Natural Hazard Research

THE NIÑO AS A NATURAL HAZARD; ITS ROLE IN THE DEVELOPMENT OF CULTURAL COMPLEXITY ON THE PERUVIAN COAST

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SUMMARY

Assertions that marine resources of the Peruvian coast could not have supported large populations during the Cotton Preceramic period (2500-1750 B.C.) rest on tenuous and misleading assumptions. On the contrary, it can be shown that preceramic populations of the Peruvian coast depended primarily on marine resources during normal periods, and periodically shifted to agriculture during disturbances of the marine ecosystem caused by Niños. Niños are incursions of warm surface water southward along the coast. Anomalies in the interaction of the ocean and the atmosphere, Niños are of varying intensities and recur on an average of once every seven years. Great Niños occur less frequently. According to intensity, they inhibit upwelling and its rich phytoplankton content, cause fish and shellfish to migrate or die, and force higher forms of life dependent on the fish also to migrate or die.

These higher forms of life can be birds, or they can be human beings. The individuals and groups living on the Peruvian coast during the Cotton Preceramic adapted to periodic maritime food shortages by turning to agriculture in river valleys to tide them over. Centralized authority developed to facilitate and maintain long-term responses to Niños and to counter the centrifugal tendencies of a maritime-oriented adaptation. The distribution of preceramic monumental architecture along the coast supports the hypothesis.

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PREFACE

This paper is one in a series on research in progress in the field of human adjustments to natural hazards. It is intended that these papers be used as working documents by those directly involved in hazard research, as well as inform a larger circle of interested persons. The series was started with funds from the National Science Foundation to the University of Colorado and Clark University, but it is now on a self-supporting basis. Authorship of the papers is not necessarily confined to those working at these institutions.

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INTRODUCTION

The prehistory of the Peruvian coast, in particular that period known as the Cotton Preceramic (ca. 2500-1750 B.C.), has recently become the focus of a controversy concerning the nature and potential of maritime cultural adaptations. According to Moseley (1975), exploitation of the rich marine resources of the central Peruvian coast supported large sedentary communities that exhibited varying degrees of sociocultural complexity during the Cotton Preceramic, and laid the foundations for the development of intensive agriculture and state level societies by 1000 B.C. In Moseley's view, farming was a relatively unimportant subsistence mode on the coast until the end of the Cotton Preceramic, when the development of irrigation technology led to the shift of populations inland along the coastal river valleys.

Osborn (1977) and Wilson (1981) have concluded, on the other hand, that the productivity of marine ecosystems is too low to support high-density populations. They argue that the development of sociocultural complexity along the coast, exemplified principally by those sites with platforms and other types of public architecture, occurred in an agricultural rather than maritime context. Wilson contends further that periodic disturbances of the Peruvian marine ecosystem caused by the Niños produced productive bottlenecks that severely limited the human carrying capacity of that ecosystem.

This paper suggests that all the arguments concerning the primacy of maritime vs. agricultural subsistence on the coast during the Cotton Preceramic are overly simplistic. They do not take fully into account the complexity and unique characteristics of the Peruvian coastal environment, and tend to ignore the ability of cultural systems to adapt to temporal environmental variation. Instead, I propose that several alternative modes of subsistence were maintained during the Cotton Preceramic, and the relative importance of each of these modes varied in response to periodic resource fluctuations. The same climatic conditions (the Niños) that temporarily reduced the carrying capacity of the marine ecosystem also increased river discharges along the coast, thus enhancing agricultural potentials in coastal valleys. It would be expected, then, that populations shifted to terrestrial modes of subsistence when significant downturns in marine productivity occurred, and returned to the primary exploitation of marine resources when the marine ecosystem recovered (Lischka, 1975).

Osborn (1977, p. 193) and Yesner (1980, p. 735) have suggested that cultural responses to periodic resource fluctuations along the Peruvian coast stimulated the development of cultural complexity and centralized leadership as means of coping with those fluctuations. The frequency and intensity of marine disturbances, however, exhibit significant variability along the coast and it seems likely that the form of cultural response exhibited similar variation. I argue that there were qualitative differences in the kinds of cultural response and that these differences are reflected by the differential distribution of monumental architecture along the coast during the Cotton Preceramic.

Elaboration of this hypothesis requires an assessment of maritime resource potentials, description of relevant features of the marine and terrestrial environments of the Peruvian coast, and investigation of the responses of cultural systems to temporal environmental variation generally and to natural hazards specifically.

THE PERUVIAN MARINE ENVIRONMENT

The marine environment of the Peruvian coast is determined largely by the Peru Current, which flows north along the coast from about 10° S to 4° S, where it veers westward away from the coast to merge with the South Equatorial Current (see inset, Figure 1). The Peru Current is produced and maintained by the counterclockwise circulation of the southern Pacific and persistent trade winds that trend north along the western coast of South America. Oceanographic and biological studies of the Peru Current, particularly off the Peruvian coast, have accelerated in recent years, stimulated largely by the importance of marine resources in the economy of Peru. Comprehensive summaries of these studies are presented by Guillen (1976), Santander (1976), Schweigger (1964), and Wyrtki (196[illegible]).

Surface temperatures of the Peru Current average 17.5° C along the Peruvian coast, with local and seasonal variations ranging between 13.5° C and 20° C under normal conditions. The highest temperatures occur during the Peruvian summer, from January to March (Schweigger, 1964, pp. 93-94). This temperature range is 8° to 10° cooler than open ocean surface temperatures at the same latitude and is responsible for the extension of what is essentially a temperate marine faunal and floral regime north along the coast into the tropical latitudes.

Upwelling, a phenomenon that occurs primarily along the west coasts of continents and is related to the motion of the large oceanic currents, along the Peruvian and north Chilean coasts is somewhat unusual, compared to other parts of the world, in that it persists year round. Upwelling causes subsurface waters, generally from depths of 100-200 meters, to move upward to the surface. Water in the upwelling zones has a higher

