (63.2)	769.5 (85.0)	0.957 (.043)	
GLP	31	319.0 (2.4)	630.3 (21.2)	547.3 (23.3)	1.018 (.016)	

(Continued)

Table IX. (Continued)

GEM	11	313.5 (4.0)	655.4 (34.9)	602.8 (57.8)	1.094 (.056)
FLM-G	24	313.6 (2.7)	690.0 (18.5)	686.4 (29.8)	1.075 (.028)
FEM-Y	7	322.6 (6.4)	619.9 (35.5)	578.3 (40.6)	1.060 (.023)
Adult females					
GEP	7	288.3 (6.0)	669.9 (48.6)	557.6 (52.8)	1.141 (.064)
GLP	30	305.4 (3.6)	537.4 (25.8)	426.0 (24.3)	1.096 (.021)
GEM	8	301.0 (5.6)	566.0 (26.8)	406.2 (32.6)	1.125 (.026)
FLM-G	24	298.8 (2.6)	540.6 (21.6)	466.9 (24.9)	1.099 (.028)
FEM-Y	12	293.4 (3.2)	496.5 (26.3)	415.7 (24.0)	1.141 (.040)

Note. Values are mean and SE, with the latter in parentheses. *Femur midshaft properties*: Length$'$: biomechanical length (see Ruff and Larsen, 1990); CA: cortical area (mm^2); J: polar second moment of area (mm^4); CA$_{\text{STD}}$: (CA/Length$'^3$) × 10^8; J_{STD}: (J/Length$'^{5.33}$) × 10^{12}; I_x/I_y: AP/ML second moments of area. *Femur subtrochanteric properties*: CA: cortical area (mm^2); J: polar second moment of area (mm^4); CA$_{\text{STD}}$: (CA/Length$'^3$) × 10^8; J_{STD}: (J/Length$'^{5.33}$) × 10^{12}; I_{max}/I_{mn}: maximum/minimum second moments of area. *Humeral mid-distal properties:* Length$'$: biomechanical length (see Ruff and Larsen, 1990); CA: cortical area (mm^2); J: polar second moment of area (mm^4); CA$_{\text{STD}}$: (CA/Length$'^3$) × 10^8; J_{STD}: (J/Length$'^{5.33}$) × 10^{12}; I_x/I_y: AP/ML second moments of area.

[a] Adapted from Ruff and Larsen (2001).

[b] GEP: Georgia early prehistoric; GLP: Georgia late prehistoric; GEM: Georgia early mission; FLM-G: Florida late mission–Guale; FEM-Y: Florida early mission–Yamasee; FEM-T: Florida early mission–Timucua.

mission Yamasee are similar to the late prehistoric Georgia. The temporal pattern for females is broadly similar to males, except that females show a small decline in J_{STD} from early prehistoric to late prehistoric. The early and late mission females are the most robust for any of the periods. For the humerus, again the early prehistoric Georgia group is the most robust. The late prehistoric Georgia values decrease markedly for both males and females. Then, males show an increase and females show a continued decrease in the early mission Georgia sample; both sexes show an increase in the late mission period. The early mission Yamasee males and females are most similar to the late prehistoric Georgia.

Overall, the findings show a general reduction in sexual dimorphism, reflecting increasingly similar kinds of activities that males and females are engaged in, especially during the mission period.

Mobility

The cross-sectional shape index of I_x/I_y is also highest in the early prehistoric Georgia group for both males and females. For females, the values then decline through the next three periods—late prehistoric Georgia, early mission Georgia, and late mission Georgia. For males, the value of I_x/I_y declines in the late prehistoric Georgia groups, but then increases in the early mission Georgia and decreases in the late mission Florida. The index values for females and males in the early mission Yamasee are most similar to the values for the late prehistoric Georgia group. The levels of sexual dimorphism—difference between males and females—in the I_x/I_y ratio for the femur midshaft for the Guale series shows an interesting pattern of change. Sexual dimorphism is considerably higher in the early and late mission samples (22 and 20%, respectively) than in the early and late prehistoric samples (10 and 3%). The data show that some contact period male were similar to females, but other males had much higher mobility ratios than females. This is consistent with the historical records showing that only some males were recruited for labor projects involving long-distance travel (see also Ruff and Larsen, 1990).

