Chapter 17

Diet, Dental Health, and Cultural Change among Recently Contacted South American Indian Hunter-Horticulturalists

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ABSTRACT

Dental health data were collected on 227 South American Indians from three groups that, until recently, have had little contact with the outside world: the Yanomamo of Venezuela, the Yora of southeastern Peru, and the Shiwiar of Ecuador. There are many similarities in the diets of these Native Americans. Most of their carbohydrates come from the manioc, bananas, and other crops grown in their gardens. Hunting and fishing are important sources of protein.

In spite of these broad dietary similarities, the dental health of these groups differs in some significant respects. The Yanomamo have lower caries rates and higher anterior tooth wear rates than the Yora and Shiwiar. The anterior teeth of the Yora have more carious lesions than do those of the other groups. Molar wear rates are higher among the Shiwiar than they are among the Yanomamo and Yora. High caries rates in the permanent teeth of Yanomamo and Shiwiar children suggest that dental health is declining in these groups owing to the effects of western contact.

These contrasts in dental health can be attributed to differences in consumption of cariogenic foods such as sugarcane, food preparation techniques, use of the teeth as tools, and access to exotic foods through trade and contact with outsiders.

Key Words: diet, caries, tooth wear, hypoplasia.

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INTRODUCTION

Opportunities to document the oral health of people who have had little contact with Western culture are rapidly diminishing. Such research is important because it serves as a basis for both understanding and mitigating the health problems suffered by people undergoing such transitions. Studies of previously isolated non-Western societies are also a valuable source of ethnographic analogies that anthropologists can use to understand similar cultural transitions experienced by people in archaeologically documented societies. For example, increases in the caries rates of prehistoric populations are often interpreted as indicating a shift from hunting and gathering to greater dependence on cariogenic cultigens (Turner, 1979). The data we present on South American Indian hunter-horticulturalists shows that inferring diet from dental health in this way is far from straightforward. Our ethnographic data suggest that small differences in patterns of food consumption and processing can produce large differences in the oral health of people with broadly similar diets.

Populations Surveyed. Dental health data were collected on 227 South American Indians from three groups that, until recently, have had little contact with the outside world: the Yanomamo of Venezuela, the Yora of southeastern Peru, and the Shiwiar of Ecuador (Figure 1, Table 1). All three groups rely on horticulture for most of their carbohydrates, and, to varying degrees, on hunting, fishing, and foraging for their protein.

The Yora (or Shara Yaminahua) are a group of Panoan-speaking people who live in the Amazonian lowlands of southeastern Peru. The Yora remained isolated until their first peaceful contacts with outsiders in 1984. Before this, they effectively kept their territory free of colonists by raiding the camps of the oil-workers and woodcutters who penetrated into the upper reaches of the Mishagua and Manu rivers. Yora currently live in three locations. One village of 37 inhabitants (as of 1986) is located near the headwaters of the Manu River where it meets the Cashpajali River (Hill and Kaplan, 1989). The second village, Putaya, is at the confluence of the Putaya and

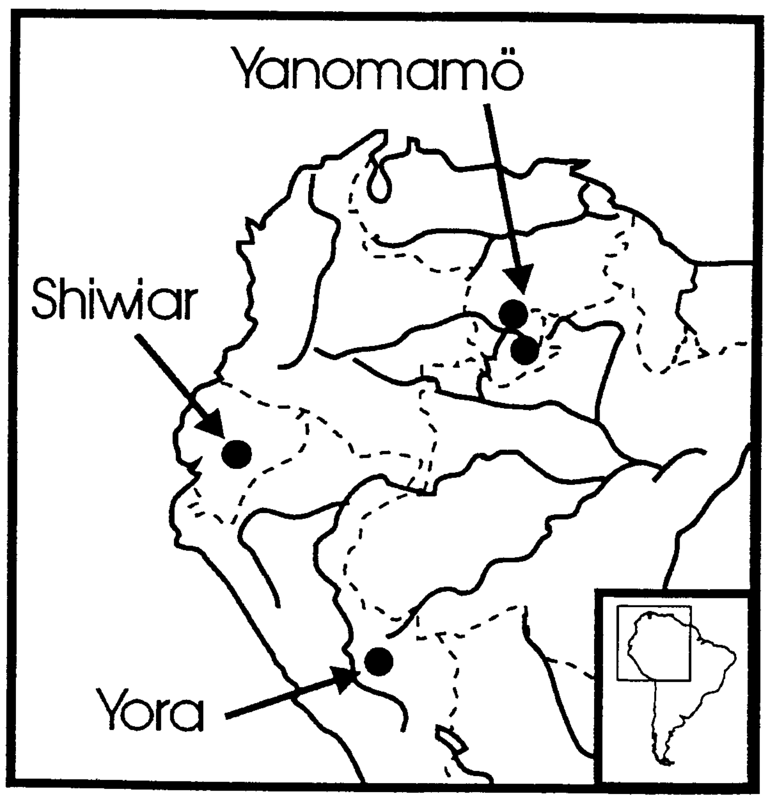

Figure 1. Map showing location of study groups.

Table 1: Demographic data on groups surveyed.

Group	Sex	Age in years 6-15	16-29	30+	Total
Yanomamo	Male	2	16	17	35
	%	5.71	45.71	48.57	100.00
	Female	2	14	8	24
	%	8.33	58.33	33.33	100.00
	Both	4	30	25	59
	%	6.78	50.85	42.37	100.00
Yora	Male	2	8	7	17
	%	11.76	47.06	41.18	100.00
	Female	4	9	7	20
	%	20.00	45.00	35.00	100.00
	Both	6	17	14	37
	%	16.22	45.95	37.84	100.00
Shiwiar	Male	3	4	4	11
	%	27.27	36.36	36.36	100.00
	Female	1	10	4	15
	%	6.67	66.67	26.67	100.00
	Both	4	14	8	26
	%	15.38	53.85	30.77	100.00
Conambo	Male	34	10	10	54
	%	62.96	18.52	18.52	100 00
	Female	37	8	6	51
	%	72.55	15.69	11.76	100.00
	Both	71	18	16	105
	%	67.62	17.14	15.24	100.00

Mishagua rivers. In 1990, there were 66 full-time residents of Putaya. A third small group of Yora live in Sepahua, a frontier town at the confluence of the Urubamba and Sepahua rivers. The Yora dental data presented in this paper were collected by Sugiyama at the village of Putaya between July and August of 1990.

The Shiwiar are Jivaroan people who live in the southern oriente (eastern tropical forest) of Ecuador along the Corrientes River and its tributaries. Although outsiders often refer to them as Achuar, they speak a distinct dialect and Shiwiar is the word they use to refer to themselves. Some aspects of Shiwiar culture, for instance making ceramic bowls for drinking chicha, have been adopted from the neighboring Quichua. Our Shiwiar dental data were collected by Chacon in the community of Alto Corrientes between June and August of 1993. Additional dental data were gathered by Sugiyama at the village of Conambo between February and May, 1993. Conambo is an ethnically mixed community inhabited by Shiwiar and Saparo Indians. Although the Saparo were once identifiable as a distinct ethnic group by their language, there is only one fluent Saparo speaker left. The Saparo now speak Quichua and would be indistinguishable from other lowland Quichua groups by outsiders.

The Yanomamo number some 20,000 individuals living in villages scattered throughout southern Venezuela and northern Brazil. Many Yanomamo continue to have almost no direct contact with outsiders while others have been interacting with missionaries for as long as 30 years. Our Yanomamo dental data were collected by Sugiyama and Chacon in the summer of 1991 in Venezuela. Data were gathered along the Ocamo River from residents of Shashanawa -teri, Widokaiya-teri (Lechoza), and much farther upriver, from people living at the villages of Siboa-teri, Yabroba-teri, and Ugushiteri. Observations were also made in Dorita-teri on the Dorita branch of the Shanishani River and in Boreyaromoba-teri.

METHODS

Subjects or their guardians were asked to participate in a study of dental health. If they agreed, we asked them to wash out their mouths with water to remove any debris adhering to their teeth. The dental examination was made using a dental mirror and a penlight was used for illumination. The condition of each tooth was recorded on specially designed forms. The presence of deciduous teeth was noted and any unerupted or missing teeth were marked on the standardized chart. If they had missing teeth, the person was asked how the tooth was lost. Usually, the response was that the tooth fell out or that a visiting dentist extracted it. The size and location of carious lesions was recorded by marking the area of the lesion on the form.

Tooth wear was recorded in two ways. For the incisors and canines, the amount of crown height reduction was estimated by drawing a line across diagrams of unworn teeth on the recording form. Molar wear was recorded by scoring each quadrant of the tooth using the Scott (1979) system. Finally areas of linear enamel hypoplasia on the incisors and canines were recorded by drawing the lesion on diagrams of the anterior dentition.

ETHNOGRAPHIC DATA ON DIET

There are many similarities in the diets of the Yanomamo, Yora, and Shiwiar. All of these groups obtain their food through hunting, gathering, and slash-and-burn agriculture. However, a detailed examination reveals age, sex, and intergroup differences that have significant oral health implications. Since these differences in food production, preparation, and consumption patterns appear to explain much of the variation we documented in our dental surveys, we will discuss the ethnographic data we have collected on each of these groups in some detail.

Yora. The Yora practice slash-and-burn horticulture typical of many Amazonian Indians, including the Shiwiar and Yanomamo. Initial reports suggested that, until recently, the Yora relied almost entirely on hunting and gathering for a livelihood (Hill and Kaplan, 1990). Now, however, horticultural products are a major part of their diet (Sugiyama and Chacon, 1993). Edible garden products include manioc, plantains, corn, sweet potatoes, jicama, sugarcane, taro, papayas, and lemons. Our Yora consultants report that all these, except for papayas and lemons, were dietary staples before contact. They also told us that they have helped with gardening tasks since childhood. Yora elders pointed out several old garden sites (now indistinguishable from surrounding forest) upstream and downstream from their current village at Putaya.

