Food and the State: Bioarchaeological Investigations of Diet in the Moche Valley of Perú

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ABSTRACT The Moche of north coastal Perú were among the earliest New World societies to develop state socio-political organization. The Moche State (AD 200-800) was a centralized hierarchical society that controlled the Moche Valley as well as valleys to the north and south. Prior to the establishment of the state, a series of less hierarchical organizations were present in the valley. Irrigation agriculture has often been cited as central to development of the Moche State. To test this assertion I examined 750 individuals recovered from the largest cemetery at the site of Cerro Oreja. Although the most important occupation of Cerro Oreja was during the Gallinazo phase (AD 1-200), many individuals were interred here during the earlier Salinar period (400 -1 BC). Consequently, the Cerro Oreja collection holds a key to understanding the development of one of the earliest and most extensive states in the Americas. The teeth and/or alveoli of each individual were examined for the presence of dental caries, periodontal disease, abscesses, and antemortem tooth loss. My analysis suggests women and children did increasingly focus their diet on agricultural products. These findings seem to support the hypothesis that increased irrigation and reliance on agricultural production was fundamental to the development of the Moche state. However, men's diets remained consistent through time. Status seems to have been of little import in determining diet before and during early periods of state development, in dramatic contrast to what we know of its importance during the zenith of the state's power. I suggest that increasing differentiation of gender roles was important to the development of the state, and that gender differences may have been the most salient force in the transition to political hierarchy and social stratification in the Moche valley. *Dental Anthropology* 2004;17(2):45-54.

The Moche of north coastal Perú were among the earliest New World societies to develop a bureaucratic state organization (Moseley, 1992; Bawden, 1996). The Moche State (AD 200–800) was a centralized hierarchical society that controlled the entire Moche Valley and perhaps valleys to the north and south (Fig. 1). The Moche elite marshaled their economic resources to build large public works, such as roads and monumental ceremonial structures (Hastings and Moseley, 1975; Moseley, 1975), and to dramatically increase arable land through canal construction (Moseley and Deeds, 1982). The elite also amassed great personal wealth, as indicated by archaeological excavations of wealthy tombs (Donnan and Castillo, 1992; Alva and Donnan, 1993). To exert their influence, the elite used ideological power manifested in public rituals held at large monuments, and iconography that supported state ideologies. Physical power, in the form of warfare, conquest, and sacrifice, was also central to elite control (Shimada, 1978; Bawden, 1996; Billman, 1996; Bourget, 1996. 2001; Verano, 2001).

Prior to the establishment of the state, societies in

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Table 1. Moche Valley cultural periods and work projects

Phase	Estimated Dates	Cultural Horizon[1]	New Canals Excavated	Ceremonial Architecture
Middle Moche	AD 400–700	Early Intermediate Period	312,000 m^3	416,000 m^3
Gallinazo–Early Moche	AD 1–400	Early Intermediate Period	0 m^3	15,000 m^3
Salinar	400–1 BC	Early Intermediate Period	60,000 m^3	67,000 m^3
Cupisnique	1800–400 BC	Initial Period–Early Horizon	42,000 m^3	1,291,000 m^3

[1]Following Moseley (1992) and Billman (2002).

the valley were organized in less hierarchical political structures (Topic and Topic, 1978; Brennan, 1980; Topic, 1982; Billman, 1997, 1999). It was the people of these societies who first opened the desert lands of the Moche valley to agriculture (Table 1). Construction of the valley-wide canal system that enabled agriculture production began during the Cupisnique phase (1800–400 BC), when approximately 4200m^3 of canals were built, irrigating 4100 hectares. This system was expanded by approximately 60,000 m^3 during the Salinar phase (400–1 BC), allowing for the cultivation of 6750 to 7300 hectares. During the Gallinazo and Early Moche phases (AD 1–400) no new land appears to have been brought under cultivation. Later, the Moche State doubled agricultural production through the irrigation of 12,550–13,200 hectares (Billman, 2002). This dramatic increase in agricultural production has led researchers to suggest that in Perú, as elsewhere, irrigation played a central role in state development (Steward, 1949; Rowe, 1963; Moseley, 1974; Haas, 1987). This is because staple crops could be produced on a grand scale in irrigated fields creating storable surpluses. By controlling these stores, elites financed their state building activities (D'Altroy and Earle, 1985; Earle, 1997). Because increased agricultural production is reflected in an increase in the consumption of agricultural products, the link between irrigation and state development can be tested by tracking prehistoric changes in diet. To this end, I examined individuals who lived during the Salinar and Gallinazo phases, just prior to and during the beginnings of state formation, for evidence of increased prevalence of dental pathological conditions indicative of the increased consumption of starchy and/or sugary agricultural products. An advantage of using biological rather then ethnobotanical data to chart consumption is that these data are linked to specific individuals for whom sex, age-at-death, and status information is known. This allowed me to examine not only changes in agricultural production, but who these changes affected, and thus link changes in social roles, particularly gender roles, to changes in political organization.