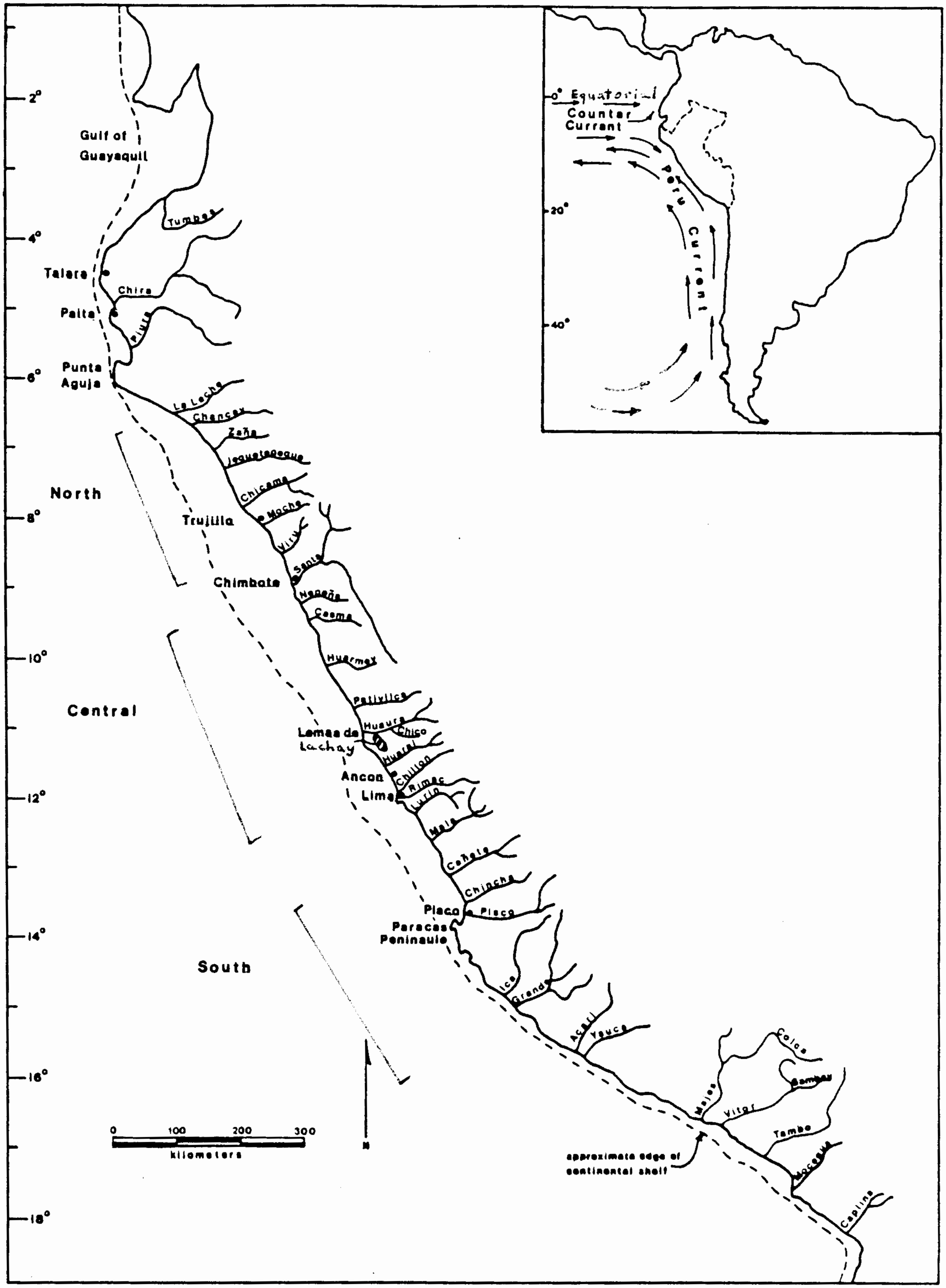

FIGURE 1

GEOGRAPHIC FEATURES AND CITIES CITED IN TEXT, AND RIVERS LISTED IN TABLE 2 nutrient content than surrounding ocean water, and support an ext[illegible] high rate of phytoplankton production in the euphotic zone. Estimates of the rate of carbon fixation, a sensitive measure of biological productivity, range from 45 to 200 mgC/m^3/day in the upwelling zones, compared to a rate of less than 5 mgC/m^3/day in the open ocean. Fixation rates in the Peru Current are lower than in the Benguela Current along the west coast of southern Africa, but several times higher than estimated figures for any other upwelling area in the world (Gulland, 1971, p. 137).

The phytoplankton of the Peru Current are the first trophic level of one of the most productive marine food chains in the world. This food chain includes a variety of species of fish, shellfish, marine birds and sea mammals. During the nineteenth and early twentieth centuries, the principal export of Peru was guano obtained from the nesting areas of millions of marine birds on offshore islands. More recently, guano exports have been overshadowed by the export of anchovy fish meal, which by 1971 constituted about 20% of the world's fish catch.

The Peruvian marine ecosystem appears to be a complex combination of two basic ecosystem types. Ecosystems of upwelling areas are relatively immature and characterized by short food chains, low species diversity, high energy flows, and low stability ([illegible], [illegible], pp. [illegible]; Osborn, 1977, p. 190). Dominant species tend to be small, short-lived and fast-growing, and exhibit high rates of population increase. Population densities are usually maintained well below carrying capacity. Such ecosystems are referred to as *physically controlled* because population levels are controlled by the variation of relevant environmental variables. *Biologically accommodated* ecosystems, on the other hand, are characterized by species that are large, long-lived and long-lived. Population densities are maintained near potential carrying capacity. Energy flow through such ecosystems is relatively low because food is mainly invested in the maintenance, rather than the growth, of organisms. Biologically accommodated ecosystems are found primarily in environments with little seasonal variability.

Although dominant species of the Peruvian marine ecosystem, such as the anchovy, are characteristic of physically controlled ecosystems, species diversity is relatively high and includes several large faunal species. This combination of characteristics is probably due to the stability and persistence of upwelling and to the flow of the Peru Current, both of which maintain environmental variables within relatively narrow limits under normal conditions. While there is some seasonal variation in primary productivity, seawater temperatures, and salinity, the range of variation is considerably less than that in other upwelling marine ecosystems (cf. Gulland, 1971). It would be expected, then, that species of the Peruvian marine ecosystem are stenothermal (adapted to narrow temperature ranges) and stenohaline (adapted to narrow salinity ranges), and that biological productivity is closer to potential carrying capacity than in other upwelling systems. Significant changes in these environmental variables should have correspondingly large effects on the rest of that ecosystem.

Anomalies of the Peru Current

The stability of the Peruvian marine ecosystem is occasionally affected by unpredictable anomalies of several types. The principal type of anomaly is the incursion of warm surface water southward along the coast. Although these warm water incursions may appear at any time, they typically occur during the Peruvian summer, between January and March. These phenomena are referred to as "El Niño" (The Christ Child) by coastal inhabitants because they usually occur soon after the Christmas season. According to Schweigger (1964, pp. 67-90), a true Niño is an annual warm water incursion extending south from the Gulf of Guayaquil. These annual occurrences do not usually have a marked effect on local marine fauna and flora and rarely extend south of Paita (5° S).

The term is also used in the published literature to refer to occasional appearances of the Equatorial Counter Current along the Peruvian coast (see Figure 1). These incursions first appear at a latitude of about 5° S and move south along the coast, covering the waters of the Peru Current with a layer of nutrient-poor, low salinity water that may be 5° – 8° warmer than the water of the Peru Current. Effects on the Peruvian marine ecosystem are variable and depend on the intensity and duration of the Counter Current.

Of particular interest here are the frequencies of Niños of different magnitudes and their effects on maritime resources. There has been considerable recent research on the causes of Niños and their effects on anchovy because the anchovy is the mainstay of the Peruvian fishing industry. Relatively little is known, however, about effects on other marine organisms. Another problem is that different sets of criteria are used by different researchers to define the nature and extent of Niño occurrences. Oceanographers use warm water temperatures as a primary criterion, meteorologists focus on climatic events, and other researchers may consider only the effects on anchovy or guano birds.

These different phenomena, however, may appear independently or in combination (Prohaska, 1973, p. 106). Published references to [illegible] effects of Niños on prehistoric coastal populations rarely consider that fact, and also tend to emphasize the destructive aspects of the phenomenon (Nials _et al._, 1979a, b; Moseley, 1975; Osborn, 1977; Wilson, 1981; Yesner, 1980). Wilson, for example, identifies 19 "very abnormal" and at least 24 "abnormal" Niños between 1726 and the present (1981; pp. 101-103). The interval between these events varies between six and 20 years with no regular periodicity. Wilson bases his study in part on an analysis by Quinn _et al._ (1978) of correlations between Niños and climatic events of the southwestern Pacific. In their classification, strong events involve surface temperature anomalies in excess of 3^{0} C, moderate events exhibit anomalies in the 2.0^{0} - 3.5^{0} C range, while weak Niños are characterized by anomalies in the 1.0^{0} - 2.5^{0} C range. According to the Quinn analysis, strong Niños occurred 23 times between 1726 and the present (1978; Table 1). According to Schweigger (1964, pp. 87-88), however, the major Niño of 1891 is the earliest Niño for which we have oceanographic and climatic data. Inadequate data prior to that time make an assessment of Niño magnitude problematic.

