

## RESOURCE USE THROUGH TIME AT PALOMA, PERU

Elizabeth J. Reitz<sup>1</sup>

Animal remains from Paloma, a Preceramic site in the Chilca Valley occupied between 7800 and 4700 B.P., indicate that marine resources were primary to animal-based subsistence. In the Paloma material, terrestrial vertebrates and terrestrial invertebrates contribute 10% of the estimated biomass, whereas marine vertebrates and invertebrates contribute 90% of the biomass. This stratified site offers evidence for subsistence change, but the focus on marine resources did not change. Vertebrates of warm-temperate waters are common in the Paloma assemblage and more common than at Peruvian coastal sites farther north at this same time. Decline in anchovies between 5300 and 5100 B.P. coincides with the brief presence of warm-tropical animals and increase in diversity. At approximately 4700 B.P., there is another decline in anchovies, an increase in high-trophic-level fishes, and a decrease in diversity. Data are consistent with the end of the warmer, more humid Hypsithermal around 5000 B.P.

**Key words:** Archaic Period, climate change, marine resource use, mid-Holocene, Peru, zooarchaeology

Archaeologists have long debated the extent to which humans used marine resources relative to terrestrial animals and plants. The debate has centered on the ability of marine resources to support large, sedentary populations with complex social organizations and monumental architecture, such as at the late Preceramic site of El Paraiso, Peru (Quilter and Stocker 1983). From a nutritional perspective, it is unlikely that people ever concentrated exclusively upon either terrestrial or marine resources (e.g., Weir et al. 1988; Weir and Dering 1986), but vertebrate and invertebrate data from the middle Preceramic village of Paloma, on the central coast of Peru, support the argument that marine resources provided most of the animal-based portion of the diet during the Preceramic Period. Data from Paloma and other Peruvian sites do not support the hypothesis that this pattern developed out of an earlier coastal hunting tradition focused on terrestrial resources.

The Paloma data, however, do support the hypothesis that a change in fishing strategy occurred after 5300 B.P. when changes in subsistence strategy also occurred at other coastal sites. At sites on the Peruvian north coast, this change is seen as a shift in focus from warm-tropical fishes to warm-temperate fishes (Reitz 2001) and a decline in mean trophic level of the catch (Andrus 2000). At Paloma, it appears as a decrease in warm-temperate fishes associated with upwelling, specifically a decrease in anchovies, and an increase in mean trophic level of the catch.

In 1975, Michael Moseley (1975) proposed the Maritime Foundations Hypothesis. This hypothesis proposes that the economic foundation of a civilization need not be agricultural; a complex social organization could be supported with maritime resources as the subsistence base. Moseley's hypothesis applies to the period between 3000 and 1000 B.C. It also has application to the subsistence base at Paloma during the centuries preceding the late Preceramic, or Formative, Period (Reitz 1988a, 1988b).

This paper examines the contributions of maritime resources to coastal economies before 3000 B.C., rather than implying that those resources formed the subsistence base for complex social organization after that time. The argument will focus on data from the Preceramic (Archaic) village of Paloma. These data from Paloma indicate that the maritime subsistence base of Peruvian coastal economies in the late Preceramic was not a recent phenomenon in Peruvian history, but appeared as early as 7800 B.P. In fact, data from six Peruvian sites occupied between 10,575 and 4780 B.P. support this hypothesis (Keefer et al. 1998; Reitz 1995, 2001; Reitz and Sandweiss 2001; Sandweiss et al. 1989; Sandweiss et al. 1998).

The Paloma data are important in this argument because the site is stratified, permitting an examination of marine resource use over a 3000 year period. The faunal remains from Paloma clearly demonstrate continuity in the marine focus throughout this time. They also indicate two important discontinuities. The first discontinuity appears after 5300 B.P. as a decrease in the use of anchovies with the brief presence of warm-

<sup>1</sup>Professor of Anthropology, Georgia Museum of Natural History, University of Georgia, Athens, GA 30602-1882, USA.

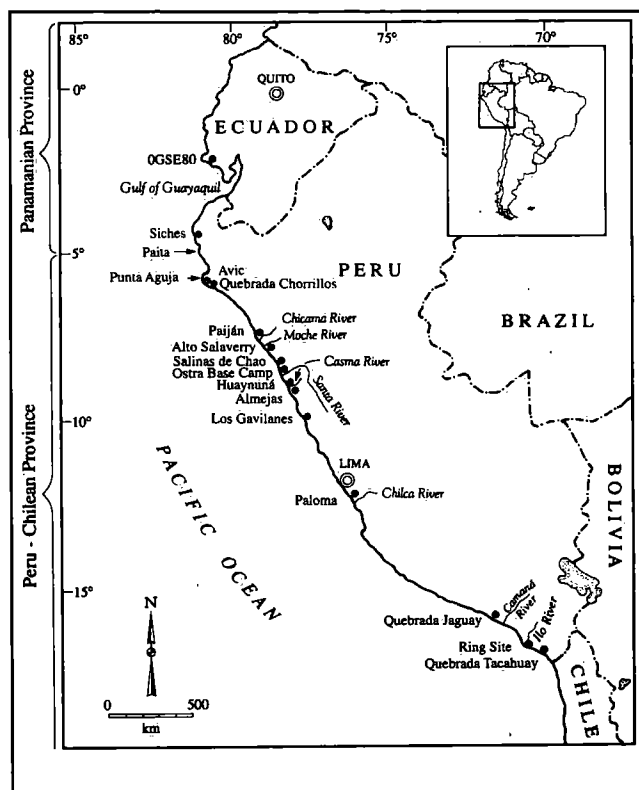


Figure 1. Location of Paloma and other sites.

tropical animals and an increase in diversity. The second discontinuity is a further decrease in the use of anchovies, an increase in mean trophic level of fishes represented, and a decrease in diversity of fishes caught at the end of the occupation, around 4700 B.P. Fishes associated with upwelling shift in importance in the catches at Paloma after 5300 B.P. The mean trophic level of marine vertebrates exploited at sites further north is consistently higher than that at Paloma. Over the period that the mean trophic level of fishes used at Paloma increases, the mean trophic level at northern sites declines (Andrus 2000).

Located in the Chilca Valley of Peru, about 65 km south of Lima (Benfer 1984, 1999; Engel 1980; Fig. 1), Paloma is an Archaic, or middle Preceramic, village with no monumental architecture. Paloma is situated on an alluvial plain 200-250 m above sea level on the north edge of the *lomas* of Paloma. *Lomas*, also known as fog oases, are plant communities found at about the 200 m line along the desert coast of Peru. *Lomas* plants are generally seasonally available, sustained by the austral winter fog that forms at this elevation. The plain is approximately 250 x 600 m and the village occupies approximately 15 ha. The Chilca River is dry, except for the summer when

some runoff from the highlands flows down its course. The coast near the village is composed of both rocky and sandy beaches. Paloma is located in the warm-temperate Peru-Chilean Province.

More than 55 houses, associated with over 200 burials, were encountered in the 2,860 square meters excavated. The village is about 8 linear km north of the Chilca River and approximately 4 linear km from the Pacific Ocean.

The number of levels per square varied depending on the depth of the deposit. Four strata are represented, designated as Levels 100 through 400. Level 100 is the most recent stratum and Level 400 is the oldest. Earlier strata were present at the site, but faunal remains from them were not represented in the probability samples reported here. Uncorrected radiocarbon dates indicate the village was occupied between 7800 and 4700 B.P. (Benfer 1990). In order of increasing depth, the dates for each level are: Level 200 (4700-5100 B.P.), 300 (5100-5300 B.P.), and 400-600 (5300-7800 B.P.). For Level 100, the occupational date is not based on radiocarbon tests. Stratigraphically, Level 100 was deposited after 4700 B.P. and the occupation probably ended before 3000 B.P. Level 100 is considered pre-Formative (before the Cotton Preceramic) because neither ceramics nor cotton were recovered. The end of the Hypsithermal is roughly associated with the 5200-5000 B.P. date, occurring at the end of the Level 300 occupation or during the Level 200 occupation (Benfer 1999).

#### FAUNAL SAMPLES

Two sampling strategies were followed by Benfer and his colleagues for recovering faunal remains (Fig. 2). During excavation of the 6 x 6 meter squares in 1976 and the 3 x 3 meter squares in 1979 some faunal materials were collected as they were encountered, generally without the aid of a screen. Fauna from these "grab" samples are published elsewhere (Reitz 1988a, 1988b). Because they provide the only evidence for marine mammals, seasonal occupation, and long-distance trade, the grab samples are important to the interpretation of the site.