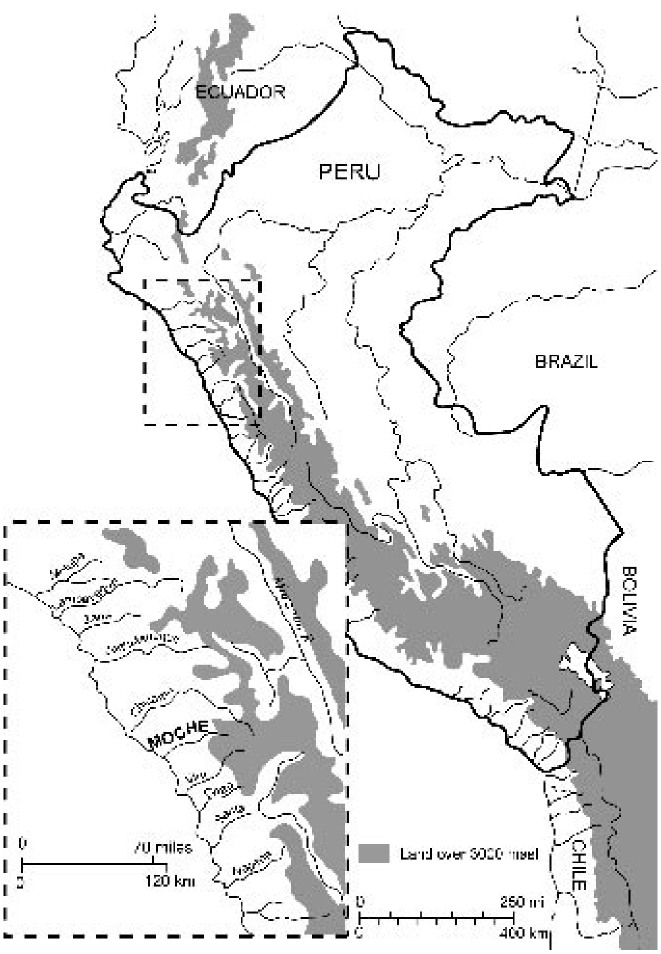

Fig. 1. Perú with north coast inset, from Moseley 1992.

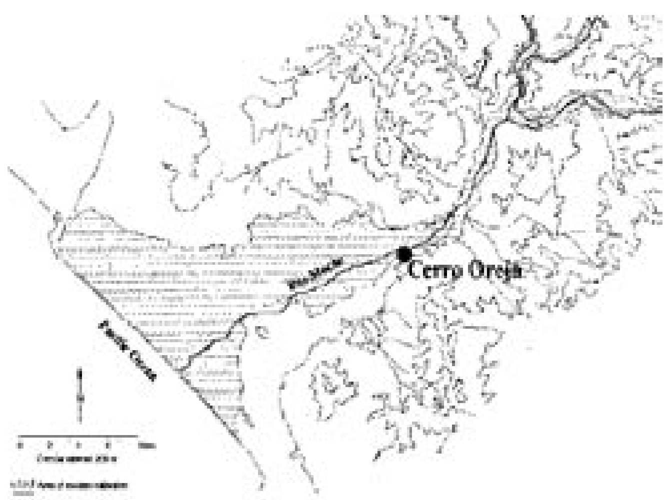

Fig. 2. Map of the lower and middle Moche valley locating Cerro Oreja, from Billman 1999.

