Chapter 11

Fishing, farming, and the foundations of Andean civilisation

Michael E. Moseley and Robert A. Feldman

The 'Maritime Foundations of Andean Civilisation' hypothesis challenges the axiom that agriculture is necessary for the rise of complex societies. It argues instead that a maritime economy, based primarily on net-catching of anchovies, underwrote the beginnings of civilisation in coastal Peru. It contrasts the simple fishing technology with the more complex and demanding irrigation technology needed for farming the Andean coastal desert. El Niño perturbations – often claimed to limit maritime-based populations below the needed level – are shown to have a greater negative impact on irrigated agriculture than on traditional fishing.

Introduction

In boldest form the 'Maritime Foundations of Andean Civilisation', or 'MFAC' hypothesis, holds that the rise of pristine civilisation along the Peruvian Pacific coast was initially based upon uniquely rich marine resources. More specifically the proposition states that netting of anchoveta (the Peruvian anchovy) and other small schooling fish localised in near-shore waters in the zone between latitudes *c.* 9° and 15°S underwrote: (1) coastal sedentism; (2) population growth; (3) large communities and (4) complex social organisation which found graphic expression in monumental construction projects of the third and second millennia BC, including the largest group of elite masonry architecture yet discovered in the western hemisphere for this time period (Moseley 1978b).

The assertion that the earliest big monuments in the New World are expressions of a fishing rather than a farming economy faces certain intrinsic problems. First, the maritime mainstay – the anchovy – is something people associate with the tops of pizzas, not the foundations of civilisation. And, second, the maritime proposition runs contrary to the anthropological axiom that agriculture is the midwife of civilisation.

The axiom that civilisation can only arise in the context of an agricultural economy is a basic premise for conceptualising social evolution in developmental stages of savagery, barbarism and civilisation, or bands, tribes, chiefdoms and states. This time-honoured scheme was cemented in the foundation of anthropology by figures such as E. B. Taylor and L. H. Morgan. If all civilisations could be shown to arise only from agricultural origins then the scheme of evolutionary stages would have universal applicability and enjoy law-like status. To achieve this status, the founding fathers of social evolutionary theory established the axiom of civilisation's agricultural origins on the basis of nineteenth-century ethnographic comparisons and the literature of classical antiquity, read at a time when dynastic Egypt was thought to represent man's archetypical stage of early civilisation. There were no other data, and the evolutionary formulations that enshrined farming as the mainspring of civilisation were laid decades before Sir Flinders Petrie wrote *Methods and Aims in Archaeology* (1904) and laid out the principles by which prehistoric inquiry proceeds. In a very real sense the axiom of agrarian origins was fully established in anthropology long before archaeology became a discipline. Indeed, archaeology did not begin to examine systematically the issues surrounding plant domestication and the rise of complex society until the 1950s. Initial research efforts in different Near Eastern settings did not produce a unitary model of early farming and civilisation, but rather resulted in what might be called the 'Battle of Jericho and Jarmo', which pitted the 'hilly flanks' of plant domestication against the 'urban oases' of settled life in a struggle to represent the one true archetypical path to civilisation.

The debate prompted awareness of ecological parameters as a source of variability in the archaeological record of early civilisations. In subsequent decades, field studies have explored plant cultivation and the rise of complex societies in diverse settings, and have repeatedly reconfirmed the role of ecological variability in generating diverse adaptations, and thus variability in the development of civilisation. Yet what form such development might assume in the context of global environmental extremes of either temperature or moisture – extremes that set absolute limits on plant growth – has not been sufficiently pondered. Nor have environmental extremes that offer non-agrarian economic options drawn anthropological attention.

The world's driest desert stretches along the western watershed of the Andean Cordillera from about 4° to 30°S (Lettau and Lettau 1978). In turn, the ocean's richest fishery is found in the nearshore currents that sweep along the desert coast from *c.* 4° to 25°S: as of 1970 it supplied one-fifth or more of all seafood consumed worldwide (Hartline 1980).

The environmental extremes of the Andean coast provide two specialised economic options for securing large quantities of food. Securing high agricultural yields is dependent upon canal irrigation fed by highland runoff, while securing high maritime yields is dependent upon netting nearshore schools of anchoveta (*Engraulis ringens*) that can be dried and ground to fish meal. Today both economic specialisations produce high capital returns by supplying the international food market. In recent decades the greatest returns have come from fish-meal export, followed by sugar cane grown by agro-industrial co-operatives controlling prime irrigated land.