To obtain quantitative data on Yora food consumption patterns and subsistence activities, we recorded the frequency of different activities using a scan sampling technique (Table 2). The time allocation and food consumption data presented here are based on 100 instantaneous scan samples of activities at the village of Putaya between June and August 1990. We ran from two to six scans on each of 29 days. During the study period the population of Putaya varied between 56 and 71 people living in 12 households. These scans yielded 6448 behavioral observations. Additional data were collected on the time spent foraging. When people were seen leaving on a foraging trip, they were asked what they were planning to do and the time and tools taken were recorded. When they returned, we noted the time spent on the trip and weighed the game killed.

Protein in the Yora diet comes mostly from hunting and fishing. At Putaya, 14% of their subsistence activities were devoted to hunting. Before contact, men hunted with bow and arrows, either by stalking their prey or using hunting blinds. Since the first peaceful contacts between the Yora and outsiders in 1984, hunting dogs have been introduced and are highly prized as hunting aids. Typically, a man will leave in the morning on a hunting trip accompanied by his dogs and one or two other men or older boys. Occasionally a woman or girl will also go along. As the hunters walk, they look and listen for signs of game and the dogs search for scent. When a dog picks up a scent, or flushes an animal, the chase is on. The dogs run after their quarry barking, and the men race cross-country after the dogs. Peccaries are often cornered in small caves, as are coati, paca, agouti, and even jaguar. If the animal is cornered in a cave or burrow, the hunters quickly close up the entrance by cutting poles,

Table 2: Data on the frequency foods were consumed by Yora living the village of Putaya collected through scan sampling.

	Males		Females		Total	
Food Types	n	%	n	%	n	%
Plant Foods						
Manioc	99	24.5	71	18.5	170	21.6
Plantains	45	11.1	31	8.1	76	9.7
Sugarcane	37	9.2	41	10.7	78	9.9
Wild plants	3	0.7	2	0.5	5	0.6
Potatoes	4	1.0	9	2.3	13	1.7
Yams	12	3.0	9	2.3	21	2.7
Tubers (yosho)	18	4.5	19	5.0	37	4.7
Corn	11	2.7	16	4.2	27	3.4
Animal Foods						
Wild Game	59	14.6	71	18.5	130	16.5
Fish	88	21.8	90	23.5	178	22.6
Chicken/Eggs	28	6.9	24	6.3	52	6.6

sticking them into the ground in front of the entrance, and then lashing them together with vines. The hunter then digs a small hole in the roof of the cave through which he either shoots the animal with an arrow or stabs it with his unstrung bow. Once the animal is dead the hunters dig it out. Peccaries are carried to nearby water to be butchered or, if no stream is near, butchered on the spot. Smaller game, such as coati, paca, and anteaters are carried back to the village whole and processed there. Besides the terrestrial animals hunted with dogs, Yora hunters also take a variety of arboreal game, such as monkeys, birds, and squirrels, when the opportunity arises. They also collect wild fungi, hayahuasca, and wild fruits while hunting.

Game animals accounted for 23% of our food consumption observations. During the study period, 218.5 kilograms of game were taken in 160.3 hours of hunting; a yield of 1.5 kilograms per hour. The primary game animal in the Yora diet, both in absolute weight taken and in percentage of consumption observations (10.94%), was peccary. Second in importance in number taken were paca (2.4% of consumption observations). Other game animals in order of importance were capybara, coatimundi, agouti, various monkeys, tamandua, acouchy, birds, squirrels, and lizards. In addition, one short-eared dog, and one jaguar were killed during the study period. These rare animals were eaten only by a few villagers and most people considered them inedible.

Fish accounted for 22.8% of observed consumption. A host of fish species were taken with bow and arrow, cast net, or hook and line. During the study period, 137.3 kilograms of fish were taken in 324.5 hours of fishing; a yield of 0.42 kilograms per hour of fishing. This underestimates the fishing returns for this period because we were unable to weigh some of the fish caught by boys, girls, and women in the river around the village. We were also unable to weigh fish caught and consumed on some overnight fishing trips. Among the commonly caught fish were catfish (zungaro), carachama, sabado, and fresh water stingray. Although these are the most abundant fish during the dry season, many other smaller species are also taken.

We did not see any insects eaten, and the Yora were repulsed by suggestions that giant earth worms are edible. The Yora do eat small quantities of turtle and lizard eggs. Honey was not eaten during the study period. We were told that it was not the honey season and that honey was consumed at other times of the year along with seasonally available wild fruits and nuts. Our Yora consultants also said that palm heart was a much more important food before the recent introduction of steel tools for gardening. Papayas, chickens, and lemons are recently introduced foods and were not eaten before contact. Salt is the only food traded in from the outside.

Cultigens accounted for 45% of the food we observed Yora eating. Their main garden staple is sweet manioc and both boiled manioc and manioc beer are part of almost every meal. In 22% of our food consumption observations, people were eating manioc or drinking manioc beer. Plantains are also an important food and accounted for 10% of the foods consumed. In the Yora village of Cashpajali, feral plantains were the dietary staple (Hill and Kaplan, 1989), but this may be the result of disturbances due to recent contact (Sugiyama and Chacon, 1993). Except for 40 kg. of feral plantains taken from an abandoned garden, all the plantains eaten at Putaya were harvested from cultivated plants. Yora were also observed eating jicama, maize, and sweet potatoes. Maize is either eaten on the cob after roasting in the fire or ground into cornmeal in a wooden mortar. This cornmeal is then mixed with water to make chicha. Wild tubers, nuts, and fruits gathered from the forest constitute only a small fraction of the diet.

Sugarcane is frequently eaten and accounted for 10% of the consumption acts recorded. It is of special interest from the perspective of oral health because of its potential cariogenicity (Harris and Cleaton-Jones, 1978). Women and children cut stalks of sugarcane while working in the gardens. They invariably eat some stalks there, but the rest are brought home and gnawed on while the women go about their household chores. Sugarcane is tough and fibrous and is eaten by crushing it with the teeth and sucking it until its juice is gone. It takes a long time to eat a stalk or two. When one person at a house is eating sugarcane, most of the others are, too. For these reasons we were more likely to see someone eating sugarcane than, for example, drinking a bowl of manioc beer, which takes less than a minute. The nutritional importance of sugarcane, therefore, is overestimated in our scan survey data. However, our data do point out the large amount of time that Yora, especially women and children, spend eating sugarcane. This is significant because of the relationship between dental caries and the length of time that cariogenic foods are in the mouth (Gustafsson et al., 1954).

The principal Yora cooking method is boiling, followed by roasting, steaming, and smoking. They currently have access to aluminum pots but also continue to use traditional earthen cookware. Yams and taro are boiled and eaten as is. Manioc is boiled, roasted on the fire, or used to produce manioc beer. This is made by stripping the outer skin of the manioc tuber, boiling it, chewing the boiled manioc into a pulp, and spitting the bolus of pulp into a pot. Some water is added to the mash and the brew is either left to ferment a day or two or consumed immediately. Only women make manioc beer.

Although parts of medium and large game animals are sometimes roasted directly over a fire, their meat is usually boiled and eaten along with the broth and some manioc. Birds are also usually boiled. Small birds, rodents, and other small animals caught by children are roasted. Small fish are often boiled with plantains and mashed to create a fish soup. Large fish, such as Pacu, are boiled. Medium-sized fish are usually wrapped in leaves and steamed over the fire.

Meat from a kill is distributed throughout most of the village and stores of surplus meat are a rarity. Most of an animal will be consumed within a day of the kill. However, when there is a surplus, or an animal is killed that few in the village will eat, the meat is smoked to preserve it. Surplus fish are also smoked.

Shiwiar. The Shiwiar differ from the Yora in that they place greater emphasis on gardening. A Shiwiar household usually has one garden that is producing heavily, one garden that is being cleared or is still quite young, and another that is being reclaimed by the forest but is still producing sugarcane, papayas, bananas, chonta, and other long-lived or feral fruits. While this is the typical gardening pattern, the number of gardens per household observed in the study area ranged from one to five. Palm hearts and wild fruits are sometimes gathered from the forest, but the vast majority of Shiwiar carbohydrates come from garden sources. These cultigens may provide up to 65% of the calories in the diets of Jivaroan peoples (Harner, 1972). Although the number of cultigens grown in an area varies with local soil conditions, over sixty species can be found in some Shiwiar gardens (Descola, 1989).

Most Shiwiar carbohydrates come from a few staple crops. As with the Yora, sweet manioc is the most important of these. Sweet potatoes and taro are also grown, and are second to manioc in importance. In some areas it is reported that Shiwiar raise peanuts, but they were not grown in the villages we visited. Plantains and maize are the most important non-tuberous crops. Other common edible garden products are green onions, sugarcane, papaya, guajjava, naranjilla, chilies, cacao, pineapple, chonta, guavas, and squashes.

Shiwiar cultivate a larger variety of foodstuffs than the Yora and their diet is, therefore, more varied. Also, while Yora cooking is very simple, the Shiwiar use spices like green onions and hot chiles to add to the basic flavors of meat, fish, and manioc. As with the Yora, large quantities of manioc beer are consumed. This beer is a basic part of their diet and two to four gallons may be consumed daily (Harner, 1972). From our observations it is clear that Shiwiar consume more manioc beer than the Yora. Producing beer is a major activity of the women, and many leisure hours are spent sitting and talking while drinking it.