Table 2. Study sample

Age in years	Salinar	Early Gallinazo	Middle Gallinazo	Late Gallinazo
fetal	0	5	8	0
birth - 4.9	24	110	90	49
5 - 9.9	11	21	12	9
10 - 14.9	3	12	4	3
15 - 19.9	5	10	11	7
20 - 24.9	2	9	4	5
25 - 29.9	0	9	7	11
30 - 34.9	6	6	10	7
35 - 39.9	8	10	10	3
40 - 44.9	5	10	8	4
45 - 49.9	4	5	5	2
50 - 54.9	0	0	2	0
55 - 59.9	1	0	0	0
> 18	2	5	1	5
> 20	3	20	28	26
> 30	2	11	10	13
> 40	0	2	5	1
50 +	0	0	0	1

THE SAMPLE

The remains I examined in this study were excavated by the Instituto Nacional de Cultura (INC) from the site of Cerro Oreja (Fig. 2). Cerro Oreja, located at the neck of the Moche valley, was the largest urban center in the valley during the Gallinazo phase (Billman, 1999). Downstream from this location the Moche valley widens as the river drains into the Pacific. At the neck and upstream, the Río Moche cuts into the Andean foothills. Here bottom land is limited and valley slopes rise steeply. It is in this area that people, both in the past and present, have built irrigation canal intakes. Although the most important prehistoric occupation of Cerro Oreja was during the Gallinazo phase, many individuals were also interred here during the Salinar phase.

Of the 909 burials excavated from Cerro Oreja by the INC, I examined 681. Several burials contained the remains of more than one individual, and as a result the study sample represents 750 individuals. The INC made phase designations based on burial goods and stratigraphic location. The sample I analyzed for this study included the remains of 61 Salinar, 142 Early Gallinazo, 109 Middle Gallinazo and 69 Late Gallinazo individuals (Table 2). Although the mortuary analysis of the Cerro Oreja cemetery is in its preliminary stages, information about the presence of grave goods is available. Using these data, I divided individuals into two status categories, those with goods and those without.

Age-at-death and sex identifications were made as a joint effort by the members of the Cerro Oreja Bioarchaeology Project, which is co-directed by Dr. Patricia Lambert of Utah State University and Dr. Brian Billman of the University of North Carolina at Chapel Hill. During the summer field seasons of 1999, 2000, and 2001, I worked with Dr. Lambert and Bonnie Yoshida, a graduate student at the University of California at Santa Barbara, to make age-at-death and sex estimations for 243 individuals. During an extended research season, Yoshida identified the age-at-death and sex of an additional 183 individuals. In 2003, I examined these individuals as well as the remains of 324 additional individuals.

Our age-at-death and sex identifications were made following *Standards* (Buikstra and Ubelaker, 1994). We based subadult age estimates primarily on tooth formation and eruption (White, 1991). Skeletal development and fusion (Johnston, 1962; Fazekas and Kósa, 1978; Buikstra and Ubelaker, 1994) were used in estimating the age-at-death of fetuses and infants, as well as of individuals for whom the dentition was not preserved. Adult ages were estimated based on combined morphological changes at the pubic symphysis and auricular surface, and also on cranial suture closure (as presented in Buikstra and Ubelaker, 1994). Occasionally sternal rib ends were well-enough preserved to be included in our age assessments (see Bass, 1987). We assigned individuals a mean age and an error estimate. Errors ranged from several months for well-preserved children to as much as 15 years for fragmentary adults. For this analysis, I grouped individuals in five-year categories based on their mean age. Adult remains too fragmentary to be assigned a mean age were not included.

Sex identification of adults was established using the Phenice Method and qualitative observations of pelvic morphology, such as relative size of greater sciatic notch, length of the pubic ramus and width of the subpubic angle. We also considered cranial morphology and robusticity when sexing adults (White, 1991; Buikstra and Ubelaker, 1994). If the os pubis was extremely fragmentary or absent, we used metric data from the femora, tibiae, and humeri to support cranial sex identifications (Iscan and Miller-Shaivitz, 1984; Dittrick and Suchey, 1986). Not all individuals could be assigned a sex with the same degree of certainty. To incorporate our varying error, we employed a four-tier system to rank our identifications: female/male, probable female/male, possible female/male, and unidentified. Individuals in the last two categories were excluded from this analysis.