The MFAC hypothesis rests upon the premise that irrigating the world's driest desert is technologically and organisationally more demanding and complex than netting the ocean's richest fishery. The latter is today done by small craft with small crews, whereas canal irrigation is a co-operative venture involving the interdependency of many individuals. Because the netting of small schooling fish produces exceptionally high yields with simple technological and organisational prerequisites, the maritime hypothesis holds that the coastal fishery influenced the course of economic evolution in a number of fundamental ways.

First, following early economic dependency upon hunting and gathering, there was a period of primary caloric reliance upon marine resources prior to the advent of irrigation agriculture. In simplest form, the rich fishery is believed to have interjected a middle stage of maritime subsistence into local economic development.

Second, this middle-stage adaptation, the so-called 'cotton pre-ceramic period', supported the advent of sedentism, the growth and nucleation of coastal populations, and construction of monumental architecture requiring large-scale labour organisation. In other words, the fishery is argued to have sustained the initial rise of complex societies on the Peruvian coast.

Third, the formation of large-scale labour organisation in a maritime context facilitated subsequent early-ceramic-stage construction of large-scale canal systems and the opening of the desert to intensive agriculture. This is to say, the fishery fostered developments leading to its displacement by irrigation agriculture as the mainspring of economic development.

In overview, the MFAC hypothesis sees the coastal fishery as a uniquely rich resource complex that came under intensive exploitation at an early date and sustained the evolution of large, politically organised populations prior to the time when agriculture assumed economic primacy.

Criticisms of the maritime hypothesis

Critics of the MFAC hypothesis are not drawn from the ranks of archaeologists who have excavated pre-pottery coastal sites. Rather, the basic criticism of the hypothesis – that sea resources are incapable of supporting large sedentary communities due either to aperiodic El Niño downturns in marine productivity (M. Parsons 1970) or to inherent caloric inadequacies that make hunting or farming more productive (Osborn 1977a, b) – are purely theoretical, not empirical propositions. Other papers have elaborated themes of the 'calorie-free sea' and 'El Niño the grim reaper' in order to argue for either an early Meso-American maize-type economy (Wilson 1981), or an early tropical forest tuber-type economy (Raymond 1981). In turn, these themes have been reiterated by Thomas Lynch, whose experience with highland Andean lithic-period cave sites leads him to the conclusion that

> Human beings are terrestrial animals and they generally rely on sea food only after the preferred fruits of the earth have become scarce from competitive exploitation. Some years ago, Mary Parsons (1970) cautioned us that exclusive reliance on marine resources would hardly be possible through several human generations, given the disastrous effects of 'El Niño' on coastal ecology . . . I doubt that coastal Peruvians in any numbers were ever shortsighted enough to subject their destinies to the vicissitudes of such a delicate and specialized economy (1981: 223).

This statement might well strike economists and Peruvians as short-sighted indeed, given that in recent decades the national economy enjoyed significantly greater returns from anchoveta exploitation than from coastal irrigation agriculture. It would also strike coastal residents as strange that small-craft fishing is supposedly a 'more delicate and specialised economy' than agriculture, dependent as the latter is upon construction and maintenance of the largest canal systems in the continent.

Why Peru's recent and distant economic past represents a unified, consistent set of subsistence adaptations that defy anthropological expectations is largely explained by predictive spinoffs from the so-called 'Ocean-Atmosphere' paradigm and the biotic relationships it structures.

The Ocean-Atmosphere connection

Because of the serious consequences recent Niños have had on the world economy, they have been the subject of intensive scientific inquiry. Brought together in what has been termed the 'Ocean-Atmosphere connection', these studies have focussed upon the Andean coast and the El Niño perturbations that are uniquely disastrous to the region. As a result, the scientific understanding of normal and abnormal environmental conditions along the Peruvian coast is exceptional and qualitatively different from other areas of the world (Wyrtki *et al.* 1976, Cromie 1980).