Hunting and fishing provide the bulk of Shiwiar dietary protein. Blowguns or muzzle-loading shotguns are used in hunting. Although Shiwiar men use dogs to chase down animals such as peccary, agouti, and paca, they hunt without dogs much more than the Yora. This may be related to the greater efficiency of their shotguns and blowguns in comparison to the bows and arrows used by the Yora (Hames, 1979, Yost and Kelley, 1983).

Fishing is done with hooks and line and fish poisons. Throughout the rainy season the bulk of the protein comes from hunting. During the transition to the dry season emphasis on fishing gradually increases as the larger rivers become shallow and suitable for damming and the use of fish poisons. These dry season fish poisonings are often village-wide events and can produce a large surplus of fish. After a successful fish poisoning or after a week-long hunting trip in anticipation of a party, the surplus is preserved by smoking over an open fire. If it is re-smoked each day, this meat can be kept for several weeks.

In addition to game and fish, Shiwiar eat a variety of small animals such as grubs, ants, crabs, frogs, and snails. Some of these delicacies are seasonally abundant. In February, at the beginning of the rainy season, millions of frogs descend from the trees to breed and the entire village spends time capturing them. Edible ants are harvested in August.

Shiwiar settlements are now clustered near airstrips cleared in the forest. As a result, the Shiwiar now have access to missionary emergency medical flights and nontraditional foods. Although these imported foods are a small part of the diet, they may be affecting Shiwiar dental health. When someone flies out of the jungle, they usually send food back to their families on an incoming flight. The most common items received in this way are bread, hard candy, cooking oil, sugar, and salt. These flights of small single engine aircraft are not at all regular or frequent. It is common for several months to pass without a flight coming in and sometimes 4 months or more pass without a plane landing at a village. Perhaps more important in terms of its effects on dental health is a missionary food aid program. Although missionaries are not resident in the villages, they provide school-aged children in some villages with rice, flour, oil, salt, and sugar as a kind of school lunch program. This program has existed from four to ten years in the villages that participated on our dental survey.

Traditional Shiwiar dental hygiene was accomplished by using a twig as a toothbrush and rinsing one's mouth with water after each meal. Another traditional form of dental care is to rub pitch from a tree (probably *Calatola costaricensis* or *Neea* sp.) on the teeth (Lewis and Elvin-Lewis, 1984:53). This turns the teeth black and is said to harden the outside of the teeth and to protect them from caries. The pitch wears off after about three months but the protection is said to have lasted for several years. Another traditional practice was to treat aching teeth by putting sap of plants on them. This relieved the pain and caused the tooth to disintegrate so that the pieces could be extracted by hand after about a week. This tooth extraction technique was evidently practiced mainly by women of childbearing age (Lewis and Elvin-Lewis, 1984:55).

Like the Yora, the Shiwiar use a variety of cooking techniques including roasting, boiling, smoking, and steaming. Garden products such as manioc, yams, maize, taro, and plantains are prepared much as they are among the Yora. Sugarcane is eaten, although not as much as by the Yora. Perhaps this is because the Shiwiar have access to a greater diversity of fruits than the Yora and they satisfy their sweet-tooth with guayaba, pineapple, breadfruit, and the like. There is also a difference between the Yora and Shiwiar in the way sugarcane is prepared. Yora peel a whole stalk and then gnaw and suck on it from the end, ripping off sections at the cane joints after having sucked the cane dry in that section. This entails much chewing and crushing of the cane using the anterior dentition. The Shiwiar, in contrast, often peel a cane and then partially chop through it with a machete at 4-5 cm intervals so that the pieces remain attached to each other but are easily removed in bitesized chunks. Because of this, Shiwiar use their anterior teeth much less than the Yora when they eat sugarcane.

Although Yora and Shiwiar take a similar variety of game species, meat is not shared as widely among the Shiwiar as it is among the Yora. Yora consume a peccary within a day or two by sharing it throughout the village. A Shiwiar hunter, in contrast, shares with fewer families and, as a result, there is more surplus meat to be smoked for storage. Smoking meat repeatedly to preserve it results in a very tough, jerky-like product. People sometimes tear off pieces of this dried meat as a snack. For meals, however, pieces of dried meat and fish are usually boiled to soften them. These are then eaten with the broth and some manioc or taro. Medium-sized game such as paca, agouti, toucan, macaw, and curasou are usually boiled and served in a soup unless the game is killed in anticipation of a party or is killed on a hunting trip away from the village. In these situations medium-sized game animals are also smoked to preserve them. Small game such as squirrel and small birds are roasted directly over the fire. Much of the fish eaten by the Shiwiar is smoked and then eaten or put in soup. Fish are also steamed by wrapping them in leaves and placing them in a fire.

Yanomamo. Yanomamo practice pioneering swidden horticulture and, like the Yora and Shiwiar, the bulk of their carbohydrates come from their gardens. They contrast with the Yora and Shiwiar by using plantains and bananas as a staple instead of sweet manioc. These plants can account for 70% of the total Yanomamo caloric intake. Up to 90% of their calories come from cultigens (Chagnon, 1992). Additional garden products in order of dietary importance include ocumo (*Xanthosoma*), yams, sweet potatoes, and sweet manioc (Smole, 1976). Various fruits are also grown including peach palm and papaya. Maize, peppers, sugarcane, and avocados are only rarely encountered in Yanomamo gardens (Pereira and Evans, 1975; Smote, 1976). Like the Yora, the Yanomamo cultivate a lower diversity of crops than the Shiwiar.

Yanomamo hunt with bow and arrow and differ from the Yora and Shiwiar by rarely, if ever, using dogs. Before 1984, when hunting dogs were introduced to the Yora, their hunting success is likely to have been similar to that of the Yanomamo. The animals killed by Yanomamo hunters are very similar to those hunted by the Yora and Shiwiar. Peccary, tapir, paca, capybara, armadillos, monkeys, squirrels, agouti, anteaters, coatimundi, kinkajou, and lizards are important game species. Curassow, macaw, parakeet, toucan, trogan, pigeon, and other fowl are also taken. The Yanomamo also eat a variety of snakes (Smote, 1976).

In contrast to the Yora and Shiwiar, who obtain a large portion of their protein from fishing, the Yanomamo rely very little on fishing. They are primarily inter-riverine people and their settlement does not center on navigable waterways. They have no specialized fishing equipment or water-craft (Smote, 1976). Most fish are collected from small pools in streams during the dry season. Men also shoot fish with bow and arrow, trap them with weirs, or use barbasco to poison fish in small streams (Chagnon, 1992).

This lack of reliance on fishing may be the reason for another major difference between Yanomamo and the Shiwiar and Yora: the great variety of insects, arthropods, and other small animals that are included in their diet. Grubs harvested from felled palms are enjoyed by all three groups. Yanomamo also eat ants and other insects such as termites and termite larvae, a variety of caterpillars, grubs of certain beetles, and a type of pupae called "kasha" (Smote, 1976). In addition, they eat tarantulas, frogs, tadpoles, and salamanders. Turtles, turtle eggs, snails, crayfish, and crabs round out their diet. As with the Yora and Shiwiar, honey is a favorite Yanomamo food. The consumption of certain kinds of natural clays has also been reported.

Yanomamo prepare their food by grilling, boiling, and roasting (Pereira and Evans, 1975). Large game are cut up and small game are grilled whole over a fire. Small game are also roasted by throwing them into fire to burn off the hair or feathers. After the outer layer of cooked meat is eaten, the process is repeated. This method of cooking introduces considerable grit into the diet. Small game and fish are cooked in clay pots. The Yanomamo do not brush their teeth or practice other forms of oral hygiene (Pereira and Evans, 1975).

RESULTS

There are differences in the demographic structures of the populations we studied that need to be considered when making intergroup comparisons. The Conambo sample most accurately reflects the general demographic makeup of this multiethnic community (Table 1). Although it contains a significantly larger proportion of 6 to 15-year-old children than the other samples, the ages and sex ratios of the Conambo adults are comparable to those of the other groups. The Yanomamo, Yora, and Alto Corrientes Shiwiar data were gathered primarily to obtain dental data on people older than twelve years of age. Many of the Yanomamo observations were made during short visits to isolated villages with medical personnel. It was necessary, therefore, to gather the data from strangers. Children tended to be the least cooperative under these circumstances. Nevertheless, Yanomamo, Yora, and Shiwiar samples do not differ significantly in their sex ratios ($\chi^2 = 1.3$, $p = 0.5$) or age structures ($\chi^2 = 0.9$, $p = 0.65$).

Carious and Missing Teeth. The Kruskal-Wallis test shows that there is a highly significant difference among groups in the proportion of diseased and missing teeth. The Yora (χ^2= 19.9, p=0.0001) and the Shiwiar (χ^2=6.1, p= 0.01) have a significantly higher proportion of diseased and missing teeth than the Yanomamo (Tables 3, 4, 5, Figure 2). Although the proportion of diseased and missing teeth is higher among the Yora than the Shiwiar living in Alto Corrientes, this difference does not reach the level of statistical significance. There are significant differences between the Yora and Alto Corrientes Shiwiar and the ethnically mixed, but predominantly Shiwiar, population of Conambo. The Conambo population differs from the other groups, mainly in having a relatively low frequency of missing teeth (Figure 3, Table 1). This is in part a result of the large number of 6 to 15-year-old children in the Conambo sample. Missing teeth were not present in any of the groups surveyed among children of this age (Table 5).