Fig. 2 shows the data from probability samples collected from the walls of sixteen 3 x 3 m probability squares, of which six are reported here. These six were collected using a nested series of geological screens with 6 mm, 3 mm, and 1.5 mm mesh (Weir et al. 1988). The samples were collected as standardized volumetric 5-liter (5000 cm<sup>3</sup>) samples from each natural level. As Fig. 2 shows, the portion of the site excavated was quite small, but the samples are thought to represent the site

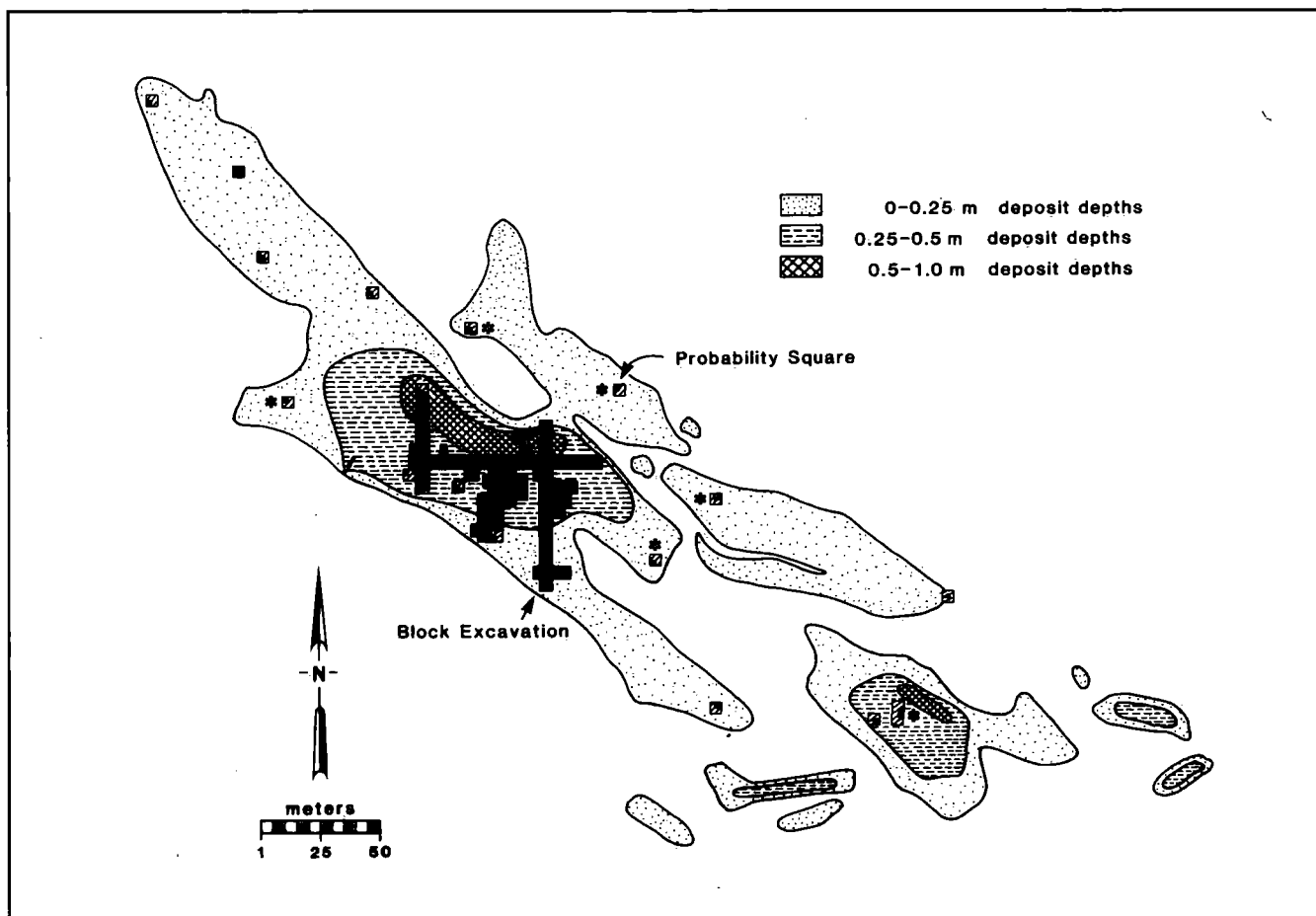


Figure 2. Map of Paloma. Probability squares are shown as hatched squares and general block excavation units are darkened. The squares from which the samples reported here were taken are designated by stars. The three strata also delimit the site.

as a whole because they are random stratified samples of three areas of site defined by density of deposits (Benfer 1990, 1999).

Standard zooarchaeological methods were used during identification and analysis of the animal remains. The identifications were made using the comparative skeletal collection of the Environmental Archaeology Laboratory, Florida Museum of Natural History, University of Florida. Minimum Numbers of Individuals (MNI) are estimated using conservative criteria. For vertebrates these criteria include symmetry, size, and age. For gastropods, MNI is based on the number of apices. In the case of bivalves, symmetry for valves with hinge areas intact is determined, and the larger count (left or right valves) is used as an estimate of MNI. Each probability square is treated as a separate analytical unit because the units were widely spaced across the site. Each level within a square is also a separate analytical unit. MNI is not normally estimated for high taxonomic categories such as class. However, in the

case of Unidentified Mammal, the five unidentifiable mammal specimens represent at least one additional mammalian individual because they were too large to be from the Unidentified Rodent. Hence the MNI includes one Unidentified Mammal individual and one Unidentified Rodent individual. It is not possible to determine if the Unidentified Mammal was a marine or terrestrial animal. The single bird specimen indicates that at least one bird individual, of unknown family, genus, or species, was present.

Although MNI is a standard zooarchaeological quantification method, it has several problems (Reitz and Wing 1999:194-199). A faunal assemblage may have a higher percentage of anchovy individuals than guanaco individuals, although it is unlikely that anchovies contributed more meat than did guanacos. Further, MNI is based upon the assumption that the entire animal was utilized at the site. This ignores a basic facet of human behavior: exchange and trade. In addition to these problems, MNI is based upon paired elements. A large

Table 1. Allometric values used in this study.

Faunal category	n	log a	b	r <sup>2</sup>
<u>Biomass from bone weight, kg</u>				
Mammal	97	1.12	0.90	0.94
Bird	307	1.04	0.91	0.97
Chondrichthyes	17	1.68	0.86	0.85
Osteichthyes	393	0.90	0.81	0.80
Non-perciformes	119	0.85	0.79	0.88
Siluriformes	36	1.15	0.95	0.87
Perciformes	274	0.93	0.83	0.76
Serranidae	18	1.51	1.08	0.85
Carangidae	17	1.23	0.88	0.86
Haemulidae	25	0.84	0.82	0.42
Sciaenidae	99	0.81	0.74	0.73
<u>Edible meat wgt. from shell wgt., gm</u>				
Pelecypod	79	0.018	0.681	0.83
Gastropod	134	-0.162	0.918	0.89

quantity of unpaired elements, such as anchovy vertebrae and drum teeth, generally indicates only one individual in spite of the large number of vertebrae or teeth present. In addition, the manner in which data from multiple archaeological proveniences are aggregated during analysis influences MNI results (Grayson 1973). Some elements are more easily identified than others. The taxa represented by such elements may appear more significant in the species list than they were in the daily diet.

One way to overcome these difficulties is to estimate the amount of meat the identified animals contributed to the diet. Estimates of meat (biomass) contributed by the identified specimens and an animal's body size can be made using the allometric principle that the proportions of body mass, skeletal mass, and skeletal dimensions change with increasing size. Meat weight, estimated from the allometric relationship between body mass and skeletal mass, provides information on the quantity of meat supplied by the identified species. The relationship between body mass and skeletal weight or a skeletal dimension is described by the allometric equation

$$Y = aX^b$$

(Simpson et al. 1960:397). In this equation,  $X$  is the skeletal weight,  $Y$  is the quantity of meat,  $b$  is the constant of allometry (the slope of the line), and  $a$  is the  $Y$ -intercept for a log-log plot using the method of least squares

regression and the best fit line (Reitz and Wing 1999:221-231). Values for  $a$  and  $b$ , derived from calculations based on data at the Florida Museum of Natural History, University of Florida, and the Zooarchaeology Laboratory, Georgia Museum of Natural History, are presented in Table 1.

Several factors need to be considered when evaluating the biomass results. Biomass estimates for invertebrates may be in error because no Pacific taxa were included in the data from which the formulae were obtained. Likewise, few Pacific vertebrates are included in the vertebrate formulae. It is, however, doubtful that the growth patterns for Pacific members of the drum family, for example, are very different from that for Atlantic members of that family. An additional problem is that the allometric calculations in which specimen weight is used to predict meat weight are influenced by the weight of the specimens themselves, which in turn is influenced by a variety of factors (Reitz and Wing 1999:170). The formulae for invertebrates predict soft-tissue weight from archaeological shell weight, whereas that for vertebrates predict specimen and soft-tissue weight from the weight of the archaeological specimen. The estimated biomass values for invertebrates and vertebrates, therefore, are not as equivalent as the treatment of them here would suggest. Improved allometric formulae are needed to correct this problem.