Approximately 56% of the individuals in this study had preserved teeth and/or alveoli that I could examine for the presence of the following dental pathological conditions: caries, periodontal disease, abscesses, and antemortem tooth loss.

METHODOLOGICAL CONSIDERATIONS

Biological anthropologists have effectively used the frequency of dental pathological conditions to chart changes in diet, particularly with regard to the consumption of agricultural products (see Kelley and Larsen, 1991; Hillson, 1996; Larsen, 1997). Because of the nature of human dentitions and the vagaries of skeletal preservation, researchers have struggled with several sampling issues. The primary issue is scalar: Should individuals or teeth be the unit of analysis? In an analysis at the individual level, individuals are diagnosed as having or not having a particular condition. Such an analysis can provide researchers with useful information; but it can also obscure variation. At this level, an individual with 32 observable teeth, only one of which is carious, cannot be distinguished from an individual with 32 carious teeth, though these two individuals certainly had different diets. Characterizing individuals by the percentage of affected teeth addresses this issue, but raises questions about sample comparability. An individual with 32 observable teeth, all of which are carious, and an individual with only two teeth, also carious, would both be classified as 100% affected. To mitigate the effects of individual preservation differences, researchers often exclude individuals who do not have some minimum number of observable teeth.

In addition to these issues of comparability, substantial data loss occurs when each individual is characterized by only one datum point. In the comparison described above, 32 teeth were observed. However, when these data are analyzed at the individual level, there is only one datum point—the presence (or absence) of carious lesions, or the percentage of affected teeth. This loss can result in sample sizes that are insufficient to address research questions.

To maximize data and address comparability difficulties, many researchers analyze their data at a higher scale (following Turner, 1979). All the teeth of many individuals are pooled into groups, the boundaries of which are defined by the questions to be addressed. These types of studies yield some interesting information about diet. However, statistical analyses of data grouped in this way assume that each tooth in the group is independent of all others. This assumption does not hold, as the teeth of an individual are affected by her/his diet and are therefore more likely to resemble each other than the teeth of other individuals. Additionally, the pooling of samples can increase group heterogeneity, leading to spurious results. To test for diet change over time, all individuals from each period can be grouped to create a lesion rate for each. Statistical analysis of these rates may not identify significant differences among groups because the differences that do exist may average out. Summary measures of a bimodal distribution (*e.g.*, female teeth are always affected while male teeth are not) can be very similar to those of a standard distribution (*e.g.*, both female and male teeth are often affected). To address this issue, groups can be more narrowly defined, creating a larger number of groups each of which includes fewer individuals. Doing so, however, decreases sample size and the power of statistical tests to identify differences among the groups.

Two other factors complicate both individual and group level analysis: the differing susceptibility of different tooth types to dental pathological conditions, and the varying ages-at-death of sample individuals. Teeth vary in their overall size and the complexity of their shape. Both of these factors affect a tooth's probability of developing pathological lesions. At the individual level of analysis for example, a person with eight observable anterior teeth is much less likely to display carious lesions than someone with eight observable molars. At the group level, samples pooled for comparison might contain substantially different distributions of tooth types. Dental pathological conditions are also age-dependent. For this reason, researchers segregate subadults and adults in both individual and group level analyses. In some cases the adult sample is further divided into young, middle, and old categories. As with other attempts to mitigate sample heterogeneity, the level of error must to be balanced against decreasing the sample size.

To address these persistent problems, I analyzed these data using logistic regression. A log-linear model simultaneously explores the complex relationships between a categorical independent variable, in this case the presence or absence of a dental condition, and any number of numeric and/or categorical dependent variables (*e.g*, age-at-death, sex). Secondly, it solves the dilemma of analytical scale. Model estimates of population parameters are calculated using individual teeth, allowing the largest possible sample size. However, the teeth of an individual remained linked, preserving individual-level information. This nesting sampling strategy adjusts for sample-effects by weighting the value of the independent variable for each tooth according to how much additional information it provides about the individual. Finally, interactions among dependent variables can be examined for significance. If two dependent variables vary simultaneously their interaction will be more significantly associated with the independent variable than either would when independently analyzed.