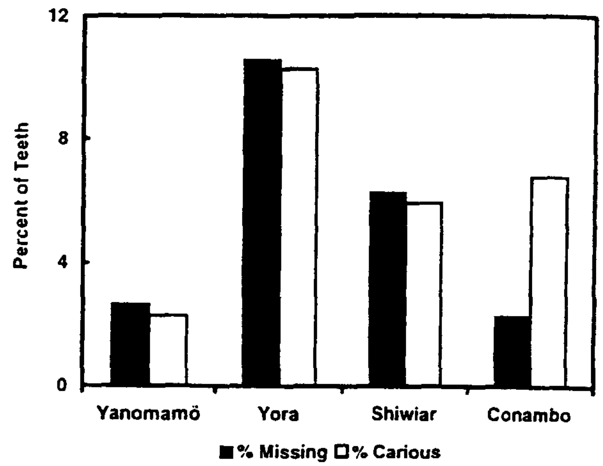

Figure 2. Percent of missing and carious teeth. % missing = missing teeth/(missing teeth + teeth present) x 100; % carious = carious teeth/teeth present x100.

When the proportion of missing teeth is examined for people in the older age groups, it is clear that the Conambo population has a low rate of age-related tooth loss relative to that of the Yora and Shiwiar. In this respect they are very similar to the Yanomamo. The Kruskal-Wallis test shows that for people 16 or older the proportion of missing teeth is significantly higher among the Yora than among Yanomamo (χ^2=13.9, p= 0.003), the Alto Corrientes Shiwiar (χ^2=4.9, p=0.03) or the Conambo population (χ^2=8.2, p=0.004). On the other hand, the difference in missing teeth between the Yanomamo, Alto Corrientes Shiwiar, and the Conambo population are not statistically significant (χ^2= 0.307, p=0.86).

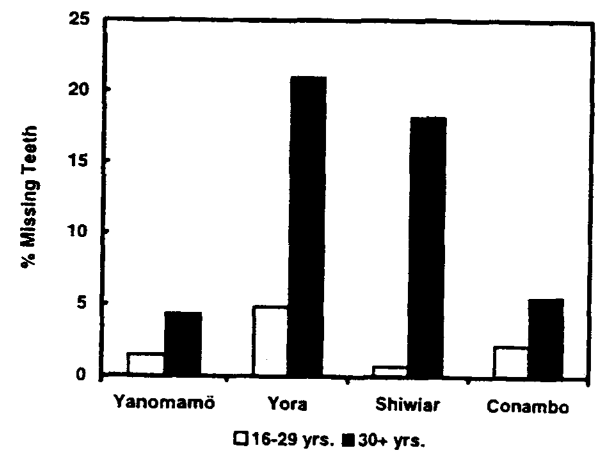

Figure 3. Percent of teeth missing. No missing teeth were observed in people 6-15 years of age.

The proportion of teeth with carious lesions also differs markedly among the groups. Yanomamo have a lower caries rate than any of the other groups (χ^2= 18.5, p= 0.0001). The Yora caries rate, in contrast, is comparatively high: about twice that of the Shiwiar and the Conambo population and five times that of the Yanomamo (Figure 2, Tables 4 and 5). There are also significant age-related differences in caries (Figure 4). The Yora and Alto Corrientes Shiwiar show the usual pattern of age related increase expected with a constant caries risk. The Yanomamo and the Conambo population deviate from this pattern; in these groups, the proportion of teeth with carious lesions is higher among 6 to 15-year-old children than it is among adults. This suggests that the children in these groups are experiencing new cariogenic influences the adults were not exposed to.

There are significant group differences in the distribution of diseased and missing teeth within the dentition. Yora have a much higher proportion of diseased and missing incisors and canines than do the other groups (p <0.005, Figure 5). They also have more diseased and missing premolars and molars, but in this respect they differ significantly only from the Yanomamo (χ^2=14.3, p=0.0002) and the Conambo population (p=4.6, p=0.03).

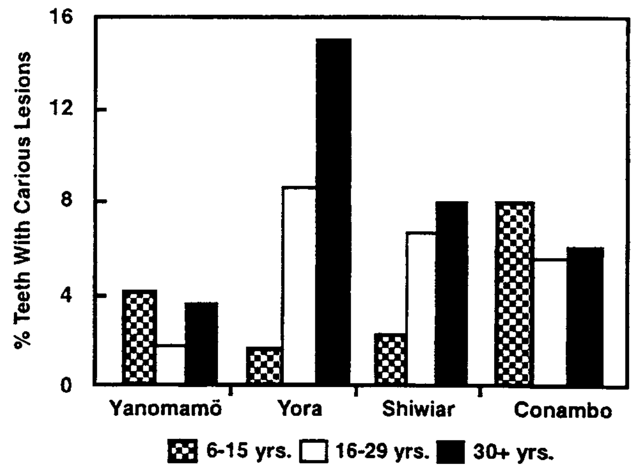

Figure 4. Age differences in the percent of teeth with carious lesions.

Male-female comparisons reveal few sex differences (Figure 6). In all of the groups, men and women have similar caries rates. In the Yora, Shiwiar, and Conambo populations women have a higher proportion of missing teeth than men. This sex difference is age-related and statistically significant (χ^2=4.2, p=0.04) only for people older than 29 years of age.

Wear Rates. The difference between the wear scores of the first and second molars provides a wear rate index (Table 6). The logic behind measuring wear rates in this way derives from the fact that the first molars erupt and begin accumulating wear at about the age of 6 and the second molar erupts 6 years later at about the age of 12. The difference in wear exhibited by the first and second molars, therefore, provides information on the rapidity of wear. If wear rates are low, the average difference between the wear scores of the first and second molars will also be small. If wear rates are high, the first molar will show much more wear than the second molar and the difference between their wear scores will be large (Walker et al., 1991).

The Kruskal-Wallis test shows that the differences between the three groups for which wear rate data are available (Yanomamo, Yora, Conambo) are not statistically significant for either the maxillary or mandibular molars. However, when comparisons are made between males and females some significant intergroup differences are apparent (Figure 7). Yanomamo male mandibular molar wear rates are much lower than those of Conambo males (χ^2=11.2, p=0.0008). The maxillary wear rates of the men in these groups, in contrast, are similar to each other (Figure 8). The wear rates of Yanomamo women are also significantly higher than those of Yanomamo men for the mandibular molars (χ^2=4.6, p=0.03) but not the maxillary molars.

Table 3: The number of permanent teeth observed in each group and Condition includes permanent teeth of children. (Conambo is a sample containing mostly Shiwiar, but also some Quichua speakers).

Tooth	Group	Sex	Number D/M Teeth	Tooth Positions Examined	Positions D/M ,%	Teeth Missing,%	Teeth with Carious Lesions,%
I	Yanomamo	M	5	279	1.79	1.82	0.00
N		F	1	192	0.52	0.00	0.52
C	Yora	M	13	136	9.56	3.03	6.82
I		F	19	160	11.88	4.58	7.84
S	Shiwiar	M	0	88	0.00	0.00	0.00
O		F	6	120	5.00	5.26	0.00
R	Conambo	M	8	254	3.15	2.42	0.81
		F	10	240	4.17	3.45	0.86
C	Yanomamo	M	0	140	0.00	0.00	0.00
A		F	0	96	0.00	0.00	0.00
N	Yora	M	6	68	8.82	3.03	6.06
I		F	12	80	15.00	6.67	9.33
N	Shiwiar	M	0	44	0.00	0.00	0.00
E		F	0	60	0.00	0.00	0.00
	Conambo	M	0	119	0.00	0.00	0.00
		F	0	120	0.00	0.00	0.00
P	Yanomamo	M	5	280	1.79	1.08	0.72
R		F	0	192	0.00	0.00	0.00
E	Yora	M	8	136	5.88	1.49	4.48
M		F	14	160	8.75	7.38	2.01
O	Shiwiar	M	1	88	1.14	0.00	1.14
L		F	7	120	5.83	6.19	0.00
A	Conambo	M	7	208	3.37	0.48	2.90
R		F	8	166	4.82	2.47	2.47

Table 3. Continued.

	Yanomamo	M	52	399	13.03	6.97	6.97
M		F	26	267	9.74	5.95	4.37
O	Yora	M	67	179	37.43	30.66	18.25
L		F	72	196	36.73	29.80	17.88
A	Shiwiar	M	30	110	27.27	13.40	17.53
R		F	46	152	30.26	17.83	17.83
S	Conambo	M	65	343	18.95	2.69	16.77
		F	51	308	16.56	4.05	13.18
A							
L	Yanomamo	M	62	1098	5.65	3.20	2.63
L		F	27	747	3.61	2.05	1.64
	Yora	M	94	519	18.11	10.66	9.38
T		F	117	596	19.63	12.88	9.28
E	Shiwiar	M	31	330	9.39	4.10	5.68
E		F	59	452	13.05	8.65	5.53
T	Conambo	M	80	924	8.66	1.76	7.05
H		F	69	834	8.27	2.96	5.56

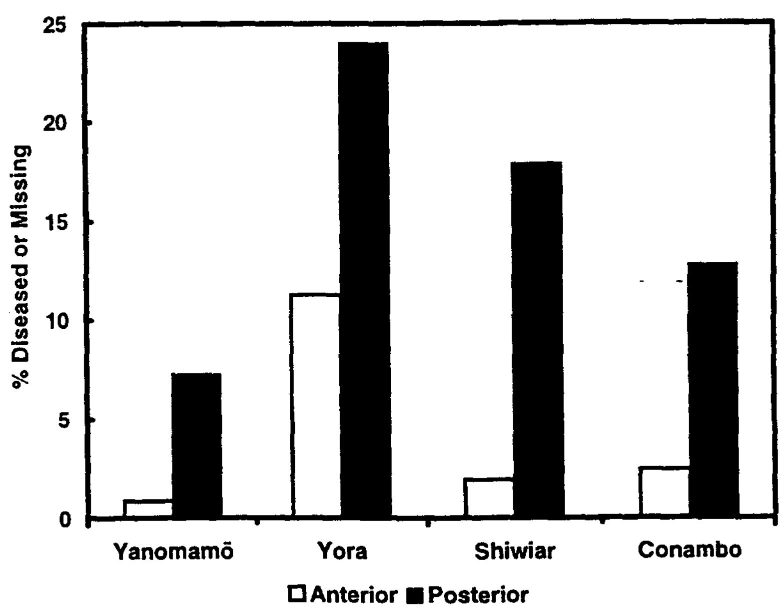

Figure 5. the percent of diseased and missing teeth in the anterior (incisors and canines) and posterior (premolars and molars) dentition.