Diet and Activity

The relationship between second moments of area (J_{STD}, I_x/I_y) and stable isotope values of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) is presented in Fig. 8. Regression analysis reveals a statistically significant positive correlation between $\delta^{13}C$ and humeral J_{STD} ($r = .282$, $p = .04$) and a positive (but non-significant) correlation between $\delta^{13}C$ and femoral midshaft J_{STD} ($r = .309$, $p = .07$). These findings suggest an association between greater values of bone strength and maize consumption for the humerus but not the femur. Thus, greater humeral mid-distal torsional strength (J_{STD}) is associated with greater maize consumption. The correlation between $\delta^{13}C$ and femoral midshaft I_x/I_y ratio is negative, although not statistically significant ($r = -.220$, $p = .18$). These findings, then, suggest less mobility associated with greater maize consumption: people who eat more maize have less mobility. It is also possible that it was the labor and grinding or working the maize that created greater bone strength, and not the consumption of it.

Statistical analysis of $\delta^{15}N$ and cross-sectional geometric properties shows statistically significant negative correlation between $\delta^{15}N$ and J_{STD} for both the humeral mid-distal and femoral midshaft sections ($r = -.310$, $p = .02$; $r = -.320$, $p = .05$). That is, less positive $\delta^{15}N$ values are associated with higher values of J_{STD}: those who consume less marine foods have greater bone strength than those who consume more marine foods. The statistical analysis of $\delta^{15}N$ and the I_x/I_y mobility ratio shows a positive, albeit non-significant, correlation ($r = .273$, $p = .09$). The correlation coefficient approaches statistical significance, therefore suggesting that those individuals who consumed more marine foods had a lifestyle that included relatively greater mobility than those who consumed less marine foods.

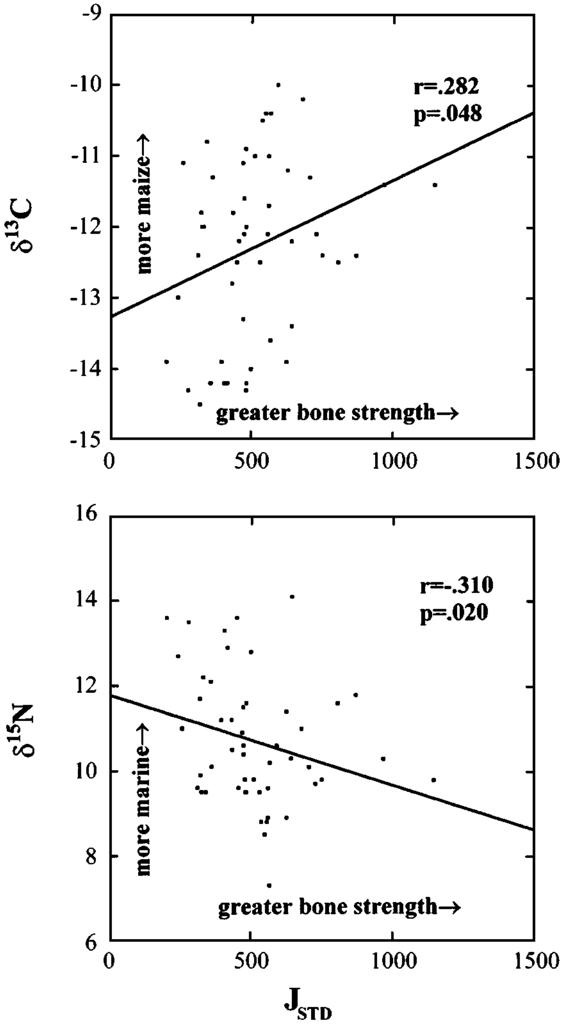

Fig. 8. *Top:* Plot of humerus robusticity (J_{STD}) as a measure of bone strength against $\delta^{13}C$ as a measure of maize consumption. Least squares regression line is drawn through the samples. The positive correlation is significant, indicating that greater bone strength is associated with more maize consumption. *Bottom:* Plot of humerus robusticity (J_{STD}) against $\delta^{15}N$ as a measure of marine food consumption. The negative correlation is significant, indicating that greater bone strength is associated with less marine food consumption.