The model I used in this analysis was programmed in SAS with the help of Chris Wiesen, staff statistician for the Odum Institute at the University of North Carolina at Chapel Hill. In this model age-at-death was the only numeric, dependent variable. We treated this variable as numeric because it behaved linearly, even when described in 5-year intervals. The categorical variables we included were period, status, sex, and tooth-type. Period, status, and sex identifications have been discussed above. I defined several tooth-types based on differing susceptibility of each type to various dental conditions. All teeth were assigned to either one of four permanent types (anterior, premolar, first or second molar, third molar), or to one of three deciduous types (anterior, first molar, second molar). This classification allowed us to modify the model so that it accounted for variation in the number of teeth from each type that were observable in each individual. Additionally, tooth-types were weighted based on their expected occurrence in the population (0.375, 0.25, 0.25, and 0.125, 0.6, 0.2, 0.2, respectively). The inclusion of these dependent variables in the model controlled for variation in the analysis without breaking the sample down into multiple subgroups, thus preserving sample size.

RESULTS

Permanent and deciduous teeth were considered separately in all analyses. The first analytical step was to calculate rates of dental pathological conditions at both individual and tooth levels. I grouped all individuals who had at least one observable tooth by their status, and compared the percentage of people affected by each condition across periods. No significant status differences were identified (Table 3). Similarly, no significant status differences were found when teeth were grouped by status and compared across time (Table 4). Differing patterns were found when adult individuals, and the teeth of adults, were divided into female and male samples and compared across periods (Table 5 and 6). Therefore, a sex-by-period interaction was included in the log-linear model, and individuals of unknown sex were excluded from further analyses.

As part of the logistic regression, the Wald statistic was calculated to test the null hypothesis that groups are characterized by similar rates of dental pathological conditions. To create a visual representation of these data, rates of dental conditions, adjusted for sample variations in size, age-at-death, and tooth-type, were plotted.

Deciduous teeth affected by carious lesions generally increased through time (Fig. 3), although this pattern is not statistically significant ($P < 0.2680$). Female adult carious lesions rates show a similar trend (Fig. 4), which is significant ($P < 0.0077$). Temporal variation in male carious lesion rates are not significant ($P = 0.4903$), and shows no pattern (Fig. 4). Significant differences were identified between female and males in the Middle and Late Gallinazo phases ($P = 0.0051$ and 0.0286,

Table 3. Individuals affected by dental pathological conditions

Period Status	Deciduous Carious Lesions		Permanent Carious Lesions		Permanent Periodontal Disease		Permanent Abscesses		Permanent Tooth Loss	
	n	%	n	%	n	%	n	%	n	%
Salinar										
high	28	25	31	74	14	86	17	47	19	68
low	1	0	5	100	3	100	3	67	3	33
Early Gallinazo										
high	27	37	36	64	6	83	21	43	22	59
low	35	29	42	50	7	71	15	47	16	69
Middle Gallinazo										
high	10	30	21	71	7	86	15	53	16	63
low	32	44	36	61	12	67	20	35	24	58
Late Gallinazo										
high	4	25	11	73	4	100	6	17	6	67
low	21	29	18	67	7	43	11	45	11	55

Table 4. Teeth affected by dental pathological conditions

Period Status	Deciduous Carious Lesions n	%	Permanent Carious Lesions n	%	Permanent Periodontal Disease n	%	Permanent Abscesses n	%	Permanent Tooth Loss n	%
Salinar										
high	263	20	350	18	236	39	360	7	616	13
low	15	0	81	12	69	30	113	7	159	3
Early Gallinazo										
high	153	16	287	21	62	24	281	12	683	11
low	217	10	293	19	116	45	310	13	717	12
Middle Gallinazo										
high	62	13	159	30	92	20	170	12	409	11
low	262	15	323	21	47	45	260	7	627	7
Late Gallinazo										
high	98	11	69	35	54	41	75	7	196	23
low	29	10	154	23	22	73	217	8	478	7

respectively).