Both the Ocean-Atmosphere paradigm and the MFAC hypothesis are structured by unique physical conditions that prevail along the Pacific seaboard of Peru. In 1970 the narrow band of nearshore waters known as the 'anchoveta belt' produced a maximum harvest of *c.* 12 million metric tons of fish, representing one-fifth of all seafood caught the world over (Idyll 1973). In 1972 it rained in significant amounts on the desert coast for the first time since 1946; during the intervening decades the total precipitation, measured at 8°S, was only 46 mm, an astounding annual average of 1.7 mm (Nials *et al.* 1979).

These global extremes in marine and meteorological conditions and the biotic relationships they structure are not independent variables, but interdependent physical conditions generated by a uniquely regimented coastal regime of oceanic and atmospheric currents that are mechanically articulated with the greater circulation system of the tropical Pacific basin. The strength of this articulation is such that El Niño perturbations such as that which brought about the 1972 showers, as well as disruption of the fishery, can be forecast in advance by the ocean-atmosphere paradigm on the basis of sea-level and temperature changes off the coast of Peru and in the vicinity of Indonesia (Cromie 1980). These mechanical relationships are critically important to the MFAC proposition, which rests upon the contention that 5000 years ago the fishery was equally as rich and the desert was equally as dry as they are today. Indeed, for other than a basically modern regime of coastal currents to have prevailed, the entire tropical Pacific circulation system would have to have been altered, for which there is little evidence. However, there is unequivocal evidence that Peru's present marine and meteorological regime is no less than 5000 years old. The data range from guano deposits left by marine avifauna feeding upon small schooling fish (Hutchinson 1950), through ^{14}C dated marine shell deposits of extant molluscan species on Holocene beaches (Richardson 1974, Sandweiss 1986), to a multitude of coastal midden sites with preserved organic remains indicative of extreme aridity.

The anchoveta fishery

Commercial exploitation of anchoveta peaked during the late 1960s, with catches of over 10 metric tons per year. The very large yields of this fishery have been attributed to the high primary production in the coastal upwelling currents and the high efficiency of the food chain, in which the anchoveta feed directly upon phytoplankton. In reality, however, such direct feeding may characterise only a limited northern portion of the anchoveta belt. Anchovy egg and larva abundance in waters north of Lima, along the broad continental shelf, is thought to reflect a short food web (phytoplankton-anchovy) with a 10% ecological efficiency. But functioning over an area perhaps ten times as great, there appears to be a longer food web (phytoplankton-zooplankton-anchovy) with a lower ecological efficiency. The upwelling zone, about 50 km in width and extending some 2000 km along the Andean coast (4° to 22°S), produced total catches of 10 million metric tons per year for the entire area (10^5 km^2), suggesting maximum average yields of about 100 metric tons per km^2 per year, reflecting a food chain efficiency of less than 1% (Walsh 1981). Such anchovy yields are an order of magnitude higher than marine harvests presently derived from the North Sea, the Mid-Atlantic Bight, or the Bering Sea (*ibid.*). It is on the basis of the relative yields of this century's commercial fisheries that the MFAC proposition holds that the indigenous Pacific maritime adaptation of South America had access to potentially far richer and more abundant marine resources than did the parallel adaptation in North America.

The richness of the maritime resources is reflected in the diversity of marine plants and animals recovered from well-preserved coastal middens. Food remains include seaweeds, tunicates, molluscs, large and small fish, marine birds, sea-lions, and occasionally whales (Patterson and Moseley 1968, Pozorski and Pozorski 1979). Although species diversity was important, the rise of coastal civilisation was predicated upon resource abundance. The MFAC hypothesis holds that the abundance of the anchoveta allows it to be understood as a resource akin to an agricultural staple.

It is useful to consider briefly the demographic 'ceiling' of the anchoveta support base in order to establish the population limits below which level the MFAC proposition should be intelligible. Harvests of 10 million metric tons per year are thought to represent the maximum cropping rate of 50 to 60% of the total per-1972 anchoveta biomass, beyond which the reproductive stock cannot sustain continued yields. The harvests of 1971–2 exceeded this limit; coupled with the strong El Niño of 1972, this overfishing seriously depleted the anchoveta stock. It still has not recovered to its pre-1972 levels. The nutritional values for anchovy are approximately 99 calories/100 g and 21 g protein/100 g edible portion. Extrapolating from these values, the annual production of food energy for one-half the anchovy biomass is 1.089×10^{13} kilo