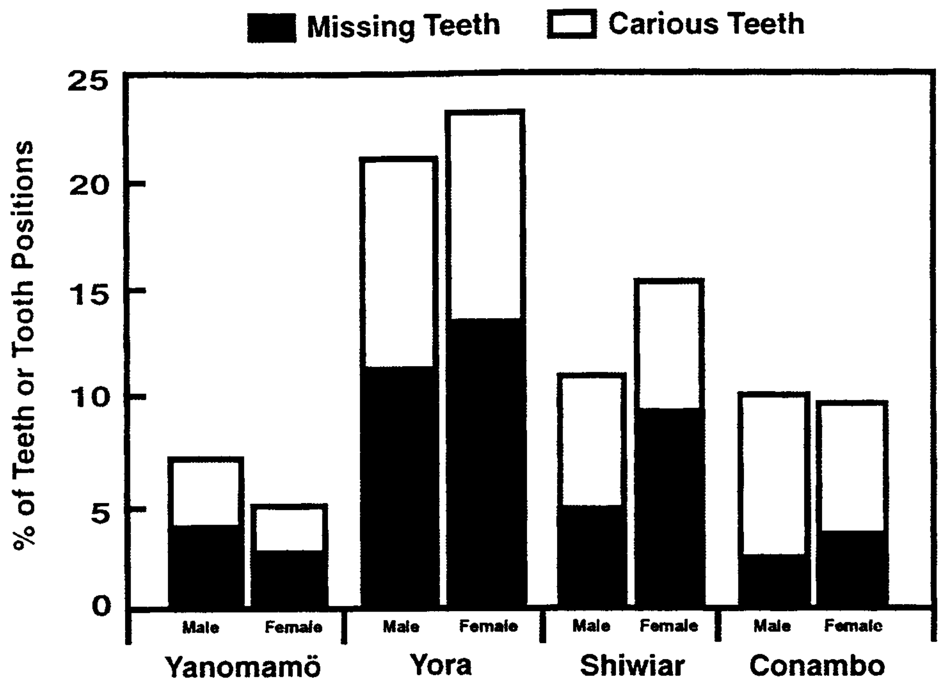

Figure 6. Sex differences in the proportion of missing teeth. % carious teeth = teeth with carious lesions / number of teeth present x 100; % missing teeth = number of missing teeth / number of tooth positions examined x 100.

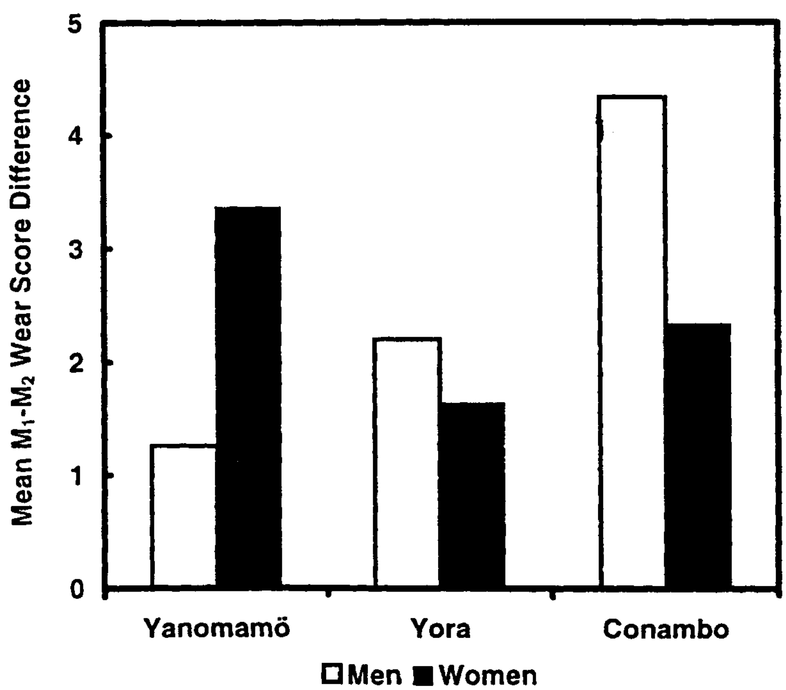

Figure 7. Mean differences in the Scott (1979) wear scores of mandibular first and second molars.

In these wear rate comparisons, we used the sum of the wear scores assigned to each quadrant of a molar as an index of the severity of that molar's wear. Although this has the advantage of providing an overall wear measure, it obscures significant group differences in the variability of molar attrition. It was our subjective impression in the field that molar wear was much more regular among the Yanomamo than among the Yora or the Conambo population. This is confirmed by an analysis of differences in the wear scores assigned to each molar quadrant (Table 7). The comparative regularity of Yanomamo wear is apparent when a wear score variability index is calculated by summing the absolute differences of the scores assigned each molar quadrant. The mean Yora mandibular first molar variability scores are more than four times those of the Yanomamo and those of the Conambo population are twice those of the Yanomamo. The Kruskal-Wallis test indicates that these group differences in intracrown variability are highly significant (χ^2=21.9 p= 0.0001)

Wear of the anterior teeth was quantified using estimates of crown height reduction sketched in the field on diagrams of the incisors and canines. Using these diagrams anterior

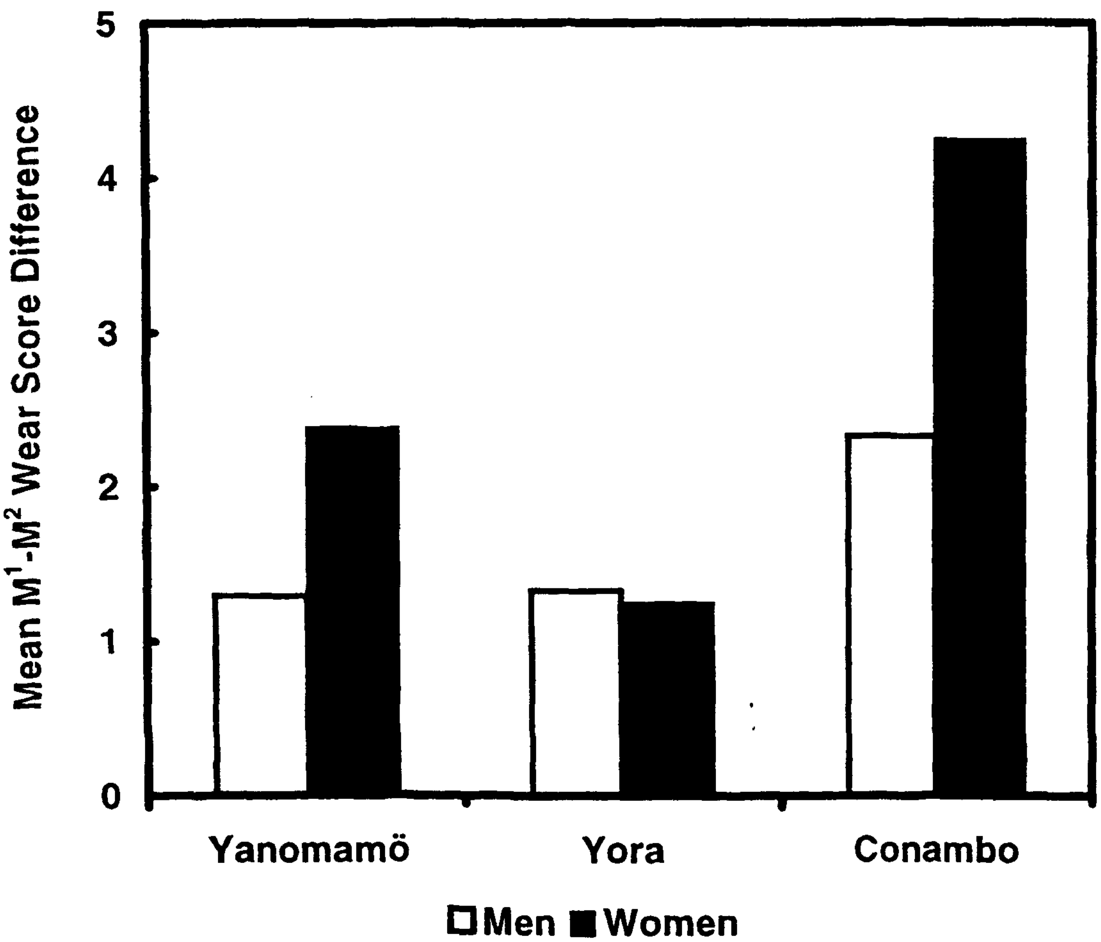

Figure 8. Mean differences in the Scott (1979) wear scores of maxillary first and second molars.

Table 4: Statistics on condition of permanent teeth by group and sex. For the Shiwiar and the Conambo population the carious tooth frequencies include filled carious lesions.