Adult periodontal disease rates show changes over time for both females (P = 0.2383) and males (P = 0.0871), but the pattern of change is different than that seen in carious lesion rates (Fig. 5). Among both females and males periodontal disease rates increased from the Salinar to the Early Gallinazo phase and then fell from the Early to the Middle Gallinazo. Throughout these periods, female rates were higher than males, but these differences are only marginally significant during the Early Gallinazo phase (P = 0.0961). The female and male patterns dramatically change in the Late Gallinazo phase, when there is a significant increase in periodontal disease among males (P = 0.0286), but female rates continue to fall.

Dental abscessing and antemortem tooth loss among females and males display no clear temporal patterns. Females are more often affected by these conditions than males (Figs. 6 and 7). Differences in the rates of abscessing are only statistically significant during the Middle Gallinazo phase (P = 0.0536). Antemortem tooth loss differences between females and males are significant during the Salinar (P = 0.0257) and Middle Gallinazo (P = 0.0286).

DISCUSSION

What do the various measure of dental pathological conditions tell us about agricultural consumption at the site of Cerro Oreja during the periods preceding the development of the state? Carious lesion rates suggest that adult females, and to a lesser extent children, carbohydrate consumption steadily increase through time (Figs. 3 and 4). This seems to support the hypothesis that an intensification of agricultural

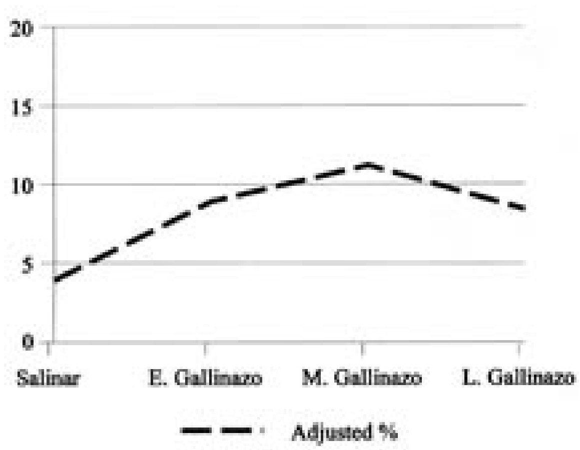

Fig. 3. Deciduous carious lesion rates by period.

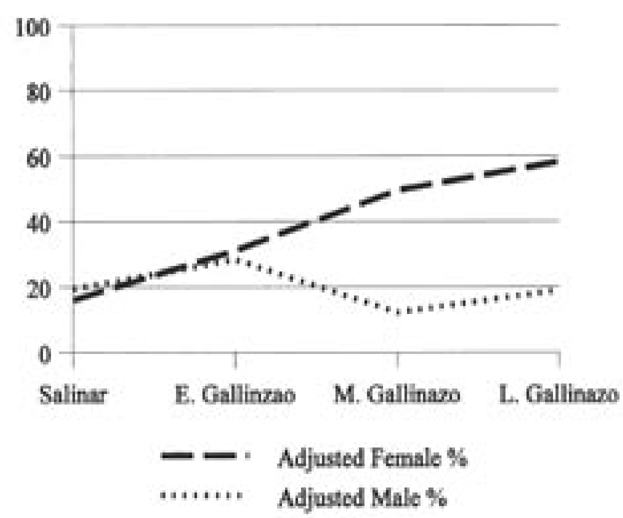

Fig. 4. Carious lesion rates for females and males by period.

Table 5. Individuals affected by dental pathological conditions

Period Sex	Carious Lesions n	Carious Lesions %	Periodontal Disease n	Periodontal Disease %	Permanent Abscesses n	Permanent Abscesses %	Permanent Tooth Loss n	Permanent Tooth Loss %
Salinar								
female	9	87	7	86	9	56	9	89
male	7	86	7	86	7	29	7	43
Early Gallinazo								
female	12	83	6	100	14	43	14	86
male	16	63	7	86	19	58	20	65
Middle Gallinazo								
female	15	93	10	80	17	53	20	75
male	7	57	7	86	10	30	11	64
Late Gallinazo								
female	7	86	8	75	10	40	10	70
male	4	50	3	67	6	17	6	50

production, and a correlated increased in staple consumption, was central to the development of the Moche state. However, adult male consumption does not follow this pattern (Fig. 4). Rather, it appears that males consumed fewer starchy and/or sugary staple agricultural products than did children and females, in amounts that did not change over time. An increasingly different diet among males, compared to females and children suggests increasingly differentiated gender roles in society.