The variety of exploited species and degree of subsistence specialization of the human inhabitants can be summarized by calculating the diversity and equitability in the species identified. Diversity measures the number of species used at the site. Equitability measures the degree of dependence on the utilized resources and the effective variety of species used at the site based on the even, or uneven, use of individual species. These indices enable discussion of food habits in terms of the variety of animals used at the site (diversity) and the evenness (equitability) with which species were utilized. Diversity is measured using the Shannon-Weaver Index (Pielou 1966; Shannon and Weaver 1949:14). Equitability is measured using the Sheldon formula (Pielou 1966; Sheldon 1969).

Diversity increases as both the number of species and the equitability of species abundance increases. A diversity index of 4.99 is the highest possible value. A sample with many species in which the number of individuals slowly declines from most abundant to least abundant will be high in diversity. Diversity is increased if a new taxon is added to the list. Diversity is decreased slightly if another individual of a taxon that is already present, though scarce, is added. A low diversity can be

obtained either by having few species or by having a low equitability, where one species is considerably more abundant than others. A low equitability value indicates that one species was more heavily used than other species in the sample. A high equitability index, approaching 1.0, indicates an even distribution of species in the sample following a normal pattern with a few abundant species, a moderate number of common ones, and many rare ones. It is important to remember that diversity and equitability are dependent on sample size (Grayson 1981:82-85). They are no more reliable than the primary and secondary data (MNI, specimen weight, number of identified specimens [NISP], or biomass) used to generate the indices.

Another way to assess the fishing strategy is to estimate the mean trophic level of the catch for each time period and to identify the trophic level from which most of the resources were taken. Daniel Pauly and his colleagues suggest that since the 1950s commercial fishing has declined in response to a significant change in marine ecosystems caused by over-fishing (Pauly and Christensen 1995; Pauly et al. 1998, 2000). They term this "fishing down the food web" and estimate the mean trophic level of commercial fisheries using modern fisheries data.

In the study of Paloma, the trophic level exploited is estimated using a modification of this approach, substituting archaeological data from Paloma for modern fisheries data. Archaeological data are assigned a trophic level using modern trophic level data presented by Froese, Pauly, and others (1998; Froese and Pauly 1998). This calculation was done using only fishes in order to be comparable to similar calculations using archaeological data from northern Peru (Andrus 2000). In some cases it was necessary to use higher taxonomic levels because the taxonomic identification in the archaeological data, the trophic level study, or both were insufficiently precise. If the archaeological taxonomic identification was not included by Pauly, the trophic level for the closest taxonomic category was used. In estimating the importance of a trophic level to the fishery of a specific time period, the formula

$$TL_i = \sum (TL_{ij})(Biomass_{ij}) / \sum Biomass_{ij}$$

was used; where  $TL_i$  is the mean trophic level for the time period  $i$ ;  $TL_{ij}$  is the mean trophic level of the taxon  $j$  for the time period  $i$ ; and  $Biomass_{ij}$  is the estimated biomass of the taxon  $j$  for the time period  $i$ . This formula estimates the mean trophic level at one point in time.

In interpreting biological materials, careful attention

Table 2. Paloma probability samples, summary, levels combined.

	MNI		Biomass	
	n	%	gm	%
Terrestrial mammals	2	0.5	84.5	8.6
Birds	1	0.2	8.9	0.9
Fish	129	30.2	746.3	75.6
Terrestrial gastropods	6	1.4	5.4063	0.5
Marine gastropods	55	12.9	10.7499	1.1
Chitons	1	0.2		
Mytilidae	203	47.5	85.9123	8.7
Other mollusca	21	4.9	45.3716	4.6
Crabs	9	2.1		
Total	427		987.1401	
Rocky beach mollusks	259	60.7	96.6622	9.8
Sandy beach mollusks	21	4.9	45.3716	4.6

should be paid to sample reliability. A clue to this is sample size. Samples of fewer than 200 individuals may be unrepresentative of the subsistence activity at a site (Wing and Brown 1979:118-121). Specimen count and MNI are interrelated; samples with low specimen counts and low MNI are probably incomplete. The species list will be too short and the relationships of the identified taxa will be inaccurate. Derived measures, such as diversity and equitability, are also dependent on sample size (Grayson 1981). In the case of the Paloma data, increased sample sizes would probably alter details of the species list and diversity for each level. It is unlikely that the basic emphasis upon marine resources observed in these samples will change with more data, but only additional work will prove or disprove this assumption.

## RESULTS

The primary data are presented in six tables. Table 2 summarizes all the probability data for the site. Tables 3 and 4 summarize these same MNI and biomass data, but for each level. MNI and biomass for taxa identified in the probability samples from each of the four levels are presented in tables 5 and 6. Table 7 presents the diversity and equitability values. Data on taxa for which MNI is not estimated (e.g., Unidentified Vertebrate) are reported elsewhere (Reitz 1988b).

Marine resources were the primary source of the diet derived from animal foods (Table 2). Less than 1% of the individuals are birds and mammals, and these contribute less than 9% of the biomass. Even these animals might represent marine rather than terrestrial

Table 3. Paloma probability samples, summary of MNI by level.

Taxa	Level 100		Level 200		Level 300		Level 400	
	MNI	%	MNI	%	MNI	%	MNI	%
Mammals					2	0.9		
Birds					1	0.4		
Fish	13	39.4	35	31.3	54	23.8	27	49.1
Terrestrial gastropods					6	2.6		
Marine gastropods	13	39.4	21	18.8	19	8.4	2	3.6
Chitons			1	0.9				
Mytilidae	3	9.1	46	41.1	129	56.8	25	45.5
Other mollusca	3	9.1	5	4.5	13	5.7		
Crabs	1	3.0	4	3.6	3	1.3	1	1.8
Total	33		112		227		55	
Rocky beach mollusks	16	48.5	68	60.7	148	65.2	27	49.1
Sandy beach mollusks	3	9.1	5	4.5	13	5.7	0	
Vertebrates	13	39.4	35	31.3	57	25.1	27	49.1
Invertebrates	20	60.6	77	68.8	170	74.9	28	50.9
Small fish	5	15.2	25	22.3	38	16.7	20	36.4
Large fish	8	24.2	10	8.9	16	7.0	7	12.7
Mytilidae	3	9.1	46	41.1	129	56.8	25	45.5

resource use because identification of the bird and one of the mammals is not sufficiently precise to determine if they were terrestrial or marine. Terrestrial invertebrates, represented only by land snails (*Scutalus* spp.), contribute 1% of the individuals and less than 1% of the biomass. Marine fishes contribute 30% of the individuals and 76% of the biomass. The remaining individuals (68%) and biomass (14%) are marine invertebrates.

Although some change can be seen in the percentage of individuals and biomass contributed by invertebrates and vertebrates during the 3000 years represented by the four levels, fish are the major contributors of biomass in all four levels (tables 3 and 4). Fish average 36% of the individuals and 83% of the biomass in the four levels. Invertebrate animals average 64% of the individuals in the four levels and 13% of the biomass. The number of vertebrate individuals is highest in Level 400 and lowest in Levels 200/300. The reverse is true for invertebrates. There is a similar change between vertebrate and invertebrate biomass in Levels 400 and 300. At the later end of the sequence (Level 100), small fishes and mussels (*Mytilidae*) are less common and large fishes are much more abundant.

*Vertebrates.* Changes in the percentage of fish

individuals and biomass are found among the levels (tables 3 and 4). Use of fish declines from 49% of the individuals and 92% of the biomass in Level 400 to 24% of the individuals and 67% of the biomass in Level 300. Fish percentages increase to 31% of the individuals and 82% of the biomass in Level 200, and 39% of the individuals and 91% of the biomass in Level 100. The decline in fish between Levels 400 and 300 affects both large fishes, such as cabrilla (*Paralabrax* spp.), jacks (cf. *Carangidae*, *Trachurus* spp.), grunts (*Haemulidae*, *Anisotremus* spp., *Haemulon* spp., *Isacia* spp., *Orthopristis* spp.), and drums (*Cynoscion* spp., *Paralichthys peruanus*, *Corvina* [*Sciaenidae*] *deliciosa*), as well as small fishes, such as herrings (*Clupeidae*) and anchovies (*Engraulidae*). However, the increase in fish in Level 100 is primarily due to an increase in MNI and biomass of grunts and drums (tables 5 and 6). Herrings are not present in Level 100 and the percentage of anchovies declines from Level 200 to Level 100. Anchovies are the most common individuals in samples from Levels 200, 300, and 400. They are the largest source of biomass in Levels 200 and 400. Compared to Level 400, in Level 100 they contribute about half the number of individuals and the biomass.

The decline in fish between Level 400 and Level

Table 4. Paloma probability samples, summary of biomass (gm) by level.