		Missing Teeth			Carious Teeth				Carious / Missing		
Sex	Teeth Without Caries	N	%	Mean Per Person	N	%	Mean Per Person	%People Without Lesions	N	%	Mean Teeth/ Person
					Yanomamo						
M	1036	34	3.10	0.97	28	2.70	0.80	62.86	62	5.65	1.77
F	720	15	2.01	0 60	12	1.67	0.48	80.00	27	3.61	1.08
Total	1756	49	2.66	0.82	40	228	0.67	70.00	89	4.82	1.48
					Yora						
M	425	50	9.63	2.50	44	10.35	2.30	25.00	94	18.11	4.80
F	479	68	11.41	2.96	49	10.23	2.30	30.43	117	19.63	5.26
Total	904	118	10.58	2.74	93	10.29	2.30	27.91	211	18.92	5.05
					Shiwiar						
M	299	13	3.94	0.93	18	6.02	1.29	42.86	31	9.39	2.21
F	393	36	7.96	2.00	23	5.85	1.56	44.44	59	13.05	3.56
Total	692	49	6.27	1.53	41	5.92	1.44	43.75	90	11.51	2.97
					Conambo						
M	844	16	1.73	0.29	64	7.58	1.25	47.92	80	8.66	1.54
F	765	24	2.88	0.53	45	5.88	1.05	53.49	69	8.27	1.58
Total	1609	40	2.28	0.41	109	6.77	1.15	50.55	149	8.48	1.56

tooth wear was classified as either heavy (10% or greater reduction in total crown height) or slight (< 10% reduction in total crown height). Significant sex differences are not apparent when wear is scored in this way. There are, however, some significant intergroup differences. Anterior tooth wear rates are highest among the Yanomamo and Shiwiar and lowest among Yora (Table 8). In general, the mandibular teeth wear more rapidly than the maxillary teeth.

Enamel Hypoplasia. Linear enamel hypoplasias are deficiencies in enamel thickness that develop in response to systemic physiological disruptions during enamel matrix formation (Kreshover, 1960, May et al., 1993). Convincing experimental and clinical evidence links enamel hypoplasia to episodes of infectious disease and malnutrition (Giro, 1947; Sweeney et al., 1969; Goodman et al., 1991; May et al., 1993).

Table 5: Statistics on carious and missing permanent teeth by age groups. For the Shiwiar and the Conambo population the carious tooth frequencies include filled carious lesions.

Group	Age Group	Teeth Examined	Number Carious	Number Missing	Percent Carious	Percent Missing	Percent Carious or Missing
Yanomamo	6- 15	109	4	0	3.67	0.00	3.67
	16-29	923	12	14	1.30	1.49	2.77
	30+	764	24	35	3.14	4.38	7.38
Yora	6-15	171	2	0	1.17	0.00	1.17
	16-29	472	39	24	8.26	4.84	12.70
	30+	354	52	94	14.69	20.98	32.59
Shiwiar	6-15	111	2	0	1.80	0.00	1.80
	16-29	415	26	3	6.27	0.72	6.94
	30+	207	13	46	6.28	18.18	23.32
Conambo	6-15	721	55	0	7.63	0.00	7.63
	16-29	522	27	12	5.17	2.25	7.30
	30+	475	27	28	5.68	5.57	10.93
Total		5244	283	256	5.40	4.65	9.80

Table 6. Mean Scott (1979) wear score differences between mandibular and maxillary first and second molars.

		Mandibular Ml-M2			Maxilla M1-M2		
Group	Sex	Mean	N	SD	Mean	N	SD
Yanomamo	Males	1.26	31	4.78	1.29	31	4.03
	Females	3.36	22	4.05	2.38	24	4.44
	Both	2.13	53	4.57	1.76	55	4.21
Yora	Males	2.20	10	5.18	1.33	15	4.75
	Females	1.63	16	3.12	1.25	16	5.87
	Both	1.85	26	3.95	1.29	31	5.27
Conambo	Males	4.33	27	3.86	2.33	24	4.19
	Females	2.33	18	5.57	4.25	16	5.07
	Both	3.53	45	4.67	3.10	40	4.60
Total	Both	2.58	124	4.51	2.07	126	4.63

Hypoplastic lesions of the canines and incisors were more frequently seen in females (11%) than in males (5%). However, this sex difference is not statistically significant (χ^2=2.7, p= 0.1). The mean age of people with hypoplastic lesions (25.4 years) also does not differ significantly (t= 0.5, p=0.6) from that of people lacking lesions (23.5 years). Significant group differences do exist in the prevalence of hypoplasia (Table 9). The Yora, Shiwiar, and the Conambo population have low hypoplasia rates and do not differ significantly from each other in the frequency of lesions. Yanomamo, in contrast, have relatively high hypoplasia rates and are much more likely to have teeth with lesions than are people in the other groups (χ^2=11.3, p = 0.001).

DISCUSSION

Although they have broadly similar diets based on foods obtained through hunting, fishing, and horticultural activities, the dental health of the groups described in this paper differs in many important respects. To some extent, these dental health differences can be attributed to local differences in patterns of food processing and consumption. Even within these groups, there are variations in dependence on hunting and gathering and horticulture that have a significant influence on oral health. For example, previous studies of the Yanomamo show that there is regional variation in the proportion of people with one or more carious lesion that ranges between 4.2% and 25.0% (Pereira et al., 1994). The lowest caries rates are found

Table 7: Mandibular first molar wear score variability indices for populations surveyed.

Group	Sex	Mean	N	S.D.
Yanomamo	Males	4.39	54	4.27
	Females	4.40	53	4.02
	Both	4.39	107	4.13
Yora	Males	24.45	33	81.00
	Females	12.88	34	47.33
	Both	18.58	67	65.84
Conambo	Males	7.20	45	3.33
	Females	6.37	38	4.12
	Both	6.82	83	3.71
Total	Both	8.88	257	34.11

The variability index is the sum of the absolute differences in the four Scott wear scores for all possible cusp pairs: Wear Score Variability Index = |(Quadrant 1 wear score - Quadrant 2 wear score)| + |(Quadrant 1 wear score - Quadrant 3 wear score)| + |(Quadrant 1 wear score Quadrant 4 wear score)| + |(Quadrant 2 wear score - Quadrant 3 wear score)| + |(Quadrant 2 wear score - Quadrant 4 wear score)| + |(Quadrant 3 wear score - Quadrant 4 wear score)|.

among mountain dwellers who subsist on a high carbohydrate diet composed mainly of birds and bananas. The highest rates are found among Yanomamo living in river valleys where game animals are plentiful and people eat a lower carbohydrate diet with meat as a staple food. The correlation between higher protein intake and higher caries rates is interesting because high protein diets are usually associated with lower caries rates than high carbohydrate diets (Walker and Erlandson, 1986; Walker and Hewlett, 1990).

Our data show that the relationship between caries rate and carbohydrate consumption is far from simple. For example, Yora have higher caries rates than the Yanomamo even though the Yora eat more meat than the Yanomamo. Our ethnographic observations suggest that dental health can be greatly affected by minor differences in the way potentially cariogenic foods are eaten. For example, the Yora peel a whole stalk of sugarcane and then gnaw on it with the anterior dentition for long periods. The Shiwiar, in contrast, usually chop the cane into bite-sized chunks and spend less time processing it with their incisors and canines. This difference in consumption patterns provides a likely explanation of the relatively high frequency of diseased and missing anterior teeth among the Yora (Figure 5).

Table 8: Frequencies of dentitions with heavy wear and slight or no wear of the anterior dentition.

Population	Mandibular Incisor and Canine Wear			Maxillary Incisor and Canine Wear		
Age Group	Slight	Heavy	% Heavy	Slight	Heavy	% Heavy
Yanomamo						
16-29	21	7	25.00	23	6	20.69
>29	9	16	64.00	8	16	66.67
>15	30	23	43.40	31	22	41.51
Yora						
16-29	15	1	6.25	16	1	5.88
>29	7	1	12.50	11	1	8.33
All Ages	22	2	8.33	27	2	6.90
Shiwiar						
16-29	3	10	76.92	5	8	61.54
>29	3	4	57.14	4	4	50.00
All Ages	6	14	70.00	9	12	57.14
Conambo						
16-29	19	1	5.00	20	1	4.76
>29	4	8	66.67	8	8	50.00
All Ages	23	9	28.13	28	9	24.32

Slight or no wear < 10% reduction in the average crown height of the incisors and canines. Heavy wear = 10% or greater reduction in the average crown height of the incisors and canines.

Some dental health differences we have documented appear to be the result of variation in the availability of western foods. Many studies of the effects of western contact on previously isolated groups show dramatic increases in caries rates with the introduction of imported foods (Pedersen, 1938; Moorrees, 1957; Mayhall, 1970; Donnelly et al., 1977; Poole et al, 1977; Schamschula et al., 1980; Kieser and Preston, 1984). All of the groups discussed in this paper are undergoing cultural changes in response to increasing contact with the outside world. This acculturation process is affecting their oral health in many ways. Some of these external influences, such as the occasional access some groups have to modern dentistry, directly affect their oral health. Other changes, such as the decline of traditional dental practices, are also influencing their oral health but in less direct ways.

Table 9: Frequency of linear enamel hypoplasia.