What kinds of changes in gender roles might have resulted in such different diets? As a point of comparison I offer the Inka state's policy of mit'a labor, in which men were required to work on large-scale, state-sponsored projects. While taking part in such work parties laborers were supplied with specialized food-stuffs (D'Altroy and Earle, 1985; Hastorf, 1990, 1991, 1993). Similarly, the substantial investment in public construction in the Moche valley throughout the study period would certainly have required elites to marshal and supply a sizable work force (Table 1). Therefore, I suggest that the men of Cerro Oreja were being increasingly drafted by the elite into similar work parties where they were provisioned with, or offered as an enticement, meat and/or marine resources, while women and children continued to tend agricultural fields and consume the staple crops they produced.

Periodontal disease rates do not follow the same pattern as carious lesion rates, for either females or males (Fig. 5). This suggests that periodontal disease in the Cerro Oreja sample is not as closely linked to consumption as carious lesion rates. To understand this pattern I examined how non-food items that people put into their mouths can affect the oral environment.

Table 6. Teeth affected by dental pathological conditions

Period Sex	Carious Lesions n	Carious Lesions %	Periodontal Disease n	Periodontal Disease %	Permanent Abscesses n	Permanent Abscesses %	Permanent Tooth Loss n	Permanent Tooth Loss %
Salinar								
female	107	17	82	54	150	1	233	13
male	111	22	90	46	130	6	199	7
Early Gallinazo								
female	109	32	45	76	148	14	284	18
male	123	28	45	64	161	23	367	17
Middle Gallinazo								
female	126	43	45	44	152	13	351	15
male	54	15	31	42	83	6	176	10
Late Gallinazo								
female	59	53	32	34	85	8	184	17
male	54	13	13	77	44	2	96	6

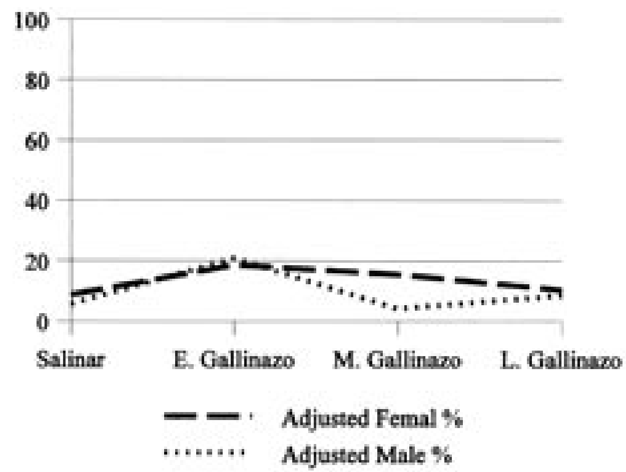

Fig. 5. Periodontal disease lesion rates for females and males by period.

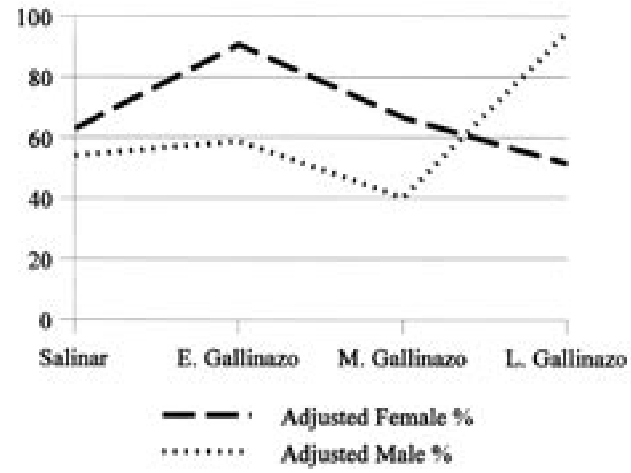

Fig. 6. Abscess rates for females and males by period.