Taxa	Level 100		Level 200		Level 300		Level 400	
	Biomass	%	Biomass	%	Biomass	%	Biomass	%
Mammals					84.5	15.3		
Birds					8.9	1.6		
Fish	84.5	90.9	186.7	82.5	369.2	66.8	105.9	91.9
Terrestrial gastropods					5.4063	1.0		
Marine gastropods	3.2552	3.5	2.8786	1.3	4.4497	0.8	0.1664	0.1
Chitons								
Mytilidae	2.7108	2.9	27.943	12.3	46.0884	8.3	9.1701	8.0
Other mollusca	2.4571	2.6	8.8602	3.9	34.0543	6.2		
Crabs								
Total	92.9231		226.3818		552.5987		115.2365	
Rocky beach mollusks	5.966	6.4	30.8216	13.6	50.5381	9.1	9.3365	8.1
Sandy beach mollusks	2.4571	2.6	8.8602	3.9	34.0543	6.2	0	
Vertebrates	84.5	90.9	186.7	82.5	462.6	83.7	105.9	91.9
Invertebrates	8.423	9.1	39.682	17.5	89.999	16.3	9.337	8.1
Small fish	23.2	25.0	110.6	48.9	221.4	40.1	61.1	53.0
Large fish	61.3	66.0	76.1	33.6	147.8	26.7	44.8	38.9
Mytilidae	2.7108	2.9	27.943	12.3	46.0884	8.3	9.170	8.0

300 is accompanied by an increase in invertebrates. However, this decline also is due to the identification in Level 300 of the only non-marine organisms in the probability samples, Unidentified Mammal, Unidentified Rodent, Unidentified Bird, and land snails (*Scutalus* spp.). This might be interpreted as a major shift in the subsistence effort were it not for the fact that the Level 300 collection is much larger than the collections from other levels. The number of identified specimens in Level 300 is 3,318 out of a total 6,152 specimens in the probability samples. The two mammals and the single bird are from the same level in the same square (N125E145). The number of identified specimens from Level 300 of N125E145 constitute 22% of all of the probability specimens included in this study. Such an increase in diversity, and the identification of unusual taxa, is what would be expected of a larger sample. (In the grab samples, Camelidae and Cervidae are ubiquitous in Level 300, but very rare in Levels 100-200.)

*Invertebrates.* Among the marine invertebrates some changes in exploitation through time are also evident (tables 3 and 4). Invertebrates increase from 51% of the individuals and 8% of the biomass in Level 400 to 75% of the individuals and 16% of the biomass in Level 300. The increase in invertebrates between Levels 400

and 300 is partly due to an increase in the use of mussels (Mytilidae), particularly *Perumytilus purpuratus* (tables 5 and 6). *P. purpuratus* increases from 14% of the individuals in Level 400 to 24% of the individuals in Level 300 even though it contributes only 5% of the biomass in both levels. Much of the increase in mussels between Level 400 and Level 300 also is due to an increase in *P. purpuratus*, a rocky shore mussel, as well as the mussel *Semimytilus algosus*.

Another reason invertebrate use increases in Level 300 is the identification of several new taxa. Two of these new taxa, the wedge clam (*Mesodesma donacium*) and the Venus clam (*Protothaca thaca*), contribute 6% of the biomass in Level 300. The more abundant of the new taxa, *P. thaca*, contributing 4% of the individuals and 5% of the biomass, is found only in Level 300 of square N125E145, the same one with the only evidence for terrestrial animal use in the probability samples. Both *M. donacium* and the land snails *Scutalus* spp. are represented in several squares. *M. donacium* and *P. thaca* are both sandy-beach resources, a biotope not represented in Level 400.

Invertebrate use appears stable between Levels 300 and 200 largely due to the identification of the mussel *Choromytilus chorus* in Level 200 of square N120E10.

Table 5. Paloma probability samples, MNI by level.

Taxa	Level 100		Level 200		Level 300		Level 400	
	MNI	%	MNI	%	MNI	%	MNI	%
Unidentified Mammal					1	0.4		
Unidentified Rodent					1	0.4		
Unidentified Bird					1	0.4		
Clupeidae (herrings)			2	1.8	8	3.5	1	1.8
Engraulidae (anchovies)	5	15.2	23	20.5	30	13.2	19	34.5
<i>Paralabrax</i> spp. (cabrilla)					1	0.4		
cf. Carangidae (possible jacks)					1	0.4		
<i>Trachurus</i> spp. (jurels)							1	1.8
Haemulidae (grunts)	5	15.2	4	3.6	3	1.3	3	5.5
<i>Anisotremus</i> spp. (grunt)			1	0.9			1	1.8
<i>Haemulon</i> spp. (grunt)					1	0.4		
<i>Orthopristis</i> spp. (grunt)					1	0.4		
<i>Isacia</i> spp. (cabinza)					1	0.4		
<i>Cynoscion</i> spp. (seatrout)					1	0.4		
<i>Paralenchurus peruanus</i> (coco)	1	3.0			1	0.4		
<i>Corvina</i> ( <i>Sciaena</i> ) <i>deliciosa</i> (lorna)	2	6.1	5	4.5	6	2.6	2	3.6
<i>Fissurella crassa</i> (keyhole limpet)			9	8.0	9	4.0		
<i>Scurria parasitica</i> (limpet)	5	15.2	6	5.4	5	2.2	1	1.8
<i>Crepidula</i> spp. (slippersnail)	8	24.2	6	5.4	5	2.2	1	1.8
<i>Scutalus</i> spp. (landsnail)					6	2.6		
Polyplacophora (chitons)			1	0.9				
<i>Aulacomya ater</i> (mussel)	1	3.0						
<i>Choromytilus chorus</i> (mussel [choro])			17	15.2				
<i>Perumytilus purpuratus</i> (mussel)			17	15.2	55	24.2	8	14.5
<i>Semimytilus algosus</i> (mussel)	2	6.1	12	10.7	74	32.6	17	30.9
<i>Mesodesma donacium</i> (wedge clam [macha])	3	9.1	5	4.5	3	1.3		
<i>Protothaca thaca</i> (Venus clam)					10	4.4		
Decapoda (crabs)	1	3.0	4	3.6	3	1.3	1	1.8
Total	33		112		227		55	

*C. chorus* contributes 15% of individuals and 8% of biomass in Level 200, though identified only from this one unit. *P. thaca* is not present in Level 200, but *M. donacium* is, contributing 5% of the individuals and 4% of the biomass, an increase from its contribution in Level 300.

The percentage of invertebrates declines between Levels 200 and 100, primarily because of a decrease in mussels (Mytilidae). *Aulacomya ater* and *S. algosus*, the only mytilids identified in Level 100, contribute only 9% of the individuals and 3% of the biomass in Level 100. Two taxa show an increase: slippersnails (*Crepidula* spp.) contribute 24% of the individuals and 3% of the

biomass in Level 100; wedge clams (*M. donacium*) increases to 9% of the individuals, although biomass decreases to 3% in Level 100.

More individuals and more biomass in each of the four levels are from rocky beaches than from sandy beaches. *M. donacium* and *P. thaca* are the only sandy beach taxa identified. *M. donacium* is not present in Level 400, but is present in small amounts in the other levels. In combination with the lower intertidal mytilid, *Perumytilus*, *P. thaca* are identified only in Level 300, where they are one of the largest contributors of invertebrate biomass. In Level 300 sandy and rocky



Table 6. Paloma probability samples, biomass (gm) by level.

Taxa	Level 100		Level 200		Level 300		Level 400	
	Biomass	%	Biomass	%	Biomass	%	Biomass	%
Unidentified Mammal					81.2	14.7		
Unidentified Rodent					3.3	0.6		
Unidentified Bird					8.9	1.6		
Clupeidae (herring)			13.4	5.9	106.1	19.2	13.4	11.6
Engraulidae (anchovies)	23.2	25.0	97.2	42.9	115.3	20.9	47.7	41.4
<i>Paralabrax</i> spp. (cabrilla)					13.5	2.4		
cf. Carangidae (possible jacks)					5.1	0.9		
<i>Trachurus</i> spp. (jurels)							9.4	8.2
Haemulidae (grunts)	30.6	32.9	25.2	11.1	38.8	7.0	17.2	14.9
<i>Anisotremus</i> spp. (grunt)			6.4	2.8			6.4	5.6
<i>Haemulon</i> spp. (grunt)					6.4	1.2		
<i>Orthopristis</i> spp. (grunt)					3.6	0.7		
<i>Isacia</i> spp. (cabinza)					3.6	0.7		
<i>Cynoscion</i> spp. (seatrout)					7.1	1.3		
<i>Paralichthys peruanus</i> (coco)	11.8	12.7			19.7	3.6		
<i>Corvina</i> ( <i>Sciaenops</i> ) <i>deliciosa</i> (lorna)	18.9	20.3	44.5	19.7	50.0	9.0	11.8	10.2
<i>Fissurella crassa</i> (keyhole limpet)			0.9383	0.4	0.4160	0.08		
<i>Scurria parasitica</i> (limpet)	0.02	0.02	0.1764	0.08	0.0932	0.02	0.0832	0.1
<i>Crepidula</i> spp. (slippersnail)	3.2352	3.5	1.7639	0.8	3.9405	0.7	0.0832	0.1
<i>Scutalus</i> spp. (landsnail)					5.4063	1.0		
Polyplacophora (chitons)								
<i>Aulacomya ater</i> (mussel)	2.1523	2.3						
<i>Choromytilus chorus</i> (mussel [choro])			18.5214	8.2				
<i>Perumytilus purpuratus</i> (mussel)			7.1029	3.1	27.7609	5.0	5.9113	5.1
<i>Semimytilus algosus</i> (mussel)	0.5585	0.6	2.3187	1.0	18.3275	3.3	3.2588	2.8
<i>Mesodesma donacium</i> (wedge clam [macha])	2.4571	2.6	8.8602	3.9	7.3590	1.3		
<i>Protothaca thaca</i> (Venus clam)					26.6953	4.8		
Decapoda (crab)								
Total	92.9231		226.3818		552.5987		115.2365	

beaches contribute similar percentages of biomass, although individuals found in rocky habitats are far more common. As individuals from rocky habitats decline, *M. donacium* individuals increase between Levels 200 and 100.