The differential effect of Niños on marine fauna is also debated. Wilson asserts, for example, that the 1975 Nino had a devastating effect on the Peruvian fishing industry (1981, p. 95). That Nino did cause a reduction of off-shore primary production and reduced the 1975 anchovy catch by 20%; however, it had no effect on coastal unwelling nor on primary production closer than 250 km from the coast (Cowles, Barber and Guillen, 1977). Additionally, according to Quinn _et al._ (1978, pp. 665-666), strong Ninos seriously affect the anchovy fishing industry. Ninos classified as strong by Quinn occurred in 1941, 1957-58 and 1972, but in fact the total fish catch almost doubled from 1940 to 1941, and more than doubled from 1957 to 1958 (see Table 1). The moderate Nino of 1965, however, caused a substantial decrease in the fish catch.

The 1972 Nino, the strongest event since 1925, dealt a blow to the Peruvian fishing industry from which it has not yet recovered. The inability of the anchovy to recover is attributed in part to over-fishing. The total fish catch dropped from a maximum of 12.6 million tons in 1970 to 4.8 million tons in 1972 and 2.3 million tons in 1973. Craig and Psuty (1968, p. 16) classify the 1891, 1925 and 1953 Ninos as "very abnormal" events, while "abnormal" Ninos occurred in 1911, 1918, 1921, 1932, 1939, 1941 and 1964.

It is clear from the above that there is little agreement on the classification and effects of most Nino events. In particular, it is evident that there is little basis for Wilson's assumption that Ninos occurring every six to 20 years reduced the carrying capacity of the Peruvian marine ecosystem to one-sixth of normal. It can be said with a fair degree of confidence that the most intense Niños, which occurred in 1891, 1925 and 1972, caused severe disturbances of the marine ecosystem along most of the Peruvian coast. Intervals between these events are 34 and 47 years. Moderate Niños have a more limited impact on marine fauna and flora, occur more frequently than intense Ninos, and affect a smaller portion of the Peruvian coast.

The effects of the 1925 Niño are described by Murphy (1926), and there are numerous reports on the Niño of 1972 (e.g., Caviedes, 1975; Ramage, 1975; Valdivia, 1976; Vildoso, 1976; Wooster and Guillen, 1974; Zuta et al., 1976). In both instances, the Equatorial Counter Current

TABLE 1.

ANNUAL FISH AND MUSSEL CATCHES OFF THE COAST OF PERU

YEAR	TOTAL CATCH FISH (TONS)	MUSSEL CATCH (TONS)
1939	4,800	-- (no data)
1940	6,400	--
1941	11,900	--
1942	21,100	--
1943	26,700	--
1944	30,300	--
1945	32,000	--
1946	27,700	--
1947	36,600	--
1948	47,700	--
1949	60,800	--
1950	83,600	--
1951	97,100	--
1952	106,600	--
1953	117,800	400
1954	146,100	400
1955	183,300	100
1956	265,300	900
1957	350,900	1,100
1958	930,200	1,900

continued

Table 1 (continued)

YEAR	TOTAL CATCH FISH (TONS)	MUSSEL CATCH (TONS)
1959	2,152,400	2,700
1960	3,531,400	3,700
1961	5,243,100	3,300
1962	6,830,000	3,400
1963	6,900,300	3,000
1964	9,130,700	3,600
1965	7,461,900	3,900
1966	8,739,000	4,400
1967	10,133,700	5,500
1968	10,520,300	5,300
1969	9,243,600	8,400
1970	12,612,800	10,200
1971	10,606,100	10,500
1972	4,768,300	11,400
1973	2,328,500	14,900
1974	4,144,858	9,374
1975	3,447,490	11,906
1976	4,343,125	16,385
1977	2,529,995	11,317

(Food and Agriculture Organization, 1978) first appeared off Talara (5°45' S) and proceeded south along the coast in late January. Water temperatures 5° - 7° C above normal and abnormally low salinity values were recorded as far south as Pisco (14° S) in 1972, while conditions south of Pisco remained relatively normal (Zuta et al., 1976, p. 23). A recurrence of Niño conditions in 1973 was felt as far south as Lima (12° S). Temperature distributions during the 1925 Niño indicate abnormally high water temperatures as far south as latitudes 16° and 18° S (Murphy, 1926, pp. 27-33). As Wilson (1981, p. 103) notes, the duration of abnormal oceanographic conditions varies as a function of latitude, being longest in the north and shortest along the south coast. While these values return to normal in a matter of months, other parts of the ecosystem may take several years to recover, especially in the most seriously affected areas.

The effects of intense Ninos on marine fauna vary, depending on the species involved and the type of effect. An immediate effect of the warm water incursion and the cessation of upwelling is a severe reduction or elimination of phytoplankton production. Mobile stenothermal and stenohaline fish retreat to colder water under the Counter Current or migrate out of the area, effectively cutting off the food supply of other species. Guano birds, whose diet consists primarily of anchovy, begin to die off by the thousands soon after the onset of Nino conditions. Survivors abandon their nesting grounds on off-shore islands and migrate south as far as the north Chilean coast. The estimated guano bird population along the Peruvian coast was reduced from five to two million by the 1972 Niño (Vildoso, 1976, p. 67). The southward migration of guano birds is often the first indication to inhabitants of the central and south coasts that a major Niño is on the way.

As indigenous species of fish disappear, they are replaced by other tropical species that normally are not found below latitude 6° S, including the skipjack (*Katsuwonus pelamis*), Spanish mackerel (*Scomberomorus maculatus*), yellowfin tuna (*Thunnus albacares*), dolphin (*Coryphaena hippurus*) and blanket fish (*Manta birostris hamiltoni*) (Villoso, 1976). Changes in mobile fish species respond closely to temperature variations. As temperatures return to normal, tropical fish disappear and are replaced by indigenous species. The temporary cessation of primary production, however, results in reduced biomasses and an interruption of reproductive cycles that may take several years to overcome.

One type of marine anomaly that occurs locally during the Peruvian summer and usually accompanies major Niños is referred to as the aguaje or "sick water" (Schweigger, 1964, pp. 186-193). Aguajes can take different forms but are usually caused by the same kind of dinoflaggelate blooms that produce red tides off the coasts of Florida, California and Alaska. Oxygen depletion and the accumulation of decay products during aguajes can cause mass mortality of sea life. The anomalous conditions of a Niño create more extensive dinoflaggelate blooms. Paralytic shellfish poisoning is often associated with dinoflaggelate blooms off the coasts of North America, but *Gymnodinium splendens*, the dinoflaggelate species usually found in Peruvian blooms, is not toxic, and there are no recorded instances of paralytic shellfish poisoning along the western coast of South America (Blasco, 1975; Dale and Yentsch, 1978).