In summary, the biomechanical analysis reveals several key findings about structural adaptation in prehistoric and contact-era Spanish Florida. First, the study shows a very remarkable plasticity of bone structure reflecting fundamental changes in lifestyle in this setting. Second, early prehistoric foragers from the region were the most robust of any of the groups. Following the adoption of a subsistence mode that involved maize agriculture (along with hunting and gathering), the overall level of physical activity declined. With the establishment of missions and the incorporation of native laborers in a new economic system, there are major changes in behavior indicated by a general increase in robusticity. Both the pathology (osteoarthritis) and cross-sectional evidence reflect these changes. Third, the populations become generally less mobile over the course of the sequence. There is some indication of increased mobility for a time in the mission period males, which may reflect the use of male laborers and their long distance travel in the *repartimiento* system. Overall, the trend reflects an increasingly round midshaft of the femur in the contact era populations. In this respect, the femoral morphology becomes less typically Amerindian and more European (see, for example, Ruff and Hayes, 1983). This we regard as a possible shift to a more "Euroamerican" behavior in this setting. Fourth, at the individual level, those individuals who ate more maize and less marine foods had greater bone humeral strength and less mobility. The idea that people consuming more maize are less mobile is consistent with the notion that agriculturalists tend to be less mobile than foragers (see Ruff, 1987, 2000). Individuals who consume relatively more maize having greater bone strength is less clear. We speculate that individuals who consumed more maize were engaged in agricultural food production and exerted more effort in their lifetime in the *repartimiento* system, thus exhibiting more bone strength.

There is some evidence to suggest that the populations living in the various missions were not affected in the same way by the labor demands placed on them. In this regard, the early mission Yamasee living at Santa Maria on Amelia Island show fewer effects of missionization and are in a number of respects most similar to the late prehistoric agriculturalists in the region, especially in regard to bone strength and mobility. The Yamasee are well within the range of prehistoric agriculturalists (and see other similarities discussed in Ruff and Larsen, 2001). Other evidence indicates that the Yamasee were less affected by contact with Spaniards and missionization than were other populations, especially the Guale. In particular, mean values of the δ^{13}C and δ^{15}N values for the Yamasee are significantly (t test; $p \leq .05$) different from the contemporary Santa Catalina population from St. Catherines Island. That is, the Yamasee values are much more similar to the late prehistoric Indians who were less committed to maize agriculture. Therefore, there is a concordance of isotope and biomechanical evidence that argues for a less "enculturated" lifeway in the Yamasee population than in their contemporaries in the Spanish colony.

SPANISH FLORIDA IN COMPARATIVE PERSPECTIVE

Analysis of various indicators of health and lifestyle in skeletal remains reveals profound changes in native populations of Spanish Florida, both before and after European contact. How are these changes in comparison with other native populations living outside of the sphere of Spanish control? We would predict different patterns of change in other regions of the Americas, especially because the contact experience in other settings involved very different relationships between Europeans and Indians. In Spanish Florida and other regions controlled by Spain (southern North America, Central America, and most of South America) native populations were closely monitored and controlled by religious and governmental authorities. In these settings, religious and political institutions exerted a strong influence on the day-to-day living practices of native peoples. In contrast, European powers (e.g., Great Britain and France) controlling other areas of the Americas emphasized entrepreneurial-oriented trade relations in their interactions with native populations. In these settings, the lives of native peoples were not under the same kinds of direct control as in the areas dominated by Spain. The health and lifestyle of native peoples were altered in the regions controlled by Britain and France, but the impact on health—and probably more important, lifestyle—were altered in different ways.

There are relatively few large skeletal series dating to the contact era elsewhere in North America (or other regions of the Western Hemisphere) that have been systematically investigated by bioarchaeologists. The following discussion is based on bioarchaeological research in settings in the American Southeast (Hill, 1996; Lambert, 2000, in press; Reeves, 2000), Texas (Miller, 1996), the southwestern Pueblos (Stodder, 1994, 1996; Stodder and Martin, 1992), Alta California (Walker, 2001; Walker *et al.*, 1989; Walker and Johnson, 1994), Maya (Cohen *et al.*, 1994; Jacobi, 2000; White *et al.*, 1994; Wright, 1990), central Great Plains (Johansson and Owsley, in press; Miller, 1995; Reinhard *et al.*, 1994; various authors in Owsley and Jantz, 1994;), northeastern North America (Baker, 1994; Gagnon, 1999; Miller *et al.*, 1999a; Pfeiffer and Fairgrieve, 1994), Ecuador (Ubelaker, 1992, 1994; Ubelaker and Newson, in press), and Polynesia (Owsley *et al.*, 1994; Pietrusewsky and Douglas, 1994).