**Diversity and Equitability.** Differences in diversity and equitability among the levels are slight in most cases (Fig. 3; Table 7). Diversity in the MNI data rises from a low in Level 400 to a high in Level 200, and then declines in Level 100. MNI equitability is high in Level 100, probably because only ten taxa were identified, but four of these dominate the collection.

Biomass diversity is generally low (Fig. 4; Table 7). Level 300 collection is the most diverse. Although three taxa dominate Level 300, the amount of biomass contributed by the remaining 19 taxa is variable. This is also the largest of the collections. The biomass diversity is similar in Levels 100, 200, and 400. Biomass equitability is relatively unchanged throughout the occupation.

Diversity and equitability estimates for MNI and biomass data indicate that relatively few taxa were used. Most of the taxa contribute individuals or biomass in relatively equal amounts, but two or three animals dominate

Table 7. Paloma probability samples, diversity and equitability.

Level	MNI				Biomass			
	MNI	n	Diversity	Equitability	Biomass, gm	n	Diversity	Equitability
100	33	10	2.0773	0.9022	92.9231	9	1.6309	0.7423
200	112	14	2.3311	0.8833	226.3818	12	1.7486	0.7037
300	227	23	2.1075	0.6721	552.5987	22	2.4071	0.7787
400	55	11	1.7231	0.7186	115.2365	10	1.7612	0.7649

the collection in each level. The abundant taxa are usually a combination of anchovies, grunts, drums, and a species of mussels. The dominant resource in terms of meat are: Level 400, anchovies; Level 300, mammals, herrings, and anchovies; Level 200, anchovies; and Level 100, anchovies, grunts, and lorna (*Corvina* [*Sciaena*] *deliciosa*).

#### TEMPERATE VERSUS TROPICAL FORMS

The method by which vertebrates are assigned to temperate and tropical groups is described in detail elsewhere (Reitz and Sandweiss 2001: Table 2). Using a number of sources (Chirichigno 1974, 1982; Fowler 1945; Hildebrand 1945; Schweigiger 1964), vertebrates found in early Peruvian and Ecuadorian archaeological assemblages are classified as warm-temperate animals; warm-tropical animals; mixed, unclassified marine animals; or terrestrial animals. Warm-temperate forms are more likely to be found in the Peru-Chilean Province and warm-tropical ones in the Panamanian Province. At most coastal sites marine vertebrates dominate the collection. The most abundant warm-temperate forms are penguins (*Spheniscus humboldti*), boobies (*Sula* spp.), herrings (Clupeidae), anchovies (Engraulidae), and some species of grouper (*Paralabrax* spp.), grunt (*Anisotremus scapularis*, *Isacia conceptionis*), and drum (*Paralichthys peruanus*, *Corvina* [*Sciaena*] *deliciosa*, *Cilus* [*Sciaena*] *gilberti*), as well as mackerel (Scombridae). These contrast with the most common warm-tropical fishes, such as bonefish (*Albula vulpes*), sea catfishes (Ariidae), other species of grouper (*Epinephelus* spp.), grunt (*Conodon* spp., *Haemulon* spp., *Orthopristis* spp.), and drum (*Larimus* spp., *Umbrina* cf. *xanti*), as well as lisas (*Mugil* spp.), and puffers (*Spheroides* spp.). Several other taxa are typical of warm-temperate waters, but may also be found in warm-tropical settings. These variable species are unclassified and referred to as mixed. While none of these species is confined to the condition in which it is classified here, this approach permits a rough classification of fishes in terms of water conditions.

The Paloma probability samples are dominated by temperate fishes typical of the Peru Current; only 1% of the individuals are tropical/estuarine. Tropical animals are present in the Paloma probability samples only in Level 300 (Table 8). This not simply a function of recovery technique; tropical vertebrates constitute only 5% of the individuals in the grab samples (Reitz and Sandweiss 2001: Table 3). The tropical species identified in either the probability samples or the grab samples are *Arius* spp., *Caranx* spp., *Haemulon* spp., *Orthopristis* spp., and *Bairdiella* spp.

#### TROPHIC LEVEL

Using modern fisheries data, Daniel Pauly and his colleagues demonstrate that the mean trophic level of commercial fisheries as reported by the Food and Agricultural Organization of the United Nations has declined throughout the world (Pauly and Christensen 1995; Pauly et al. 1998, 2000). They report a shift away from long-lived, piscivorous, high-trophic-level bottom fishes to short-lived, low-trophic-level invertebrates and small planktivorous pelagic fish in response to changes in the relative abundance of the preferred catch. Fishing down the food web to lower trophic levels initially led to larger catches, then to stagnant or declining ones. They argue that today's fishing industry is focused on small pelagic organisms, such as anchovies. This strategy is unsustainable in large part because it removes a food source that is important to higher trophic level fishes. The higher trophic level fishes are the ones that humans have more frequently preferred. In essence, humans are competing with their preferred prey for resources at the lower trophic levels.

Both the theory and the method used to support it are applicable to archaeological data. Archaeologists have occasionally argued that over-harvesting might be an explanation for cultural changes observed at various times and places around the world. Such arguments are largely qualitative; the observations upon which they are based are difficult to quantify and test within an objective

theoretical framework. In theory, such changes could be stimulated by conquest or internal cultural dynamics unrelated to environmental change. It is difficult to substantiate that a change that took place in resource use was associated with environmental change alone and none of the other alternatives. It is particularly difficult to verify that environmental change was caused by human behavior. The method used by Pauly and his colleagues (Pauly and Christensen 1995; Pauly et al. 1998, 2000) to quantify changes in trophic levels exploited provides a way to quantify fishing strategies which can be applied to archaeological data to demonstrate that a change did or did not occur in fishing strategies. The problem of causality remains unresolved, but it comes closer to resolution as it becomes more clearly defined.

In Levels 200 to 400, the focus was on fishes from trophic levels 2.2-2.6 for both MNI and biomass, but this changed in Level 100 (Fig. 5; tables 9 and 10). In Level 100, the emphasis is on trophic levels 3.4-3.5. This shift is reflected in the mean trophic level for each archaeological level (figs. 3 and 4; Table 9). The mean trophic level is relatively stable from Levels 400 through 200, but rises sharply in Level 100 for both MNI and biomass. The rise in Level 100 is accompanied by a decline in diversity. Corresponding with this shift is a decline between Levels 200 and 100 in herrings (*Clupeidae*) and anchovies (*Engraulidae*). Herrings are not present at all in Level 100 and anchovies decline from 59% of the vertebrate biomass in Level 200 to 27% of the biomass in Level 100. Temperate drums (*Paralonchurus peruanus* and *Corvina* [*Sciaena*] *deliciosa*) increase between Levels 200 and 100. Over 70% of the individuals and 56% of the biomass are from trophic levels 2.2-2.6 in Levels 400-200 (Table 10). This dominance of low trophic level resources is not present in Level 100. In Level 100, 61% of the individuals and 72% of the biomass are from trophic levels 3.4 and 3.5. This increase in mean trophic level in Level 100 can be attributed to a reduction in the use of low trophic level fishes associated with upwellings and a focus on just a few large temperate-water fish from higher trophic levels.

### SUMMARY OF RESULTS

1. Marine resources were the primary source of animal protein at Paloma, with no evidence of a developing marine focus out of a terrestrial hunting base.

2. The overall subsistence strategy at Paloma was relatively stable throughout the 3,000-year period represented by these data. There were changes, however, within that strategy.

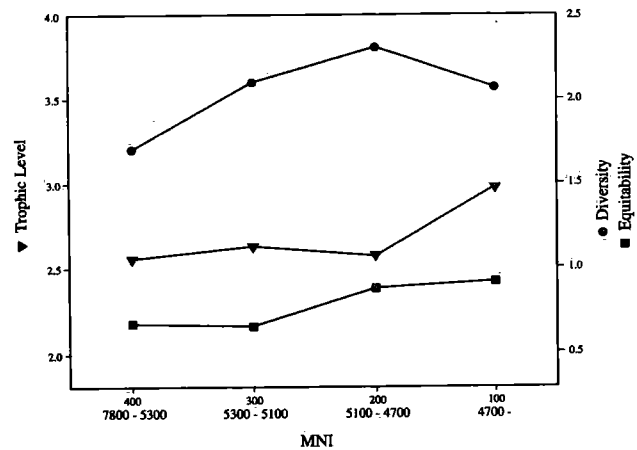


Figure 3. Paloma probability samples, trophic level, diversity, and equitability derived from MNI. B.P. dates uncorrected.