Wilson (1981, p. 113) assumes that shellfish are as severely affected by Niños as fish. Shellfish, however, occupy a littoral (along the shore) habitat and are subjected to a more variable environment than the fauna of the sub-littoral zone and the open ocean; as a consequence, shellfish are adapted to a wider range of environmental conditions (Gunter, 1957, p. 163). The most likely effect of Niños on shellfish and other sessile species of the littoral zone is an interruption of reproductive and growth cycles caused by elevated seawater temperatures and a reduction of food supply. Reductions in the biomass of these species would not reach significant levels until some time after the occurrence of a Niño. This conclusion is supported by examination of annual variations of the Peruvian mussel catch (see Table 1). Reductions in the catch occurred two years after the moderate 1953 Niño, three years after the 1957-58 Niño, three years after the moderate 1965 Niño, and two years after the 1972 Niño. We may conclude, then, contrary to Wilson's assertion, that shellfish were available as a food source during and immediately after a Niño.

The scallop (*Pecten* spp.) is an exception to this conclusion. Unlike other shellfish, scallops are mobile and can move to deeper, colder waters when conditions become unfavorable. While on a visit to Peru in 1976, I observed the profile of a test pit that had been excavated some years previously in a shell mound at Otuma south of Pisco. The profile consisted entirely of closely packed scallop shells, except for two thin lenses of mussel shells. One possible reason for the presence of the mussels is a temporary disappearance of scallops caused by anomalous conditions, forcing a temporary dietary shift.

Marine Productivity and Carrying Capacities

According to Osborn (1977, p. 179), the distribution of preceramic sites along the Peruvian coast between 7° and 12° S coincides with the areas of highest marine productivity. This estimate of marine produc-

tivity, is based on the distribution of phosphate [illegible]
[illegible], and no variation in the width of the [illegible]
pp. 19[illegible]). Other data, however, [illegible] a wider latitudinal range of
high marine productivity [illegible] of upwelling [illegible]
occur between 9° and 15° S in the summer and between [illegible]
[illegible] (see Figure 1). The [illegible]
latitudes [illegible] (Guillen, 19[illegible]) [illegible]
[illegible] of primary production [illegible]
[illegible] generally between [illegible] and [illegible] (Guillen, 19[illegible]) [illegible]

[illegible] (19[illegible], pp. 16[illegible]) [illegible] width of [illegible]
[illegible] limit of the continental shelf [illegible]
[illegible] and 10 km north of Punta Aguja [illegible]. It becomes [illegible]
[illegible] south of that point, [illegible]
[illegible]
[illegible] South to Chile [illegible]
[illegible] of correlation between shelf width and the [illegible]
[illegible] along the Peruvian coast, the [illegible]
[illegible]. There is [illegible]
[illegible], with demonstrated dependence [illegible] along the [illegible]
coast of Chile, which has a [illegible] continental shelf [illegible]

A number of studies have been [illegible]
in the [illegible]
likely to have been exploited by coastal [illegible] populations.
Ideally, we would have information on the [illegible]
nutritional values of all exploited [illegible] and [illegible]
costs and effort involved in getting them. [illegible]
[illegible], more indirect [illegible]

Unfortunately, the use of such measures [illegible]

[illegible] and sophisticated data that [illegible]

that don't [illegible] different [illegible]

of the carrying capacity [illegible]

level human population.

Based on a set of "best case" assumptions, [illegible] calculated a carrying capacity of about eight persons per kilometer of coastline, which is considered [illegible] Santa [illegible] of the central Peruvian coast [illegible] productivities of [illegible] for the [illegible] Peru Current [illegible] Figure [illegible] Peruvian coast [illegible]

[illegible] along the coast that was probably [illegible] However, [illegible] (Bickley, 1977). In addition, the number of [illegible] outside the [illegible] zone, i.e., [illegible] more complex and more productive [illegible] from the open ocean (McConnaughey, 1974 [illegible]). There is also evidence that the level of primary production [illegible] subtidal zone (Ryther and Yentsch, [illegible]). The [illegible] this environment, then, [illegible] there is little [illegible] information on the [illegible] and [illegible] quite variable, [illegible] productivity [illegible] the herbivore trophic level in a [illegible]

Ecological efficiency is a measure of the amount of food [illegible] passed through a trophic (nutritional) [illegible] level, and is a function of net production, assimilation, and exploitation efficiencies of the species at that level (Slobodkin, 1962). [illegible] 1965) uses an ecological efficiency of 10% for the primary [illegible] levels. In fact, however, ecological efficiencies vary considerably between different ecosystems and trophic levels. Odum (1971, p. [illegible]) suggests [illegible] that ecological efficiencies of [illegible] level [illegible] 20%. Ryther (1969, p. 71) assumes an efficiency of [illegible] the [illegible] level in upwelling areas. [illegible] that carnivores generally assimilate food more efficiently than herbivores, [illegible] less energy on maintaining body temperature than [illegible] physiological support structures. He estimates that ecological efficiencies [illegible] for homeotherms, and [illegible] for poikilotherms.

[illegible] Peruvian fishery, [illegible] generally occupied the primary and secondary trophic levels of the [illegible] food chain and utilized the food energy that was [illegible] and converted to [illegible] biomass by herbivores and primary carnivores. The proportion of food obtained from each of these trophic levels is not known, but it will be assumed [illegible] here that [illegible] were secondary carnivores. Based on [illegible] statement, [illegible] that the ecological efficiency of the primary [illegible]

Peruvian food chain [illegible] available to secondary consumers. [illegible] secondary consumers, it will be assumed that [illegible] available to human consumers.

Using the assumptions made above and accepting [illegible] annual caloric requirement for one person of [illegible] that 12,807 m[illegible] of the sea within [illegible] will support one person for one year. It follows that [illegible] conditions.

[illegible] conditions on the Peruvian coast are periodically [illegible] by Niños. [illegible] assumes that an abnormal Niño [illegible] productivity [illegible] 1961. [illegible] assumes further that [illegible] mortality [illegible] that the marine resources used by prehistoric [illegible] along the coast [illegible] probably [illegible] and catastrophic [illegible] population [illegible] response, given the long intervals between Niños [illegible]

[illegible] (1976) postulated an estimated population of [illegible] people for the preceramic settlements at [illegible] population utilized the marine resources [illegible] estimate of eight persons [illegible] [illegible] bones that [illegible]

[illegible] in the Aegean [illegible]

sites in Greece. A careful reading of [illegible]

in fact, [illegible]

[illegible]

[illegible]

than [illegible] Wilson's analysis.

[illegible], in a qualitative study [illegible] several Late Bronze Age sites in the Aegean [illegible] concludes that seafood [illegible] which [illegible] little [illegible] in [illegible] current techniques [illegible] quantitative [illegible] weight to the results of these analyses (e.g., Perlman, 1980, p. [illegible]). The difficulties involved in the recovery of fish remains, in particular, suggest that fish are almost always underrepresented [illegible] quantification [illegible]. A further consideration [illegible] evidence that a significant proportion of the [illegible] may be consumed away from [illegible] and that the food [illegible] by the [illegible] living on the [illegible] almost always consumed [illegible] p. [illegible]).

[illegible] Terrestrial Food [illegible]

Osborn (1977) has proposed that [illegible] terrestrial food resources rather than marine [illegible] "[illegible]" [illegible] systems. This preference, according to Osborn, [illegible] features of [illegible] than [illegible] terrestrial [illegible] amount of labor [illegible] collecting them, and [illegible] terrestrial [illegible]. [illegible] these features suggest that the situation is not a simple [illegible].