Many of the skeletal series show some evidence of increased physiological stress in the precontact to contact transition. In this regard, contact era populations generally show elevated frequencies of enamel defects (hypoplasias, pathological Retzius lines), but with some interesting exceptions. For example, in the American Northeast and Southeast, several regional studies show no increases in hypolasias (Lambert, in press; Miller *et al.*, 1999a; Pfeiffer and Fairgrieve, 1994). The few studies where pathological Retzius lines have been studied also show variation. Like Spanish Florida, dentitions from the Maya site of Lamanai (Wright, 1990) display an increase in pathological lines in comparison with earlier populations, which contrasts with the pattern observed in the Maya site of Tipu (Cohen *et al.*, 1994). These differences appear to be related to the degree of intensity of contact between Indians and Spaniards. In Spanish Florida and Lamanai, the missions involved intensive and direct contact with Europeans. However, the Tipu site experienced more peripheral contact with Europeans, and hence, less exposure to circumstances that result in acute stress.

Other biological evidence of stress—dental caries, cribra orbitalia and porotic hyperostosis, and periosteal reactions—shows an overall pattern of change reflecting a decline in health during the contact period. There are some interesting exceptions to the pattern, however. At the Creek site of Fusihatchee in Alabama, Reeves (2000) has documented a high frequency of carious lesions (15.7% of teeth), reflecting a focus on maize in diet. However, this is statistically indistinguishable from the late prehistoric Moundville sample (18.7%; Reeves, 2000). In the Coweeta Creek sample from western North Carolina, frequencies of carious lesions are also quite high before and after contact, and even decline somewhat in the later period (Lambert, in press). These findings point to the high consumption of maize in these settings. The differences between these southeastern United States settings and Spanish Florida reflect the fact that the nature of contact between Europeans and Indians in the American Southeast was quite different than in Spanish Florida. Contact between Indians and non-Indians in Alabama and North Carolina was mainly through trade exchanges. Similarly, no change in caries rates has been documented in the Mid-Atlantic region (Miller *et al.*, 1999a).

Caries rates were quite low in the contact period in the American Great Plains, reflecting relatively high access to meat and low consumption of carbohydrates in equestrian populations (Johansson and Owsley, in press) and perhaps improved health generally in the contact era (Miller, 1995). Caries rates increased in New England, which may have been because of native populations gaining access to refined sugar or flour (Baker, 1994). In a similar fashion, caries rates increase dramatically in late contact era Ecuador, which is related to the widespread availability of sugar (Ubelaker, 1994).

A number of regions show increases in cribra orbitalia and porotic hyperostosis in the precontact to contact transition. Like native populations from Spanish Florida, native populations in west-central Alabama display an increase in frequency and severity of these lesions in the contact period, which suggests a decline in iron status. In contrast, there was a decline in frequency of these lesions in the contact period in southern Ontario (Pfeiffer and Fairgrieve, 1994), no change in frequency in the mid-Atlantic (Miller *et al.*, 1999a) or Polynesia (Pietrusewsky and Douglas, 1994), and maintenance of high levels in the American Southwest (Stodder, 1994) and Southeast (Lambert, 2000, in press). Thus, although there is a tendency for an increase in cribra orbitalia and porotic hyperostosis, the trends in specific regions show variation that are clearly tied to local factors relating to diet and living circumstances.