3. The degree to which fish contributed to the diet varied during the occupation. Fish were most commonly used in the earliest occupation, Level 400. They were least abundant in Level 300, with a wider range of possibly terrestrial vertebrates and sandy beach invertebrates used.

4. Diversity in the MNI data rises from a low in Level 400 (7800-5300 B.P.) to a high in Level 200 (5100-4700 B.P.), and declines after 4700 B.P. (Level 100).

5. Biomass diversity is generally low. Level 300 (5300-5100 B.P.) is the most diverse collection in terms of sources of animal protein.

6. The Paloma probability samples are dominated by temperate fishes typical of the Peru Current. Tropical animals are present in the Paloma probability samples only in Level 300. This is also the level in which terrestrial animals are most frequent.

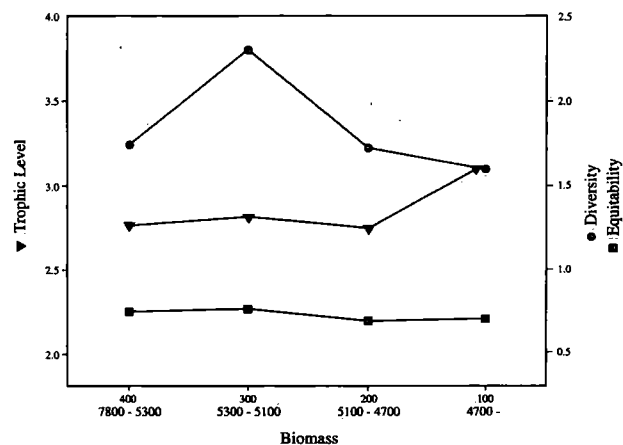


Figure 4. Paloma probability samples, trophic level, diversity, and equitability derived from biomass. B.P. dates uncorrected.

Table 8. Paloma probability samples, MNI of warm-temperate and warm-tropical vertebrates by level.

Level	100	200	300	400
Warm-tropical fishes			2	
Warm-temperate fishes	8	31	47	24
Mixed fishes	5	4	5	3
Other vertebrates	0	0	3	0
Total	13	35	57	27

7. The most commonly utilized trophic levels from 7800 to 5100 B.P. were 2.2-2.6. This changed dramatically in Level 100, where the emphasis was on trophic levels 3.4-3.5. This increased use of higher trophic levels is accompanied by a decline in diversity. The mean trophic level throughout the Paloma occupation, however, is much lower than the mean trophic level at sites in northern Peru, such as Ostra Base Camp (Andrus 2000; Reitz and Sandweiss 2001).

8. A decline in the use of anchovies between 5100 and 5300 B.P. coincides with the brief presence of warm-tropical animals (Level 300), but the mean trophic level does not change and most animal protein continues to be from trophic levels 2.2-2.6.

9. Another change occurred after 4700 B.P. There was greater emphasis on high-trophic-level grunts and drums, a decline in diversity, and a decline in the use of low-trophic-level fishes, specifically anchovies, associated with upwellings.

### DISCUSSION

Moseley (1975:40-43) postulates that marine products constituted the main source of protein in a diet in which *loma* resources contributed the majority of the food in the late Archaic. Both plants and animals could be taken from the sea as well as from the *lomas*, but the *lomas* offered few animal protein sources. Most of the *loma* resources were probably plants rather than animals. It is not known to what extent the sea provided plant foods, but marine animals clearly dominated that part of the subsistence strategy directed toward animals.

The use of terrestrial or marine plants does not necessarily correlate with the use of animals from those same biotopes. The diet might have included primarily terrestrial plants along with primarily marine animals. Zooarchaeological evidence only addresses one component of that diet, however. In order to evaluate the way these resources were combined it is necessary to have evidence of both plant and animal use.

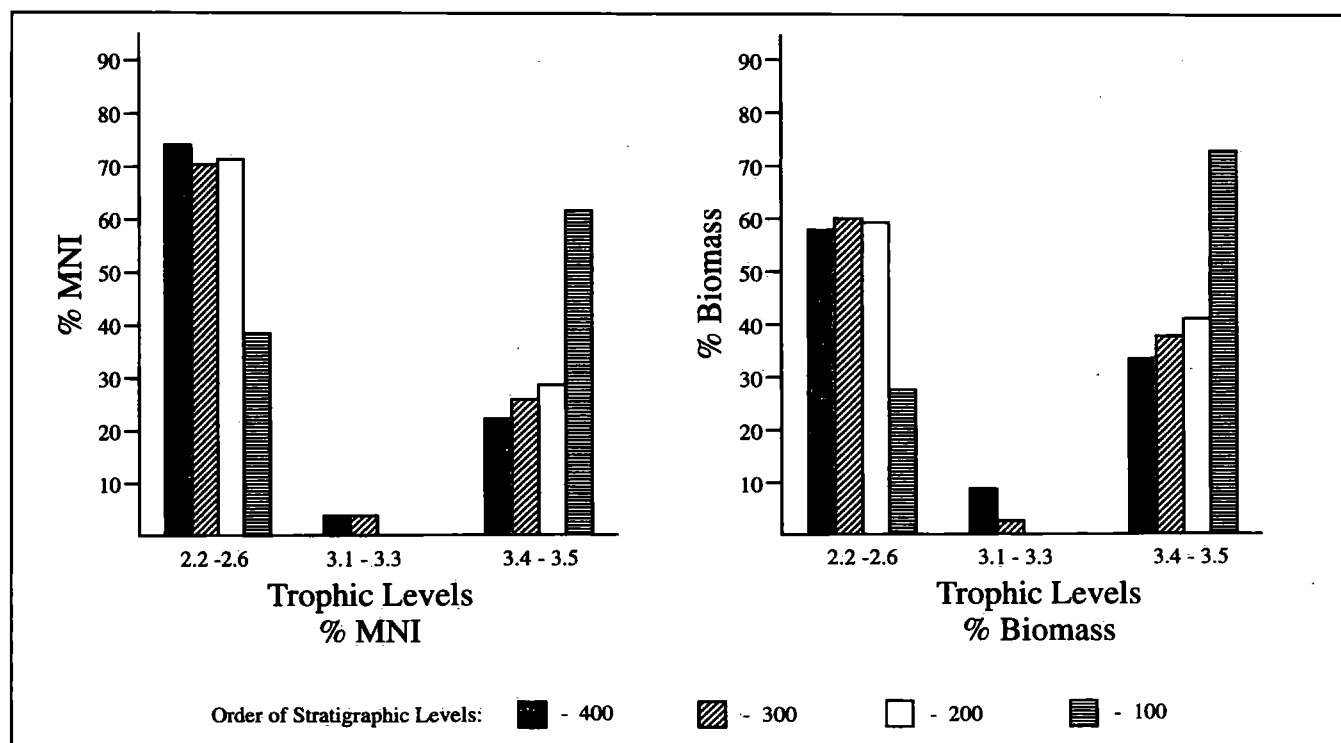


Figure 5. Paloma probability samples, percentage of vertebrate MNI and biomass from three combinations of trophic levels in archaeological levels 400 through 100.

Fortunately, plant remains from Paloma have been recovered and studied. Weir and Dering (1986; Benfer 1990, 1999) found evidence of extensive use of *lomas* plants in their study of coprolites. They report columnar cactus (*Loxanthocereus* sp.), mito (a papaya-like fruit, *Carica candicans*), as well as chenopod (Chenopodiaceae) and composite (Compositae) seeds in macrobotanical samples and coprolites. Pearsall has also found tuberous *Begonia* and amancay (non-showy spiderlilies, *Hymenocallis amancaes*). Beans, gourds, and squash, too, are present in some samples.

The Paloma data indicates heavy uses of marine resources long before the Formative Period. Although some changes occurred in the specific marine resources deposited in the identified levels of Paloma, terrestrial animals never contributed significant percentages of biomass. The only evidence for use of terrestrial animals, such as guanaco (Camelidae) and deer (Cervidae), is found in the grab samples (Reitz 1988b). The remains of an estimated three guanaco and one deer were found (Table 11). Primarily in Level 300, these do not provide evidence for a gradually developing focus on marine resources out of an earlier terrestrial hunting tradition. By the time Paloma was occupied, use of marine animals was already a major part of the subsistence strategy.

If a shift from terrestrial animals to marine animals did occur, it might have happened either before Paloma was settled or at another location. However, there is no evidence of a subsistence strategy focused on terrestrial animals at any of the early sites for which vertebrate faunal data are available. In addition to dominating the Paloma faunal assemblage, marine resources dominate the assemblages from Quebrada Tacahuay, Quebrada Jaguay, the Ring Site, Ostra Base Camp, and Almejas (Fig. 1; Keefer et al. 1998; McInnis 1999; Reitz 1995, 2001; Reitz and Sandweiss 2001; Sandweiss et al. 1989; Sandweiss et al. 1996; Sandweiss et al. 1998). These are all early sites that either were occupied prior to Paloma or were contemporaneous with Paloma. They represent early subsistence from the northern to the southern border of Peru (Fig. 1). They all support the conclusion that use of marine resources in this area was a phenomenon throughout the Holocene rather than a strategy that developed out of a terrestrial hunting tradition.