[illegible] that [illegible] food [illegible] is based on the fact that the energy available [illegible] terrestrial [illegible] and gatherers, according to Osborn, [illegible] of the second [illegible] trophic level, [illegible] gatherers [illegible] of the fourth or fifth trophic level [illegible], [illegible] obtain significantly [illegible] terrestrial [illegible] (1977, pp. 176-177).

[illegible] that [illegible] available at [illegible] total amount of [illegible] primary [illegible] terrestrial ecosystem [illegible] higher trophic level [illegible] systems [illegible] more available energy than the [illegible] level [illegible] [illegible]. The [illegible] of [illegible]

figures illustrate the potential bias in using the nutritional value of one species of shellfish to assess the potential of maritime subsistence systems everywhere.

Nutritional comparisons based only on protein can also be misleading. Koloseike (1969), in his review of the evaluation of the food values of mollusks in prehistoric sites, [illegible] to the problem. The ratio of meat weight to shell weight, for example, exhibits significant variation between species and among individual members of the same species. The ratio is also affected by variations in water temperature and by spawning cycles. [illegible] this kind of information is not generally available in the literature, [illegible] archaeologists must conduct the basic research themselves, as [illegible] Klippel (1974) have done for the various species of freshwater shellfish found in shell mound sites in the eastern United States.

[illegible] characterizes shellfish collecting as a labor-intensive activity. The amount of labor expended, however, depends on the habitat and behavior of individual species, and most species of clams and mussels are not particularly hard to collect (cf. [illegible], pp. [illegible]; Yesner, 1980, p. 730). Most species of beach-dwelling clams are found in easily accessible intertidal areas and can be collected using rakes, shovels, or the prehistoric equivalent. Potato forks are generally used in California to locate and dig up Pismo clams, but they can also be collected by moving one's feet back and forth in the sand ([illegible], p. [illegible]). Professional fishermen working Pismo clam beds with potato forks at San Quintin in Baja California each collected from [illegible] of clam meat during an average low tide (Aplin, 1947). Assuming one [illegible] tide per day, each of these fisher[illegible] satisfy the daily protein requirement of [illegible].

Abalone are harvested commercially today along the California coast by divers working at depths from [illegible] to [illegible] meters. However, they were collected aboriginally in the intertidal zone, and [illegible] still [illegible] the same today (Fitch, 1971, pp. [illegible]). Scallops (Pecten sp.) were probably more difficult to collect aboriginally because they prefer deeper waters beyond the intertidal zone. Nevertheless, [illegible] preferred mollusc in [illegible] some localities, possibly because they have a higher protein content than most other shellfish [illegible]. [illegible] mounds at the site of [illegible] on the south coast of Peru, [illegible] consist almost entirely of Pecten purpuratus shells, despite the fact that other shellfish species were present (Engel, 19[illegible], pp. [illegible]).

Shellfish are a secondary source of protein for the [illegible], but they [illegible] think of shellfish as an important food. [illegible] close to shellfish beds because they are a dependable resource that is available year round, and because shellfish can be easily collected by a broad spectrum of the population (Meehan, 1977, pp. [illegible]). Meehan estimates that a skilled woman could collect about [illegible] of shellfish in about two hours, or about [illegible] g of protein (1977, p. [illegible]).

While shellfish are a relatively good source of protein, they have a low caloric content. Wilson estimates that [illegible] of shellfish on the Peruvian coast could satisfy the annual caloric needs of only [illegible] adults (1981, p. 106). However, if we disregard the fact that [illegible] carrying capacity is one-sixth of [illegible] the caloric carrying capacity is [illegible] percent per hectare. Wilson based his estimates on the productivity of Mesodesma donacium clams [illegible].

which produce 7900 kg of meat per hectare annually ([illegible] 1967). This represents from [illegible] to [illegible] [illegible] protein values for [illegible]. Each of these [illegible] would provide the annual protein needs of between [illegible] and [illegible] adults.

It should not be [illegible] that [illegible] subsistence [illegible] shellfish [illegible] environment [illegible] characterized by high species diversity and a variety of potential marine and terrestrial resources. Shellfish are only one of a number of available food resources, and generally appear to be utilized as supplements to other food resources with higher caloric values, or as an important back-up food source when others are in short supply (Perlman 1980, pp. 286-290).

THE TERRESTRIAL COASTAL ENVIRONMENT

The relatively cool water of the Peru current, the prevailing [illegible] winds, and the presence of the Andean mountain chain combine to produce a terrestrial coastal environment characterized by exceptionally low precipitation, high relative humidity, persistent cloud cover during the Peruvian winter (June through October) and small daily temperature variations. Annual precipitation varies from [illegible] to 100 mm between [illegible] and [illegible] S, and between 0 and 25 mm south of latitude [illegible] ([illegible]). According to [illegible] ([illegible], p. [illegible]), the lack of precipitation is caused by a persistent atmospheric inversion that prevents the development of convective air currents. The inversion [illegible] the vertical transport of water vapor, resulting in high atmospheric humidity under the inversion and persistent cloud cover along the coast. The saturated air under the inversion [illegible] the ground surface at [illegible] elevations.

between 100 and 800 meters [illegible] predominantly [illegible]. The genus are most prevalent between June and October [illegible] south of latitude [illegible].

The barrenness of the coastal desert, prior to the advent of irrigation agriculture, was relieved only by natural vegetation on the flood plains of the coastal valleys, and by vegetation [illegible] lomas [illegible], between 100 and 700 meters. The lomas are watered by the condensation of fog from winter [illegible], which is apparently accelerated by the greater surface area presented [illegible] by the [illegible]. In [illegible] annual precipitation under [illegible] was 640 mm, compared [illegible] with only a few plant cover (Schweigger, 1964, p. 167). [illegible] would be correspondingly less. The lomas [illegible] susceptible to grazing pressure, [illegible] reduction of plant cover [illegible] conditions, thus [illegible] for [illegible] of plant cover. [illegible] 8° and 30° [illegible] 1966, pp. [illegible].

[illegible] rivers cut through the coastal desert from the [illegible]. They exhibit significant variation in [illegible] of their channels and the area and location of flood plains and irrigated land. There are also significant variations in annual river discharge (Robinson, 1964, pp. 163-167). River discharge, which exhibits the greatest seasonal variation of any environmental [illegible], is dependent on seasonal precipitation on the [illegible] of the Andes. Maximum discharge occurs during the months of January to March, during the height of the rainy season in the mountains, [illegible] during July and August (Robinson, 1964, pp. [illegible]).

Climatic Anomalies

Major Niños produce major changes in coastal climate, while weaker events have variable effects. During the 1925 Niño, torrential rains fell on the north coast of Peru from January through March, and increased rainfall was recorded as far south as northern Chile (Murphy, 1926, pp. 37-45). Rainfall in Trujillo totaled 394 mm from January through March, compared to an annual average precipitation of less than 5 mm. The 1891 and 1972-73 Niños also produced torrential rains on the north coast and increased rainfall on other parts of the coast (Caviedes, 1975; Murphy, 1926, pp. [illegible]). Increased river discharges and flooding of coastal valleys were due to increased rainfall in the mountains above the coastal plain. During the 1925 Niño, it occurred as far south as the Ica Valley (Murphy, 1926, pp. [illegible]). While high river discharges and coastal rains occur together during major Niños, high river discharge on the north coast can occur in the absence of coastal rains (Nials et al., 1979).