Coca leaf chewing is a common activity in the Andes with a very long history (Rostworoski, 1988; Plowman, 1985; Allen, 1985, 1988). Because of the stimulant qualities of coca and the corrosive nature of the lime with which coca leaves are chewed, this activity is associated with alveolar resorption, periodontal disease, and the development of carious lesions in the subsequently exposed tooth roots (Langsjoen, 1996; Indriati, 1997; Indriati and Buikstra, 2001). Unfortunately, the poor curation of the Cerro Oreja skeletal collection resulted in the fragmentation of many tooth roots, thus the rate of root lesions could not be compared to that of crown lesions. Such a comparison could have provided support for my interpretation.

Archaeological investigations in the Moche valley provide information relevant to the question of coca use at Cerro Oreja. Billman (1996, 1997) has identified an in-migration of highland people into the Moche valley during the beginning of the Gallinazo phase, based on the appearance of sites dominated by highland ceramics. Of particular interest is the highlander occupation of the limited coca growing areas located in the upper portion of the middle valley. The occupation of these areas by highlanders may have resulted in a reduced access to and use of coca by local residents, as indicated by the decrease in periodontal disease from the Early to the Middle Gallinazo period. Billman proposed that these distinctive highland sites were abandoned as highlanders were displaced, absorbed, and/or eliminated by the end of the Gallinazo phase. In the Late Gallinazo coca may again have been available to valley residents, but increasing gender role differentiation resulted in its use by men, not women. Since coca chewing increases work capacity (Allen, 1985; Plowman, 1985), this may again be an example of elites provisioning men as they labor on irrigation and ceremonial construction projects.

Beyond coca's dramatic biological effects, it has, and has had, important religious and social significance to Andeans (Isbell, 1978; Allen, 1985, 1988; Weismantel, 1988). Thus I would suggest, that its effects on work capacity is only part of the story. The Moche valley elite may have offered coca as payment to common men for their labor, and in this way engaged them as willing participants in their state-building projects.

Female and male rates of dental abscesses and antemortem tooth loss show little difference and no patterned change over time (Figs. 6 and 7). Because these are not primary conditions, but are the result of untreated dental caries (crown or root), periodontal disease and/or dental wear, this lack of temporally patterned variation may be the result of an "averaging"

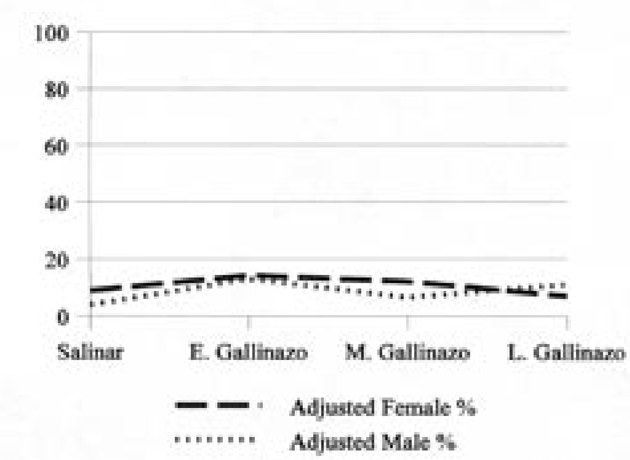

Fig. 7. Antemortem tooth loss rates for females and males by period.

of the effects of these primary pathological conditions.

CONCLUSION

In this analysis I tested the hypothesis that the development of the Moche state (AD 200–800), one of the earliest and most hierarchical in the Americas, was based on intensification of irrigation agriculture. This hypothesis is based on the dramatic increase of arable land in the Moche Valley during the Salinar and Gallinazo phases, prior to the development of the state and during the early period of state development (Table 1). As people increased agricultural production, they would also have increased their consumption of starchy and/or sugary agricultural products. My analysis suggests women and children did increasingly focus their diet on agricultural products (Figs. 3 and 4). These findings seem to confirm the hypothesis that increased irrigation and reliance on agricultural production was fundamental to the development of the Moche state. However, the story is more complex. Men's diets remained consistent through time (Fig. 4). Additionally the data suggest that women and men's use of coca varied temporally, in significantly different ways (Fig. 5). Status seems to have been of little import in determining diet before and during early periods of the state, in dramatic contrast to what we know of its importance during the zenith of the state's power. Together these data suggest that increasing differentiation of gender roles was important to the development of the state. Gender differences may have been the most salient force in the transition to political hierarchy and social stratification in the Moche valley.

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