The only major assemblage with terrestrial animals is from a complex of sites located in the Chicama Valley, representing an early hunting complex known as Paiján

Table 9. Paloma probability samples, mean vertebrate trophic levels.

Level	MNI	Biomass
100	2.99	3.13
200	2.59	2.76
300	2.63	2.82
400	2.54	2.78

(Chauchat 1988, 1992). This complex may have been in existence from about 10,400 to 8200 B.P. during the early Preceramic Period (Chauchat 1988:59; see also Chauchat 1992:340). Vertebrate remains from 11 Pampa de los Fósiles samples, Quebrada de Cupisnique, and Ascope are reported by Elizabeth S. Wing (1986, 1992). The closest of these sites to the present coastline is 14 km and the furthest is 36 km. A fine-gauge screen was used to recover these materials.

The abundant fish remains in the Paiján sites are typical of warmer coastal conditions and not of upwellings (Reitz 2001). Temperate fishes contribute less than 1% of the individuals in the Paiján complex. The temperate forms are herring (Clupeidae), anchovy (Engraulidae, *Anchoa* sp.), and coco (*Paralonchurus* sp.). The fine-gauge screen used during excavation should have captured anchovy remains had they survived in the archaeological record, but only two anchovy individuals are represented in this assemblage. Most of the Paiján vertebrates are terrestrial; 7% of the MNI are terrestrial mammals, 74% are lizards and snakes, 3% are birds, and 16% are fishes. The terrestrial mammals are primarily rodents; less than 1% of the MNI were deer (Cervidae). The lizards are primarily cañán (*Dicrodon* sp.), which constitute 70% of the MNI. Tropical fishes constitute 14% of the MNI and temperate/Peru Current fishes constitute 0.5%. Sea catfish (Ariidae) and lisa (*Mugil* sp.) are the most common fishes, though bonefish (*Albula vulpes*) and croaker (*Micropogonias* sp.) are present in some assemblages.

Table 10. Paloma probability samples, percentage of vertebrate MNI and biomass from trophic level groups.

Trophic level	MNI (%)				Biomass (%)			
	100	200	300	400	100	200	300	400
2.2-2.6	38.5	71.4	70.4	74.1	27.5	59.2	60.0	57.7
3.1-3.3			3.7	3.7			2.4	8.9
3.4-3.5	61.5	28.6	25.9	22.2	72.5	40.8	37.7	33.4

Table 11. Paloma grab samples: summary.

	MNI		Biomass	
	n	%	kg	%
Terrestrial mammals	6	0.1	8.675	10.9
Marine mammals	11	0.2	55.731	70.0
Birds	23	0.5	4.993	6.3
Fishes	235	5.1	5.361	6.7
Other*	3	0.07	0.632	0.8
All vertebrates	278	6.1	75.392	94.7
Marine gastropods	2635	57.6	3.231	4.1
Terrestrial gastropods	143	3.1	0.081	0.1
Chitons	36	0.8		
Mussels	927	20.3	0.587	0.7
Other bivalves	353	7.7	0.319	0.4
Crabs	203	4.4		
All invertebrates	4297	93.9	4.218	5.3
Total	4575		79.610	

\* Includes *Ateles* spp., *Homo sapiens*, and *Felis concolor* (Reitz 1988b).

Small numbers of mojarra (Gerridae, *Eucinostomus* sp.) and porgy (Sparidae) are also represented. Given the distance of these sites from the coast, particularly during the early Holocene when due to lowered sea level the shoreline was farther west, the percentage of coastal resources is high, although the local terrestrial resource presented by the cañán lizard was clearly a mainstay in the diet, but not what advocates of an early hunting strategy had in mind as the terrestrial dietary protein source. A more likely Paiján "hunting complex" includes the trapping of small animals.

It also seems unlikely that these sites were all abandoned seasonally. Support for this argument at Paloma is present in the grab samples, in which mammals contribute 6% of the individuals, birds 8%, and fishes 84% (Reitz 1988b). At least part of the occupation at Paloma was in both the austral summer and austral winter. Evidence for this occupation at Paloma is provided by the identification of juvenile sea lions (Otariidae), an austral summer resident on the coast, and by the presence of such austral winter *lomas* visitors as guanaco (Camelidae), deer (Cervidae), and a giant fulmar (*Macronectes giganteus*). Sea lions are far more common in the grab samples than are terrestrial animals or the fulmar, which may indicate that more people lived in the village in the summer when sea lions were present on the shore than in the winter when guanacos and deer formed part of the *lomas* community (Grimwood,

1969:71, 72). The presence of guanacos and deer in the grab samples, however, indicates that some people may have remained in the village during the winter, using terrestrial vertebrates along with other *lomas* resources. The prominence of sea lions in the grab samples (3% of the vertebrate individuals and 65% of the biomass) compared to guanaco and deer (1% of the individuals and 11% of the biomass) suggests such seasonal shifts in population. On the other hand, the ungulates may have been taken from a location closer to the Chilca River during the austral summer when the river supports vegetation along its banks.

The Paloma grab samples also contain evidence of long-distance contact in the form of a worked, proximal femur from a spider monkey (*Ateles* spp.) in a grab sample from the burial pit of a teenage male (Square N120E65, Level 300, T159). Although ordinarily it would be inadvisable to draw such a conclusion from a single element, this may be an exception because spider monkeys have specialized diets and it is unlikely that a wild spider monkey population could live on the coastal plain when Paloma was occupied. Their populations, today found in the *montaña* of eastern Peru (Eisenberg and Redford 1999; Kellogg and Goldman 1944:12), also extend to the western side of the Andes near the equator. The femur from the burial pit suggests either direct or indirect contact with one of those regions. Obsidian at Paloma appears to derive from the highland area east of Paloma, in the present-day Department of Huancavelica (Benfer 1999).

The real question posed by Moseley's Maritime Foundations Hypothesis, however, is not whether marine resources were used, but whether they provided an adequate nutritional base for such non-subsistence activities as construction of monumental architecture. This cannot be demonstrated by a simple list of taxa found at archaeological sites. To determine whether or not maritime and wild terrestrial resources could provide a base for complex social interactions without agricultural input requires additional evidence, including tests of human skeletal materials for mineral levels, morphological evidence of nutritional stress, and isotopic ratios. For this reason the human biological data reported by Benfer (1984, 1990) are important.

From Benfer's data it appears that a diet with mostly marine-derived protein was adequate to support village life, although perhaps not overly so during the early time periods (Benfer 1984, 1990). Benfer found not only that the population increased at Paloma between 7800 and

4700 B.P., but that life expectancy increased for all age levels except the oldest age categories over time. There was no peak of childhood mortality associated with weaning. Health also improved, as indicated by a reduction of skeletal indicators of stress. Stature of both men and women increased from Level 400 to Level 200. Some men between 5100 and 4700 B.P. may have been as tall as 170 cm. Benfer attributes this to a better diet, to better health during childhood, or both (Benfer 1990). There also was a strong trend for decreasing anemia. Infection levels were stable. Data on trace elements (zinc, strontium, and fluoride) support the hypothesis that human consumption of animal protein was constant throughout the occupation. Although the zooarchaeological data indicate there was a change in the protein sources used, there is no trend toward a more protein-rich diet or toward increased consumption of marine instead of terrestrial animals.

There are several indicators of activity changes over time for men and women (Benfer 1990). Bony growths (auditory exostoses) in the ear indicate that men may have done most of the diving for deep-water mollusks. A decrease in musculature of men occurred at the same time that there was an increase in musculature of women and a change in the humerus shape of both sexes. These changes may reflect a change in subsistence-related activities, especially activities which made greater use of the upper body—such as hauling nets (Benfer 1990).

### CONCLUSIONS

In reviewing not only the data from Paloma, but from other sites along the Peruvian and Chilean coast, it no longer seems appropriate to debate whether marine resources were used. The time has come to apply the best archaeological field and laboratory methods currently available to explore the diversity of ways in which people used marine resources at Paloma and other sites along the Peruvian and Chilean coast. We need to obtain large samples as unbiased as possible by recovery methods and to combine evidence provided by palynology, zooarchaeology, archaeobotany, and human biology. By reconstructing the complex early Peruvian diet, we can explore the diversity of subsistence strategies practiced on the coast and also better understand the interaction between coast and highlands.