The heavy rains and floods that accompany major Niños cause extensive destruction and the disruption of irrigation canals in coastal valleys, but have a beneficial effect on coastal vegetation and flood plain agriculture. Grasses and herbaceous vegetation flourished in normally barren areas as far south as Lima in 1925, and provided pasturage for goats for one to two years after the Niño. Water tables were elevated in the Piura Valley and caused increased agricultural production for as long as three years after the Niño (Murphy, 1926, pp. [illegible]). Similar conditions prevailed after the 1972-73 Niño (Caviedes, [illegible]). In general, it appears that the flooding of coastal valleys during major Niños, while causing major disruptions of irrigation systems, increases the potential for flood plain agriculture after the flood waters recede. It is also likely that the quantity of potential [illegible] inland resources in both areas and in the coastal valleys [illegible] reduced for a period of one to two years after a major flood.

The major problem is determining the latitudinal variation in the effects of Niños. In general, intensity and duration of the [illegible] effects of major Niños are highest in the north and decrease [illegible] moves south along the coast. A similar [illegible] varying intensity, the less [illegible] along the coast. Thus, we would expect that the north coast is affected more frequently and with greater intensity, while the central and south coasts are affected only by the major Niños. This [illegible] effect is reflected in the climatic data.

Examination of variations in river discharges indicates that river discharge is significantly more variable north of the [illegible] Virú [illegible] than along the rest of the coast. Table 2 lists maximum, minimum, and mean river discharge for most of the coastal rivers. A variability index was calculated by dividing the difference between maximum and minimum discharge by mean discharge. The mean of the variability index for rivers from the Tumbes to the Virú is [illegible], and the mean for rivers [illegible] south of the Virú is [illegible]. The difference between the two means is significant at the .01 level. The number of years [illegible] varies from river to river, with no rivers having less than [illegible] years [illegible] included (Robinson, 1964, pp. 168-171). The only major Niño during this time period occurred in 1925, but no good records of discharge [illegible]

TABLE [illegible]

MAXIMUM, MINIMUM AND MEAN RIVER DISCHARGE
IN MILLIONS OF CUBIC METERS FOR THE
COASTAL RIVERS OF PERU
(Rivers are listed sequentially from North to South)

RIVER	MAXIMUM DISCHARGE	MINIMUM DISCHARGE	MEAN DISCHARGE	VARIABILITY INDEX
Tumbes	2077.[illegible]	[illegible]	[illegible]	[illegible]
Chira	11,03[illegible]	[illegible]	[illegible]	[illegible]
Quiroz	[illegible]	[illegible]	[illegible]	[illegible]
Piura	33[illegible]7.4	0.0	[illegible]	[illegible]
La Leche	394.4	[illegible]	[illegible]	[illegible]
Chancay	[illegible]47.1	[illegible]	[illegible]	[illegible]
Zaña	626.6	[illegible]	[illegible]	[illegible]
Jequetepeque	[illegible]	[illegible]	[illegible]	[illegible]
Chicama	[illegible]	[illegible]	[illegible]	[illegible]
Moche	[illegible]	[illegible]	[illegible]	[illegible]
Virú	[illegible]	40.9	[illegible]	[illegible]
Santa	[illegible]	[illegible]	[illegible]	[illegible]
Nepeña	165.9	[illegible]	[illegible]	[illegible]
Casma	[illegible]	[illegible]	[illegible]	[illegible]
Huarmey	[illegible]	[illegible]	[illegible]	[illegible]
Pativilca	[illegible]	[illegible]	[illegible]	[illegible]
Huaura	[illegible]	[illegible]	[illegible]	[illegible]
Chillón	[illegible]	[illegible]	[illegible]	[illegible]
Huaral	[illegible]	[illegible]	[illegible]	[illegible]

continued

available for that year for the [illegible] River, as predicted for the rivers where major flooding occurred (Nial et al., 1983). [illegible] while the frequency of variations in river discharge cannot be determined from the data, the results of the analysis indicate that rainfall is significantly more variable in the watersheds of the north coast rivers, whether produced by moderate Niños or other climatic variables, than along the rest of the coast.

Prehistoric Environment

An important question is the degree to which the environment of the Peruvian coast today approximates the environment during [illegible] Preceramic times. Fossil fauna are considerably more [illegible] than native fauna today. Lanning (1967, p. 43) feels that the fossil [illegible] represent a wetter climate between 8000 and 2500 B.C. [illegible] (1970, pp. 800-801) attributes the fossil fauna to [illegible] during the [illegible] years. Cohen (1978, p. 26), on the other hand, proposes that a reduction in fauna size has occurred, but attributes it to overgrazing since the Conquest, rather than climatic change. Craig and Psuty (1968, p. [illegible]) also disagree with Lanning's hypothesis of climatic change, and note that the xeric (i.e., desert-like) adaptations of [illegible] indicate arid conditions for at least the past [illegible] years.

Craig and Psuty (1968, p. [illegible]) suggest that the ocean current and [illegible]tion system of the Southern Pacific are unlikely to have undergone sufficient change since the end of the Pleistocene to modify coastal aridity significantly. Sarma, however, postulates a [illegible] cycle of wet and dry periods during the last 6000 years on the [illegible] coast of South America, and sees evidence of two pluvial peaks during the latter

Accordingly, at 2000 and 4000 B.P. (Bell, p. 111), [illegible] period, river flow in the coastal valleys of Peru would have been greater than they are today, and the extent of flood areas would have been greater in [illegible]. Additionally, El Niño would have occurred with greater frequency and would have extended farther south along the coast.

Sarma bases his analysis on variations in the frequency of mangrove dwelling mollusks in the different strata of shell middens on the Santa Elena Peninsula of southwestern Ecuador. The variation in mangroves, according to Sarma, reflect variation in the extent of mangroves, which in turn is a function of changes in rainfall. Ferdon (1981), however, argues against the validity of Sarma's climatological interpretation by showing that variation in the rate of mangrove formation on the Santa Elena [illegible] can also be explained as a response to tectonic uplift and other changes in coastline topography. According to Paulsen (1976), the [illegible] conditions in 1476 on the Santa Elena Peninsula is evidence of a dramatic reversal of an increasingly drier climate during the twentieth century. In fact, the increase [illegible], which reached a maximum in 1972, is probably a reflection of short-term changes related to the major El Niño of 1972.

The conflicting interpretations cited above indicate that more information on Holocene climatic changes is needed. The basic climatic pattern remains, however, one of exceptional aridity along the Peruvian coast with unspecified but minor variations in river flow and El Niño frequency. These possible variations do not appear to be a significant factor with regard to the hypothesis presented here.

NATURAL HAZARD CHARACTERISTICS

Recent developments in natural hazards research and the investigation of cultural responses to environmental variation indicate that extreme events are at least as important as average conditions in the analysis of human adaptive processes (Vayda and McCay, 197[illegible]; Winterhalder, 1980). An extreme natural event is defined as any event that displays relatively high variance from the mean. An extreme event becomes a hazard when it requires some degree of human response to reduce the negative impacts of the event (White, 1974, pp. [illegible]). The types of responses made may vary from acceptance of losses to complete avoidance of the event by permanently migrating out of the area affected by the event (Burton, Kates and White, 1978, pp. [illegible]). The type of response depends, to an extent, on the nature of the event.

Hazard characteristics considered relevant by Burton, Kates and White (1978, pp. [illegible]) for a study of human adaptive responses include *magnitude*, *frequency*, *duration*, *areal extent*, *speed of onset* and *temporal spacing*. A basic distinction is also made between *pervasive* and *intensive* hazards; for example, drought is a pervasive hazard, and a tornado or flood an intensive one. As noted earlier, Niños exhibit a continuum of latitudinal variation with regard to the characteristics described above. For the purpose of discussion, however, a basic distinction will be made between the north (north of [illegible]° S), central ([illegible]° S-1[illegible]° S), and south (south of 1[illegible]° S) coasts. Differences in Niño characteristics between these different zones are summarized below.