	Yanomamo	Yora	Shiwiar	Conambo
Individuals				
N Individuals	59	37	26	94
N with Hypoplasias	11	4	0	3
% With Hypoplasias	18.64	10.81	0.00	3.19
Maxillary Canines				
N Teeth	118	63	52	120
N Hypoplastic teeth	3	2	0	0
% Hypoplastic	2.54	3.17	0.00	0.00
Maxillary Incisors				
N Teeth	231	129	99	232
N Hypoplastic teeth	10	3	0	1
% Hypoplastic	4.33	2.33	0.00	0.43
Mandibular Canines				
N Teeth	118	67	52	119
N Hypoplastic teeth	5	1	0	2
% Hypoplastic	4.24	1.49	0.00	1.68
Mandibular Incisors				
N Teeth	232	137	103	244
N Hypoplastic teeth	10	1	0	5
% Hypoplastic	4.31	0.73	0.00	2.05

N Individuals = number of individuals with one or more hypoplastic teeth.

To what extent is the breakdown in the cultural isolation of these groups associated with a decline in oral health? In terms of the availability of imported foods the Yanomamo and the Yora are clearly the most isolated. They occasionally obtain rice or other imported foods from missionaries or visitors, but these external inputs are very small. In comparison to the Yanomamo and Yora, the Alto Corrientes Shiwiar and the Conambo population are much less isolated. These people live near airstrips they have cleared in the forest and now have access to missionary emergency medical flights and imported foods. Although the imported foods are mostly seen as treats rather than dietary staples, their importance in the diet is increasing. The influence of the missionaries and availability of imported foods is much greater at Conambo than it is at Alto Corrientes. The airstrip at Conambo is much larger than the one at Alto Corrientes and a plane lands on it every month or two. At Alto Corrientes, in contrast, 4-8 months sometimes pass without a flight.

Age-related differences in dental health provide clear evidence of the influence that introduced foods are having on oral health (Table 5, Figure 4). If susceptibility to dental caries remains constant with increasing age, we would expect to see the typical pattern of increase in carious lesions with increasing age (Hollander and Dunning, 1939). In formerly isolated populations undergoing rapid dietary change, it is common to see increases in the caries rates of children so that they approach or even exceed those of adults (Collins, 1932; Russell et al., 1961; Mayhall, 1970; Poole et al., 1977; Schamschula et al., 1980; Kieser and Preston, 1984).

The linear age-related increase in carious lesions predicted for a stable population is seen in the Yora and Alto Corrientes Shiwiar. In the Yanomamo and Conambo populations, in contrast, children in the 6 to 15-year-old age group have higher caries rates than adults. At Conambo, dietary differences between adults and children probably explain the high caries rates of children. The diet of children living at Conambo differs significantly from that of adults because of a missionary-sponsored food aid program that has been active for about ten years. Although missionaries do not live in the village, they supply school-aged children with rice, flour, oil, salt, and sugar as a kind of school lunch program. Supplies of donated food are flown into the village at the beginning of each school year and parents take turns preparing either rice or fry bread, which is served to school-age children five days a week. This is accompanied by lemonade or colada (flour and water with fruit or other flavoring) that is sweetened with refined sugar. Since there is a well-established relationship between dental caries and increased consumption of refined carbohydrates such as these (Nizel, 1973; Legler and Menaker, 1980; Alfano, 1980), the school lunch program provides a likely explanation for the high caries rates of Conambo children.

Although the Alto Corrientes Shiwiar currently have a school lunch program like that at Conambo, it has been active at this relatively isolated village only for the last few years. This undoubtedly explains the comparatively low incidence of caries among the children of this community. The high caries rates of Yanomamo children in comparison to adults is puzzling since little imported food reaches the remote villages we visited. Rice is sometimes given to Yanomamo by missionaries, but we have no reason to believe that children obtain more of this food than adults. Nevertheless, our data do suggest that external influences are beginning to cause a decline in the dental health of Yanomamo children.

The tooth loss rates of some of the populations surveyed have been affected by dentists making sporadic visits to some villages. Access to modern dentistry varies markedly among the groups surveyed. The Yanomamo and the Yora have very little experience with dentists and none of their carious teeth had fillings. The Alto Corrientes Shiwiar and the Conambo population, in contrast, have occasional access to dentists who fill their carious teeth. Because of its relative isolation, the impact of dental visits has been much less at Alto Corrientes than at Conambo. Among the Alto Corrientes Shiwiar 20% of the carious lesions we observed had been filled whereas at Conambo, 64% of the carious teeth had fillings. This difference in access to dental care undoubtedly has reduced the rate of tooth loss among the people of

Conambo and probably accounts for their comparatively low frequency of missing teeth (Figure 3).

Western oral hygiene practices, such as the use of toothbrushes, have not been widely adopted by people who participated in our survey. The Yanomamo and Yora do not use any form of oral hygiene. The Shiwiar sometimes use a twig as a toothbrush and rinse their mouths out with water after eating. Through their contacts with outsiders, a few Shiwiar have obtained toothbrushes and toothpaste and use them daily.

Western contact has caused a recent decline in traditional practices involving the teeth and this may explain some of the age-related variation we have documented in dental health. Although the traditional practice of blackening the teeth with sap to protect them from caries has largely died out at Conambo and Alto Corrientes, a few adults still do it occasionally. The use of sap may have had an important influence on the oral health of the older people in our sample. According to our Shiwiar consultants, it was formerly a common practice.

Using sap to extract teeth is another traditional practice that may account for some of the variation in our dental data. As we have noted, this technique was practiced mainly by women of childbearing age (Lewis and Elvin-Lewis, 1984:55). It provides a plausible explanation for the significantly higher proportion of missing teeth in women than men among the Shiwiar (Figure 6). We were not aware of this practice when we did our fieldwork and consequently did not make direct inquiries about it. However, we were not told about the use of sap for tooth extraction when we asked our consultants about the treatment of dental problems. The practice may, therefore, have been discontinued owing to the increased availability of modern dental services.

Yanomamo tobacco use is another traditional practice that has significant oral health implications. Yanomamo men, women, and children are addicted to tobacco and habitually suck on a wad of it during their daily activities (Chagnon, 1992: 66-68). Even young children of ten years or so are habitual users. The tobacco is prepared for consumption in a complex way that contaminates it with considerable grit. Tobacco leaves are cured over a fire and then kneaded in the ashes of the campfire until the entire leaf is covered with a muddy layer of wood ash. These leaves are then formed into a wad that is administered by placing it between the lower lip and teeth.

The chronic use of this grit-contaminated tobacco by the Yanomamo may have a significant influence on their tooth wear. Smokeless tobacco commercially available in the west is heavily contaminated with abrasive inorganic material, which makes up to 0.5% of its total weight and excessive tooth wear is considered a potential hazard of using it (Christen et al., 1989; Bowles et al., 1995). Yanomamo tobacco undoubtedly contains a much higher concentration of abrasives than these commercial products since muddy wood ash is used in its preparation. It seems possible that the regularity of Yanomamo tooth wear in comparison to the other groups (see Table 8) is somehow related to the constant presence of large quantities of abrasive tobacco grit in their mouths.

It has been suggested that Yanomamo tobacco use may have a cariostatic effect (Re et al., 1985). In vitro studies, however, do not indicate any inhibition of cariogenic bacteria by tobacco (Falkler et al., 1987) and clinical studies of smokeless tobacco users have not clearly established its relationship with dental caries (Offenbacher and Weathers, 1985; Hirsch et al., 1991).

Some of the wear rate variation we have documented seems to be related to differences in the amount of mastication required by the food typically eaten as well as the amount of abrasive grit these foods contain. In the populations studied, meat consumption is associated with high wear rates. During our fieldwork, it was obvious to us that the meat based-diet of the Shiwiar required much more chewing than the softer, banana dominated Yanomamo diet. Eating the gritty meat of a smoked toucan or monkey is a formidable masticatory challenge and it is easy to imagine that consuming large quantities of this kind of food would rapidly wear the teeth. Differences in meat consumption might, for example, explain the high wear rates of people living at Conambo where meat is abundant in comparison to the Yora (Figures 7 and 8). This difference in meat availability is in part a result of the reliance of the Yora on bows and arrows instead of the more efficient shotguns and blowguns used at Conambo.

The lack of large sex differences in caries and wear rates among the Yora and Shiwiar is a surprising finding. In these groups producing manioc beer is a major activity solely performed by women that requires them to spend many hours with manioc in their mouths. A woman preparing for a party can easily spend several hours a day chewing manioc while making beer. We predicted that this sex difference in activity pattern would result in higher caries rates in women than men owing to the constant presence of cariogenic carbohydrates in the mouth. Chewing large quantities of manioc might also be expected to increase the wear rates of women. None of these predictions were confirmed by the dental data we collected. Women did not have significantly higher caries or wear rates than men.

With a little reflection, the reasons that our predictions were not confirmed seem obvious. The caries formation process depends on the colonization of the tooth surface by cariogenic bacteria that thrive on fermentable carbohydrates such as those in manioc. The presence of manioc in the mouth for long periods of time might, therefore, be expected to favor caries development. However, the constant chewing and spitting that is integral to manioc beer production mitigates against caries development. Continuous vigorous chewing has a natural cleaning action that effectively disrupts colonization of tooth surfaces by bacterial plaque.

The absence of an association between manioc beer production and elevated tooth wear rates probably is explained by a lack of abrasive contaminants in the peeled, boiled manioc that is used for beer. The lack of high wear rates among these women has an interesting implication. It suggests the amount of mastication required by a diet is less important than abrasive contamination as a wear rate determinant.

Our analysis of anterior tooth wear revealed few consistent patterns or differences between groups. This is perhaps because anterior tooth wear is subject to much individual variability owing to the use of the teeth as tools in handicrafts such as spinning, basket weaving, and net making. They also are used in the manufacture of bows, arrows, and blow guns. Many of these crafts are the specialties of individuals whose teeth sometimes show the effects of habitual use. For example, a Shiwiar man who participated in our survey is famous for the quality of the blow guns he produces and his products are highly prized by other Shiwiar men. The effects of holding bow gun binding between his teeth during long hours of wrapping blowguns can clearly be seen in his heavily worn incisors.