### ACKNOWLEDGMENTS

I wish to thank Robert A. Benfer, Frederic-Andre Engel, Glendon H. Weir, and Alice N. Benfer for the opportunity

to examine faunal materials from Paloma. Benfer and Weir made extensive comments on the manuscript, which are appreciated. The staff of the Centro de Investigaciones de Zonas Áridas, particularly Carlos López Ocaña, provided invaluable assistance. I also gratefully acknowledge the assistance of Kurt Auffenburg, George Burgess, Diana Matthieson, Oliver P. Pearson, Harold B. Rollins, Carlos Saavedra, Daniel H. Sandweiss, Richard Thorington, and Jane Wheeler. All identifications and analysis of the faunal materials were done at the Florida Museum of Natural History, Gainesville. I appreciate the generous assistance of Elizabeth S. Wing. Funding was provided by National Science Foundation grants BNS 76-12316, BNS 78-07727a/b, and BNS 81-053940, Robert A. Benfer, principal investigator. Co-principal investigators were Frederic Andre Engel (1976/77), Alice N. Benfer (1979), and Glendon H. Weir (1980/83).

### LITERATURE CITED

- Andrus, C. F. T. 2000. Oxygen isotope analysis of ancient otoliths: A mid-Holocene record of El Niño variation and human adaptation from Peruvian archaeological sites. Ph.D. dissertation. University of Georgia, Athens.
- Benfer, R. A. 1984. The challenges and rewards of sedentism: The preceramic village of Paloma, Peru. Pp. 531-558 in M. N. Cohen and G. J. Armelagos, eds. *Paleopathology and the Origin of Agriculture*. New York: Academic Press.
- Benfer, R. A. 1990. The Preceramic Period site of Paloma, Peru: Bioindications of improving adaptation to sedentism. *Latin American Antiquity* 1(4): 284-318.
- Benfer, R. A. 1999. Proyecto de excavaciones en Paloma, valle de Chilca, Peru. *Boletín de Arqueología PUCP* 3: 213-237.
- Chauchat, C. 1988. Early hunter-gatherers on the Peruvian coast. Pp. 41-66 in R. Keatinge, ed. *Peruvian Prehistory*. Cambridge: Cambridge University Press.
- Chauchat, C. 1992. *Préhistoire de la Côte Nord du Pérou: Le Paijanien de Cupisnique*. Paris: Centre National de la Recherche Scientifique Cahiers du Quaternaire 18.
- Chirichigno F., N. 1974. Clave para Identificar los Peces Marinos del Perú. Callao, Peru: Instituto del Mar del Perú, Informe 44.
- Chirichigno F., N. 1982. Catálogo de Especies Marinas de Interés Económico Actual o Potencial para América Latina: Parte II, Pacífico Centro y Suroriental. Rome: FAO.
- Eisenberg, J. F., and K. H. Redford. 1999. *Mammals of the Neotropics: The Central Neotropics*, Vol. 3, Ecuador, Peru, Bolivia, Brazil. Chicago: University of Chicago Press.
- Engel, F. A. 1980. Paloma: Village 613. Pp. 103-135 in F. Engel, ed. *Prehistoric Andean Ecology*. New York: Humanities Press.
- Fowler, H. W. 1945. Los peces del Perú: Catálogo sistemático de los peces que habitan en aguas peruanas. Lima, Peru: Museo de Historia Natural "Javier Prado," Universidad

- Nacional Mayor de San Marcos.
- Froese, R., and D. Pauly. 1998. FishBase. [Online] Available: [www.fishbase.org/trophic/t.html](http://www.fishbase.org/trophic/t.html).
- Grayson, D. K. 1973. On the methodology of faunal analysis. *American Antiquity* 38(4): 432-438.
- Grayson, D. K. 1981. A critical view of the use of archaeological vertebrates in paleoenvironmental reconstruction. *Journal of Ethnobiology* 1(1): 28-38.
- Grimwood, I. R. 1969. Notes on the distribution and status of some Peruvian mammals. Bronx, New York: American Committee for International Wildlife Protection Special Publication no. 21.
- Hildebrand, S. F. 1945. *A Descriptive Catalog of the Shore Fishes of Peru*. Washington, D.C.: United States National Museum Bulletin no. 189.
- Keefer, D. K., S. D. deFrance, M. E. Moseley, J. B. Richardson III, D. R. Satterlee, and A. Day-Lewis. 1998. Early maritime economy and El Niño events at Quebrada Tacahuay, Peru. *Science* 281: 1833-1835.
- Kellogg, R., and E. A. Goldman. 1944. Review of the spider monkeys. *Proceedings of the United States National Museum* 96 (3186): 1-45.
- McInnis, H. E. 1999. Subsistence and maritime adaptations at Quebrada Jaguay, Camaná, Peru: A faunal analysis. M. A. thesis. University of Maine, Orono.
- Moseley, M. E. 1975. *The Maritime Foundations of Andean Civilization*. Menlo Park, California: Cummings.
- Pauly, D., and V. Christensen. 1995. Primary production required to sustain global fisheries. *Nature* 374: 255-257.
- Pauly, D., V. Christensen, J. Dalsgaard, R. Froese, and F. Torres, Jr. 1998. Fishing down marine food webs. *Science* 279: 860-863.
- Pauly, D., V. Christensen, R. Froese, and M. L. Palomares. 2000. Fishing down aquatic food webs. *American Scientist* 88(1): 46-51.
- Pielou, E. C. 1966. Species-diversity and pattern-diversity in the study of ecological succession. *Journal of Theoretical Biology* 10: 370-383.
- Quilter, J., and T. Stocker 1983. Subsistence economies and the origins of Andean complex societies. *American Anthropologist* 85(3): 545-562.
- Reitz, E. J. 1988a. Faunal remains from Paloma, an Archaic site in Peru. *American Anthropologist* 90(2): 310-322.
- Reitz, E. J. 1988b. Preceramic animal use on the central coast. Pp. 31-55 in E. S. Wing and J. C. Wheeler. *Economic Prehistory of the Central Andes*. Oxford: BAR International Series 427.
- Reitz, E. J. 1995. Environmental change at Almejas, Peru. Ms. on file, Zooarchaeology Laboratory, Georgia Museum of Natural History, University of Georgia, Athens, Georgia.
- Reitz, E. J. 2001. Fishing in Peru between 10,000 and 3750 B.P. *International Journal of Osteoarchaeology* 11:163-171.
- Reitz, E. J., and D. H. Sandweiss. 2001. Environmental change at Ostra Base Camp, A Peruvian Preceramic site. *Journal of Archaeological Science* 28(10): 1085-1100.
- Reitz, E. J., and E. S. Wing. 1999. *Zooarchaeology*. Cambridge: Cambridge University Press.
- Sandweiss, D. H., H. McInnis, R. L. Burger, A. Canó, B. Ojeda, R. Paredes, M. Sandweiss, and M. Glascock. 1998. Quebrada Jaguay: Early maritime adaptations in South America. *Science* 281: 1830-1832.
- Sandweiss, D. H., J. B. Richardson III, E. J. Reitz, J. T. Hsu, and R. A. Feldman. 1989. Early maritime adaptations in the Andes: Preliminary studies at the Ring Site, Peru. Pp. 35-84 in D. S. Rice, C. Stanish and P. R. Scarr, eds. *Ecology, Settlement and History in the Osmore Drainage, Peru*. Oxford: BAR International Series 545(I).
- Sandweiss, D. H., J. B. Richardson III, E. J. Reitz, H. B. Rollins, and K. A. Maasch. 1996. Geoarchaeological evidence from Peru from a 5000 years B.P. onset of El Niño. *Science* 273: 1531-1533.
- Schweigger, E. 1964. *El Litoral Peruano*. Lima, Peru: Universidad Nacional "Federico Villarreal."
- Shannon, C. E., and W. Weaver. 1949. *The Mathematical Theory of Communication*. Urbana: University of Illinois Press.
- Sheldon, A. L. 1969. Equitability indices: Dependence on the species count. *Ecology* 50: 466-467.
- Simpson, G. G., A. Roe, and R. C. Lewontin. 1960. *Quantitative Zoology*. New York: Harcourt, Brace, and Co.
- Weir, G. H., R. A. Benfer, and J. G. Jones. 1988. Preceramic to early Formative subsistence on the central coast. Preceramic animal use on the central coast. Pp. 56-94 in E. S. Wing and J. C. Wheeler. *Economic Prehistory of the Central Andes*. Oxford: BAR International Series 427.
- Weir, G., and P. Dering. 1986. The *lomas* of Paloma: Human-environment relations in a central Peruvian fog oasis: Archaeobotany and palynology. Pp. 18-44 in R. Matos M., S. A. Turpin, and H. H. Eling, eds. *Andean Archaeology*. Los Angeles: UCLA Institute of Archaeology Monographs in Archaeology no. 27.
- Wing, E. S. 1986. Methods employed in the identification and analysis of the vertebrate remains associated with sites of the Paiján Culture. Ms. on file, Environmental Archaeology Laboratory, Florida Museum of Natural History, University of Florida, Gainesville.
- Wing, E. S. 1992. Les restes de vertébrés. Pp. 42-47 in C. Chauchat, ed. *Préhistoire de la Côte Nord du Pérou: Le Paijanien de Cupisnique*. Paris: Centre National de la Recherche Scientifique Cahiers du Quaternaire 18.
- Wing, E. S., and A. Brown. 1979. *Paleonutrition: Method and Theory in Prehistoric Foodways*. New York: Academic Press.