Niños as Hazards

Magnitude. The magnitudes of individual Niños vary, from minor events with minimal effects to the occasional major event, such as th

1925 Niño. Nials et al. (1979a) describe a Niño occurring sometime around A.D. 1100 whose magnitude, judging from the degree of flooding, was several times greater than the 1925 event. Degree of effect on resources depends in part on duration of the event.

Frequency. Major Niños occur about once [illegible] every generation. Moderate and minor Niños occur more frequently, as often as every five to ten years. Major Niños affect the entire Peruvian coast, while moderate and minor Niños affect only the north coast.

Duration. Duration varies with respect to magnitude and location. Duration of the primary and secondary effects of major Niños may be as long as several years, particularly on the north coast. Occurrence of a minor event immediately after a major Niño may impede recovery of the marine ecosystem, as happened in 1973.

Areal extent. This characteristic refers essentially to the latitudinal extent of a Niño and is a function of magnitude. Also included are effects on the terrestrial environment. Rainfall accompanying major Niños may affect the entire watersheds of coastal rivers. Correlations of Niño events have been made with variations in Antarctic climate and world-wide weather patterns (cf. O'Brien, 1978), but they are not directly relevant here.

Speed of onset. This characteristic refers to length of time between the first appearance of an event and its peak. As noted, effects on most marine fauna and on terrestrial climate appear quickly. Other effects, such as reduction of shellfish biomass, may show varying degrees of lag. The effects of major Niños show a progression down the coast, occurring several weeks later on the central coast than on the north coast.

Temporal spacing. This characteristic refers to the distribution of events through time and is related in some degree to the predictability of an event. Fires typically occur during the summer, but intervals between events, particularly the major ones, exhibit little regularity. It has not been possible to predict when a fire will occur or what its intensity will be. The randomness of such events and the fact that [illegible] is a critically important variable in choosing habitat [illegible]. A recent hypothesis, concerning the causes of fires, [illegible] preceded by one to two years of exceptionally [illegible] accompanied by a marked decrease in [illegible] op. cit.). If the hypothesis is valid, changes in [illegible] may have provided as much as [illegible] of [illegible].

Pervasiveness. Pervasiveness is related to duration and areal extent. Fires, like droughts, fall near the pervasive end of the pervasive-intensive continuum. Responses tend to [illegible] long-term adaptations rather than short-term adjustment.

Influences on choice of Response

It is apparent that selection of appropriate responses by a group is not a random process, but one that involves some consideration of hazard characteristics, population level, and [illegible], as well as an evaluation of the costs and benefits of [illegible]. [illegible] is also affected by the type of [illegible].

Population level. Although [illegible] during the [illegible] Period [illegible], [illegible] that there were relatively high rates of population increase during that period ([illegible]).

[illegible] 1973), at [illegible] Chimbote [illegible] [illegible] sites on other parts of the coast are relatively small and scattered suggesting relatively low population densities. This may be due in part, however, to the lack of adequate survey in these areas.

There is little archaeological evidence to support [illegible] assertion that central coast populations maintained their numbers below the carrying capacities. In any case, such a situation seems unlikely, given the long intervals between [illegible]. A population increase during the Cotton Preceramic, it is probable that [illegible] [illegible] coastal [illegible] [illegible].

[illegible] (1976, [illegible]) [illegible] the types of hunting and gathering subsistence [illegible] [illegible] environments [illegible] availability of individual resources [illegible] a wide range of resources [illegible] environments with dependable resources [illegible] focused on a smaller range of resources that provide the greatest return for a given amount of effort.

The shift from a generalized to a specialized subsistence orientation on the central Peruvian coast is illustrated by a change in settlement location from lomas zones to the coast at the beginning of the Cotton Preceramic. The change in settlement location [illegible] a change in subsistence [illegible] lomas, [illegible] [illegible] utilization of maritime and valley floor [illegible] domesticated plants (Lanning 1967). [illegible] is the stability of the coastal environment [illegible] that food plants were not utilized until long after the Cotton Preceramic and a more fixed exploitation of these plants [illegible] continued.

A maritime adaptation in a stable environment is normally characterized by small groups, small settlements, and relatively simple social organization, the kind of situation inferred for the Cotton [illegible] and the earliest preceramic settlements on the north and central coasts. [illegible] tion of appropriate [illegible] responses, then, would initially be made in a cultural context of simple social organization and small groups. [illegible] tendencies toward simple social organization and small groups [illegible] against the [illegible] of [illegible] groups [illegible] greater degree of organization and [illegible] authority. Such tendencies may have necessitated the use of [illegible] ment mechanisms, such as ritual, to maintain [illegible]

[illegible] of the importance of agriculture during the Cotton Preceramic is complicated by a [illegible] lack of [illegible]. Remains of a number of cultigens, including cotton, squash, lima beans, jack beans, gourds, sweet potatoes, and achira, are found in Cotton Preceramic sites on the north and central coasts. The food plants, however, are not found in sufficient quantity to [illegible]. [illegible] evidence for maize cultivation during the Cotton Preceramic is questioned (Feldman, 1977). If it was cultivated at all, it was not likely an important element of coastal agriculture. Water [illegible] is critical for the successful cultivation of [illegible] (Moseley, 1975, pp. [illegible]) [illegible]

at the sites. Additionally, [illegible] accumulation of [illegible] and the maintenance [illegible] [illegible]

The North Coast

The north coast [illegible] [illegible] effect of [illegible] [illegible] rains and flooding [illegible] [illegible] of shorter duration, [illegible] [illegible] by coastal rains, and probably [illegible] discharge. The overall effect is a more variable [illegible] and [illegible] central coast. These factors [illegible] [illegible] of agriculture, [illegible] There would be less [illegible] [illegible] the agricultural system [illegible] would be larger and [illegible] [illegible] architecture [illegible] [illegible] due to the lack of monumental architecture [illegible] [illegible]

The [illegible] [illegible] the north coast [illegible] irrigation, and [illegible] cultivation of maize [illegible]

[illegible] Cotton Preceramic.

The South Coast

Judging from the [illegible] along the south coast remained relatively low during the Cotton Preceramic. Dwelling [illegible] production [illegible] but these conditions [illegible] exploitation of [illegible] valleys [illegible] floodplains [illegible] during [illegible] until the [illegible] of irrigation [illegible] less than [illegible] of the south coast and the [illegible] and north coasts [illegible] population density, the [illegible] should have been a [illegible] migration [illegible]

[illegible]

The [illegible] of monumental [illegible] the effects of [illegible] labor [illegible] permanent [illegible] labor construction [illegible] residential [illegible] residential [illegible] labor [illegible] of residential [illegible] and [illegible]