Frequencies of nonspecific periosteal reactions show a general increase, but with some important exceptions. For example, the Maya site of Tipu shows quite low frequency of tibial periosteal reaction (8%; Cohen *et al.*, 1994; Jacobi, 2000) and no change (or no clear pattern of change) occurs in comparing precontact and contact samples in the North American Northeast (Miller *et al.*, 1999a; Pfeiffer and Fairgrieve, 1994). Moderate levels of periosteal reactions have been documented for the historic era King site in Georgia (Williamson, 1998; see Detweiller-Blakely, 1988). Detweiller-Blakely (1988) argues that the lesions are associated with traumatic injuries deriving from a battle with de Soto's forces in his entrada through the American Southeast in the sixteenth century. However, reexamination of these lesions and evidence for trauma indicates that the traumatic injuries are rare and that the lesions are likely infectious in origin and not due to sword-wielding Spaniards (Milner *et al.*, 2000; Williamson, 1998).

Specific infectious diseases—especially tuberculosis and treponematosis—are widely reported in the bioarchaeological literature, but are primarily restricted to late prehistoric or contact era settings. In Spanish Florida, the most convincing cases of these diseases are found in late prehistoric contexts (Hutchinson *et al.*, in preparation; Powell, 1990, 2000). It is clear from these studies that tuberculosis and treponematosis are present centuries before the arrival of Europeans, and at least some settings show no change in frequency in the contact era (e.g., Hutchinson *et al.*, in preparation; Miller *et al.*, 1999a; Pfeiffer and Fairgrieve, 1994).

The bioarchaeological record for activity (osteoarthritis, long bone diaphyseal structure) points to significant variation in lifestyle. Several regional studies have directly addressed the issue of consequence for lifestyle and activity in response to the arrival of Europeans indicating that at least in these settings behavior altered in appreciable ways. In the Central Plains, there is an increase in osteoarthritis severity, which suggests an increase in physical activity during the trade era (Reinhard *et al.*, 1994). A major change in lifestyle for Plains Indians during the contact era involved the introduction of the horse (e.g., the Arikara in the early eighteenth century). Analysis of the shape of the acetabulum (articulation for the femoral head and innominate) shows a distinctive shape change involving an expansion of the anterior–superior borders, which likely reflects modifications arising from habitual horseback-riding (Erickson *et al.*, 2000; cf. Reinhard *et al.*, 1994). In addition, a pattern of spinal osteoarthritis involving the lower back is suggestive of the shift to horseback riding. In contrast to a number of settings, the other skeletal indicators of health show improvements in the Great Plains, which is likely because of increased access to animal protein and decline in the use of maize in diet during the historic era (Johansson and Owsley, in press). In Polynesia (Hawai'i), there is also a tendency for increase in osteoarthritis, particularly in the shoulder. Thus, like Spanish Florida, there were clear behavioral changes, at least as it is revealed in osteoarthritis.

Only one other study of pre- and postcontact era cross-sectional geometry has been undertaken outside of Spanish Florida. In Michigan, Barondess (1998) addressed the issue of the impact on lifestyle of Native Americans in response to the fur trade during the seventeenth and eighteenth centuries. Like the populations in Spanish Florida, native groups had a mixed economy which included a dietary regime of maize (and other domesticates) and protein derived from hunting and fishing. In general, the biomechanical properties showed a similar pattern of increase in contact era Michigan, especially in the humerus. This pattern is similar overall to Spanish Florida, except that female humeri show continuous decline in bone strength in the contact period, unlike female humeri in Michigan, which show an increase in bone strength. Barondess (1998) speculates that the increase in bone strength in Michigan is related to the increased investment in physically demanding activities that would result in more materials for trade with the French to purchase highly desirable items, such as Western-style clothing, cooking and eating utensils, and other goods. In particular, it may have been the case that both men and women increased activities associated with food production for trade exchange with Europeans—hunting and fishing by males, and agricultural production by females. Native-produced foods were traded to supply the French at such posts as Mackinac and Detroit (see discussion in Barondess, 1998, pp. 109–110).

The temporal patterns of variation in cross-sectional geometric properties have been discussed from a range of North American native populations (Ruff, 1999, 2000). Ruff's analysis of various samples indicate a general decline in bone strength (J) and sexual dimorphism (especially in the I_x/I_y or mobility ratio) as population shifted from foraging to farming prior to the arrival of Europeans, which is also revealed in the Spanish Florida samples. However, at least with respect to the mission era Guale, bone strength and the mobility index reverse, looking more like prehistoric hunter–gatherers in some respects. In this setting, this reversal is due to lifestyle changes that occurred as a result of exploitation of native groups.