THE NEED FOR ETHNO-BIOARCHAEOLOGICAL RESEARCH

In archaeology much has been learned through ethnoarchaeological studies in which the activities of traditional societies are analyzed from the perspective of their implications for the archaeological record. In the same way, physical anthropological studies of traditional societies can enormously enrich the interpretations bioarchaeologists make when they study ancient human remains. There is an urgent need for more ethnobioarchaeological research. By this we mean studies in which ethnographic and physical anthropological data are collected as part of collaborative efforts to answer ethnographic and bioarchaeological questions. The inherent methodological independence of biological and cultural data produces synergies that make hypothesis testing much more efficient than is possible when physical anthropological and ethnographic data are interpreted in isolation.

Bioarchaeologists need more data like that presented in this paper in order to increase the reliability of their behavioral reconstructions. If nothing else, studies such as ours can serve as a source of cautionary tales that encourage bioarchaeologists to entertain a variety of possible explanations for the patterns they identify in skeletal collections.

Collaborative efforts between ethnographers and physical anthropologists can also be extremely valuable from an ethnographic perspective. For example, ethnobioarchaeological research conducted among modern pygmies in the Central African Republic produced dental evidence for differences in access to essential resources related to a person's sex and social status (Walker and Hewlett, 1990). This was a surprising and theoretically significant finding since ethnographers have traditionally viewed pygmy society as a model of egalitarianism.

Opportunities such as we have had to document the diets and oral health of people who have had little contact with Western culture are rapidly diminishing. Judging from the effects that introduced foods are having on the oral health of the children in some of the populations we studied, research such as that reported in this paper will no longer be possible in a decade or two. Fieldwork in remote areas such as those occupied by the people we have worked with is difficult and at times dangerous. In spite of the challenges posed by such research, we believe that the benefits of preserving the biological and cultural legacy of groups such as the Yanomamo, Yora, and Shiwiar is well worth the effort.

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REFERENCES CITED

Alfano, MC (1980) Nutrition in dental caries. In: L Menaker (ed.) *The Biologic Basis of Dental Caries*. New York: Harper and Row, pp. 343-364.

Bowles, WH, Wilkinson, MR, Wagner, MJ and Woody, RD (1995) Abrasive particles in tobacco products: a possible factor in dental attrition. *J. Amer. Dent. Assoc.* 126(3):327-31.

Chagnon, N (1992) *Yanomamo*. (fourth edition) Fort Worth: Harcourt Brace Jovanovich.

Christen, AG, McDonald, JL, Olson, BL and Christen, JA (1989) Smokeless tobacco addiction: a threat to the oral and systemic health of the child and adolescent. *Pediatrician.* 16(3-4):170-7.

Collins, HB (1932) Caries and crowding in the teeth of the living Alaskan Eskimo. *Am. J. Phys. Anthrop.* 16(4):451-462

Descola, P (1989) *La Selva Culta: Simbolismo y Praxis en la ecologia de la Achuar.* Ecuador: ABYA-YALA.

Donnelly, CJ, Thomson, LA, Stiles, HM, Brewer, C, Neel, JV and Brunelle, JA (1977) Plaque, caries, periodontal diseases, and acculturation among Yanomamo Indians, Venezuela. *Community Dent. Oral Epidemiol.* 5:30-39.

Falkler, WA, Zimmerman, ML, Martin, SA and Hall, ER (1987) The effect of smokeless tobacco extracts on the growth of oral bacteria of the genus *Streptococcus*. *Arch. Oral Biol.* 32(3):221-3.

Giro, CM (1947) Enamel hypoplasia in human teeth: An examination of its causes. *J. Am. Dent. Assoc.* 34:310-317.

Goodman, AH, Martinez, C and Chavez, A (1991) Nutritional supplementation and the development of linear enamel hypoplasias in children from Tezonteopan, Mexico. *American Journal of Clinical Nutrition* 53(3):773-81.

Gustafsson, BE, Quensel, C, Lanke, L, Lundquist, C, Grahnen, H, Bonow, B and Krasse, B (1954) The effect of different levels of carbohydrate intake on caries activity in 436 individuals observed for five years. *Acta Odont. Scand.* 11: 195-288.

Hames, RB (1979) A comparison of the efficiencies of the shotgun and the bow neotropical forest hunting. *Human Ecology* 7(3):219-252.

Harner, MJ (1972) *The Jivaro: People of the Sacred Waterfalls.* Garden City, New York: Doubleday/Natural History Press.

Harris, S and Cleaton-Jones, P (1978) Oral health in a group of sugar-cane chewers. *J. Dent. Assoc. South Africa.* 33(5):255-8.

Hirsch, JM, Livian, G, Edward, S and Noren, JG (1991) Tobacco habits among teenagers in the city of Goteborg, Sweden, and possible association with dental caries. *Swedish Dental Journal* 15(3):117-23.

Hill, K and Kaplan, H (1989) Population and dry-season subsistence strategies of the recently contacted Yora of Peru. *National Geographic Research* 5(3):317-334.

Hollander, F and Dunning, JM (1939) A study by age and sex of the incidence of dental caries in over 12,000 persons. *J. Dent. Res.* 18:43-60.

Kieser, JA and Preston, CB (1984) Oral health status of the Lengua Indians of Paraguay. *Community Dentistry and Oral Epidemiology.* 12(6):406-7.

Kreshover, S (1960) Metabolic disturbances in tooth formation. *Annals New York Acad. Sci.* 85:161-167.

Legler, DM and Menaker, L (1980) Definition, etiology, epidemiology and clinical implications of dental caries. In: L Menaker (ed.) *The Biologic Basis of Dental Caries.* New York: Harper and Row, pp. 211-260.

Lewis, WH and Elvin-Lewis, MPF (1984) Plants and dental care among the Jivaro of the upper Amazon basin. *Advan. Econ. Botany.* 1:53-61.

May, RL, Goodman, AH and Meindl, RS (1993) Response of bone and enamel formation to nutritional supplementation and morbidity among malnourished Guatemalan children. *Am. J. Phys. Anthropol.* 92(1):37-51.

Mayhall, JT (1970) The effect of culture change upon the Eskimo dentition. *Arctic Anthropol.* VII-I: 117-121

Moorrees, CFA (1957) *The Aleut Dentition.* Cambridge Mass.: Harvard University Press.

Nizel, AE (1973) Nutrition and oral problems. *Food Nutrition and Health, World Rev. Nutri. Dietetics* 16:226-252.

Offenbacher, S and Weathers, DR (1985) Effects of smokeless tobacco on the periodontal, mucosal and caries status of adolescent males. *Journal of Oral Pathology* 14(2): 169-81.

Pedersen, PO (1938) Investigations into dental conditions of about 3,000 ancient and modern Greenlanders. *The Dental Record.* 58:191-198.

Pereira, CB and Evans, H (1975) Occlusion and attrition of the primitive Yanomami Indians of Brazil. *Dent. Clin. North Am.* 19(3):485-98.

Pereira, CB, Katich, JP and Turner, CG (1994) Oral condition of three Yanomama Indian Tribes of South America. *Dent. Anthropol. Newsletter.* 8(3):8-10.

Poole, AE, Poole, DA, Harper, LR and Laughlin, WS (1977) Genetic and environmental factors in the etiology of dental disease in the Aleut. *J. Dent. Res.* (Special Issue C) 56:C79-C89.

Russell, AL, Consolazio, CF and White, CL (1961) Dental caries and nutrition in Eskimo Scouts of the Alaska National Guard. *J. Dent . Res.* 40:: 263-272.

Re, G, Re, F and Careglio, A (1985) Il Tabacco Come Energetico E Come Anticarie. *Minerva Stomatologica*, 34(2):435-45.

Schamschula, RG, Cooper, MH, Wright, MC, Agus, HM and Un, PSH (1980) Oral health of adolescent and adult Australian Aborigines. *Community Dent. Oral Epidemiology* 8:370-374.

Scott, EC (1979) Dental wear scoring technique. *Am. J. Phys. Anthropol.* 51:213218.

Sugiyama, L and Chacon, R (1993) *Yora dry season hunting, fishing, and horticultural activities*. (unpublished manuscript).

Smole, WJ (1976) *The Yanoama Indians: A Cultural Geography*. Austin: University of Texas.

Sweeney, EA, Cabrera, J, Urrutia, H and Mata, L (1969) Factors associated with linear hypoplasia of human deciduous incisors. *J. Dental Res.* 48:1275-1279.

Turner, CG (1979) Dental anthropological indications of agriculture among-the Jomon people of central Japan. *Am. J. Physical Anthropol.* 51:619-636.

Walker, PL and Erlandson, JM (1986) Dental evidence for prehistoric dietary change on the Northern Channel Islands, California. *Am. Antiquity.* 5(2)375-383.

Walker, PL and Hewlett, B (1990) Dental health diet and social status among Central African foragers and farmers. *Am. Anthropol.* 92(2): 383-398.

Walker, PL, Dean, G and Shapiro, P (1991) Estimating Age from Dental Wear in Archaeological Populations. In: MA Kelley and CS Larsen (eds.): *Advances in Dental Anthropology.* New York: Alan R. Liss, pp. 169-178.

Yost, JA and Kelley, P (1983) Shotguns, blowguns and spears: the analysis of technological efficiency. In: RB Hames and WT Vickers (eds.): *Adaptive Responses of Native Amazonians*. New York: Academic Press, pp. 189-224.