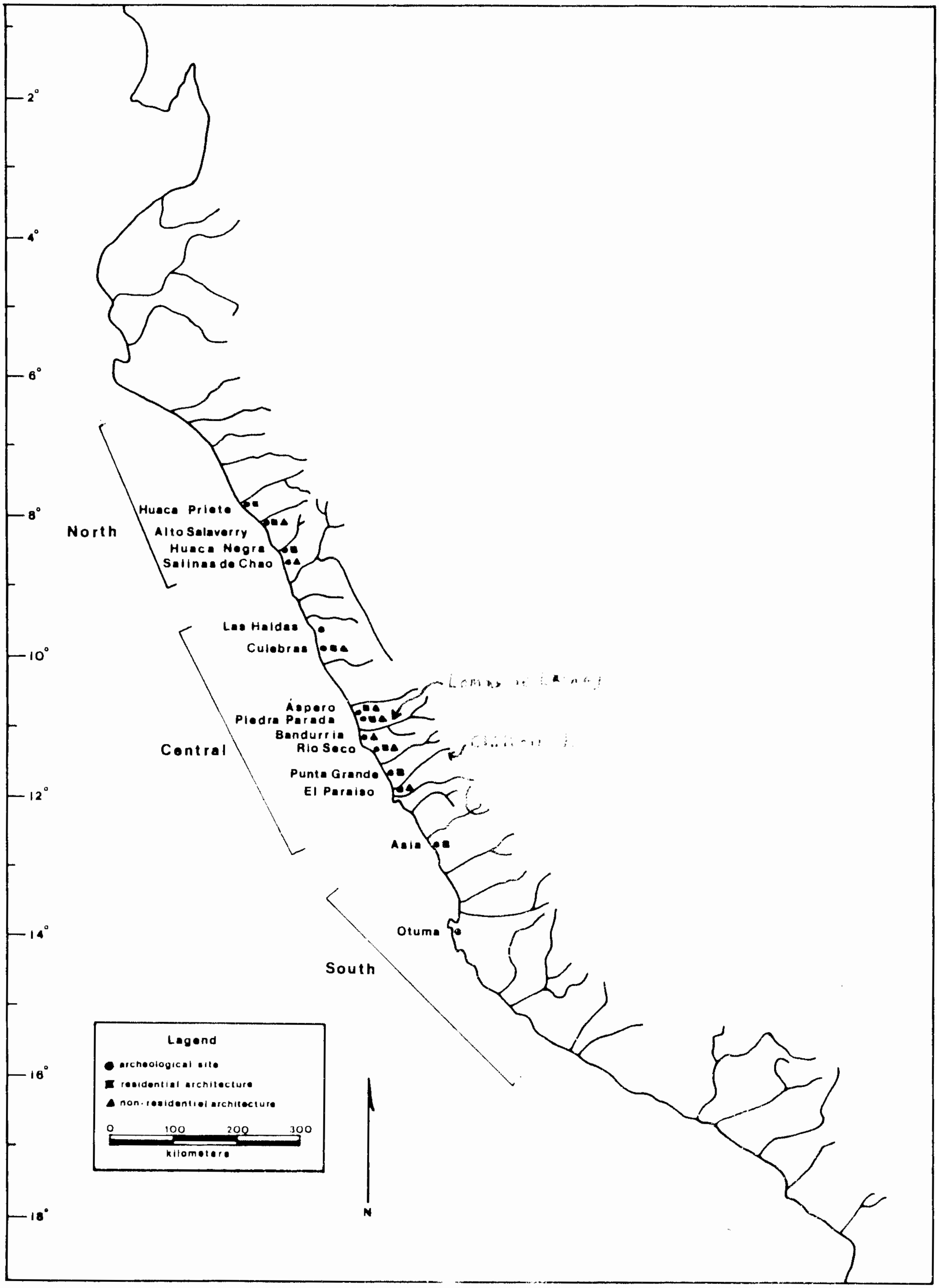

FIGURE 2

LOCATIONS AND ARCHITECTURAL CHARACTERISTICS
OF COTTON PRECERAMIC SITES NOTED IN TEXT

[illegible]

[illegible]
1977 [illegible] California Fish and Game [illegible]

[illegible], Robert [illegible]
19[illegible] "[illegible] Adaptation." [illegible] In Advances in Archaeological Method and Theory, Vol. [illegible] Schiffer, ed. [illegible] Academic Press.

[illegible]
19[illegible] [illegible] Proceedings of the First International Conference on Toxic Dinoflagellate Blooms [illegible] Wakefield, Massachusetts: [illegible] Science and Technology Foundation.

[illegible]
19[illegible] [illegible]

[illegible]
19[illegible] [illegible] Agriculture [illegible] Evolution [illegible] In Problems in Economic and Social Archaeology [illegible] London: [illegible]

Burton, Ian, Robert W. Kates, and [illegible] White
1978 The Environment as Hazard. New York: [illegible]

[illegible]
19[illegible] "[illegible] Economic Implications [illegible]

[illegible]
19[illegible] "Archaeological Plant Remains [illegible]" [illegible]

[illegible]
19[illegible] "[illegible] Shell Mound [illegible] and [illegible]" American Antiquity [illegible]

[illegible]
19[illegible] "Biological Consequences of the [illegible]" [illegible]

[illegible]

[illegible]

[illegible]

[illegible] Journal of Anthropology [illegible]

[illegible]

[illegible] for the Origin of the [illegible] at the 1977 Annual Meeting of the [illegible]

[illegible]

[illegible]

Food and Agriculture Organization
1976 Yearbook of Fishery Statistics [illegible] United Nations.

[illegible]
[illegible] California [illegible] Fish and Game.

[illegible]
[illegible] Food and Agriculture Organization of the United Nations.

[illegible]
[illegible] [illegible]

[illegible]
[illegible] [illegible]

[illegible]
[illegible] [illegible]

[illegible]
[illegible] [illegible] Working Paper [illegible]

[illegible]
[illegible] [illegible]

[illegible]
[illegible] [illegible]

[illegible]
[illegible] [illegible] California.

[illegible]
[illegible] [illegible] Prentice Hall

[illegible]
[illegible] [illegible] presented at the 1977 Annual meeting [illegible]

[illegible]
[illegible] [illegible]

[illegible]
1958 "[illegible]" [illegible] American Antiquity [illegible]

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1974 Introduction to Marine Biology. [illegible]
The C. V. Mosby Company.

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[illegible]
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[illegible], eds. New York: [illegible] Press.

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Colorado, Institute of Behavioral Science.

[illegible]
1970 [?] [illegible] Agricultural [illegible]
North Carolina, North Carolina: [illegible]
[illegible]

[illegible] [illegible] California. [illegible]

[illegible]
[illegible]

[illegible]
1978a [?] "[illegible]" Fieldiana, Field Museum of Natural History, [illegible]

1978b [?] "[illegible] Part II." Fieldiana, Field Museum of Natural History, [illegible]

[illegible]
1967 [?] [illegible]

[illegible]
[illegible]

[illegible]
[illegible] [illegible] In [illegible]. New York: Academic Press.

[illegible]
1974 [illegible]. American Antiquity [illegible].

[illegible]
[illegible]

[illegible]
[illegible]

[illegible]
[illegible]

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[illegible]
[illegible] Peruvian Coast." [illegible] Their Natural and Human Environments. [illegible] and A. W. Wilson, eds. [illegible] Press.

Pozorski, Sheila
[illegible]

[illegible]
[illegible]

[illegible]
[illegible]

[illegible]
[illegible] "Preliminary [illegible]"
[illegible]

Rappaport, R[illegible]
[illegible]

Raymond, [illegible]
[illegible]

Richardson, James B.
[illegible] "Guidelines for Development of [illegible]"
[illegible]

[illegible]
[illegible]

[illegible]
[illegible]

[illegible]
[illegible]

[illegible]
[illegible]

[illegible]
[illegible]

[illegible]
[illegible] Proceedings of the [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

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