Some interesting dental and cranial changes have been documented by Lambert (in press) in her study of the pre- and postcontact samples from western North Carolina. Nearly half of the individuals in the Coweeta Creek series display an unusual lingual wear pattern on the incisors reflecting their use in some extramasticatory function. The frequency of lingual wear is more than double the frequency of the prehistoric populations. Lambert (in press) argues that the increase reflects the use of the front teeth for processing animal hides for trade with the British, although some unknown dietary change or other practice involving the use of the teeth may have been operating.

In summary, a variety of regional studies that have employed bioarchaeological research have documented health and lifestyle changes in native populations. There are some common trends, with nearly all populations showing some amount of change and many of these in a negative sense. Our reading of the bioarchaeological record indicates that Spanish Florida native groups experienced some of the most dramatic alterations in health and lifestyle in the New World, which we believe are related to the dramatic alterations in food, nutrition, and lifestyle in the mission settings. In contrast, regions that were involved in primarily trade relationships show some (or no) change in health or lifestyle, reflecting the indirect nature of contact experience. Importantly, the variation observed across the Western Hemisphere underscores the important point that health and lifestyle are very much tied to local circumstances that are both unique to specific settings and were established well before European contact. In this regard, the adoption of agriculture based at least in part on maize had negative effects on health long before Columbus and later Europeans colonized the Americas. Perhaps it was this change in subsistence and quality of life that predisposed some groups to more rapid decline at the time of contact than other groups.

CONCLUSIONS

Historians have long observed dramatic changes in health and quality of life in native populations in the Americas that came into contact with Europeans (see Cook, 1998). However, the historical viewpoint is largely based on written sources, which provide accounts of death, dying, and population collapse owing mostly to the introduction of European infectious diseases. The historical scholarship rarely deals with other fundamental aspects of the human condition, especially health and lifestyle. With the study of skeletal remains, new method and theory in bioarchaeology, and the new interest in the study of the biological consequences of contact, there is now a much more complete picture of health and adaptation in a number of New World settings. The study of Spanish Florida reveals a number of important trends in health and lifestyle that help to expand the myopic focus on demographic collapse to a broader perspective on the history of the human condition. These changes include a general deterioration in health that began before European contact and missionization, but that were exacerbated by changes in diet, settlement, work practices, and other consequences of exploitation and colonization of the region by Spain.

In addition to these specific trends, several general findings emerge from the study of Spanish Florida and other settings. First, there is no dichotomy that emerges in comparison of health and lifestyle of pre- and postcontact populations, for any region in particular or La Florida in general. There were widespread changes in health in some settings but not in others, at least as it can be determined from skeletal remains. On the other hand, it is important to reemphasize the fact that precontact era populations were not free from debilitating circumstances that cause disease. The bioarchaeological record clearly shows the presence of disease and demanding workloads before Europeans arrived.

Second, the bioarchaeological investigations show a high degree of variability in the contact experience. Unlike the precontact period where there is a general uniformity of decline in health with the adoption of agriculture and sedentism, the picture is much more mixed in terms of patterns of health change in the contact period (and see Steckel and Rose, in press). In general, these changes are predictable in light of specific living circumstances for particular regions, including Spanish Florida. Thus, while there may be problems of interpreting health indicators from skeletal remains, or what has been called the "osteological paradox" (see Wood *et al.*, 1992), the pattern of biocultural change seen in the areas that are especially well studied suggests that the patterns observed are real and not a product of bias in the skeletal record.

Third, used in conjunction with other data—especially archaeological, ethnographical, and historical—the study of human remains offers a documentary record from which it is possible to interpret the details of human biocultural adaptation. This interdisciplinary approach has been quite productive for the study of the contact period (and see Gannon, 1992).

Finally, the decline of native populations was not permanent. With a decline in mortality and increasing fertility and life expectancy at birth during the twentieth century, there has been a dramatic rebound in population size of native peoples in North America (Thornton, 2000). Thus, despite the disastrous losses prior to 1900, the resurgence of native peoples in the present day is reforming the Native American population, reconstituting their contribution to the varied social, political, and human biological landscapes of the Americas.

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