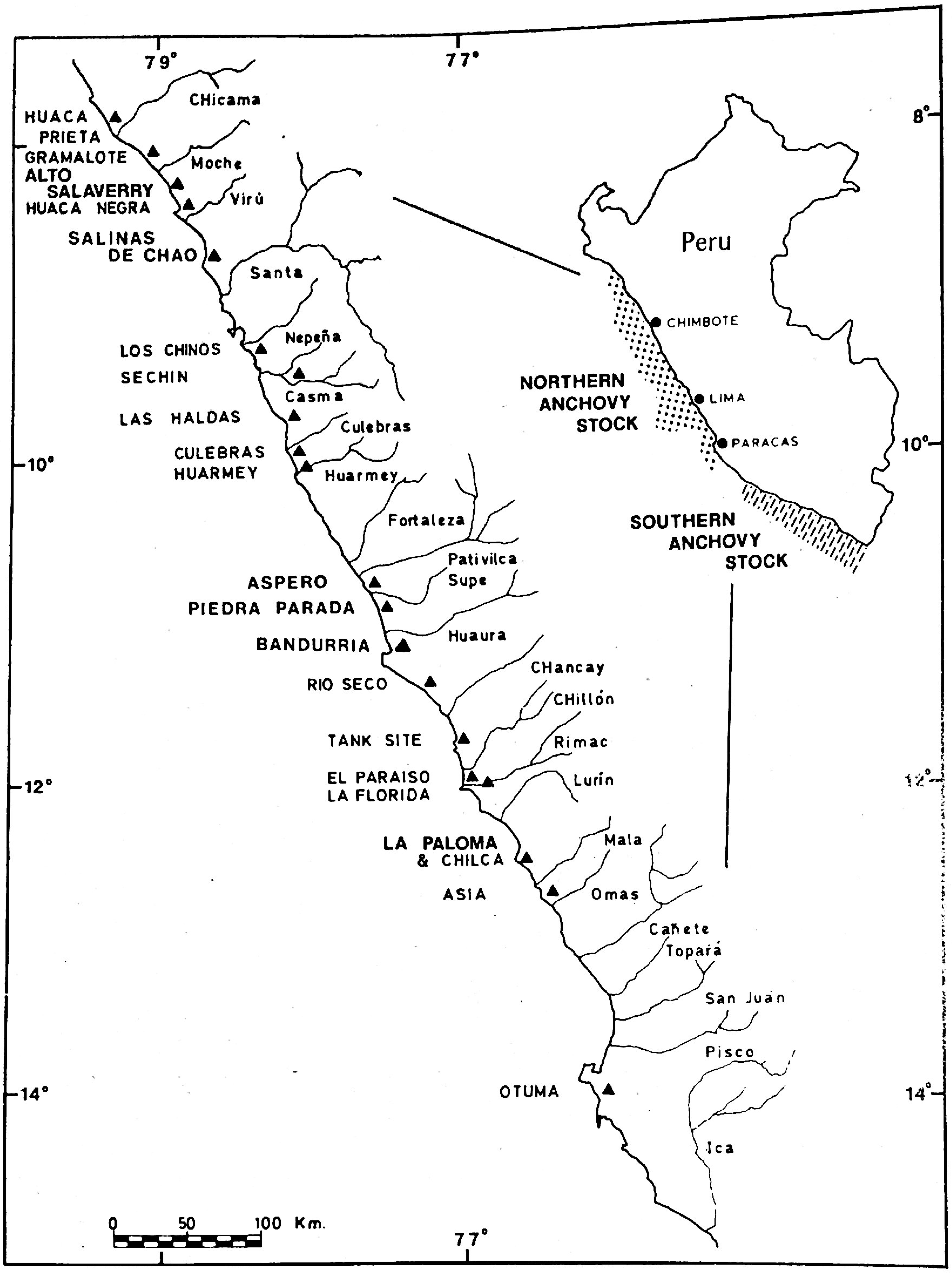

Fig. 11.1. Major coastal pre-Ceramic settlements. Inset: distribution of the two major anchovy stocks as determined by spawning areas.

calories. Assuming indigenous coastal populations lived at 60% of the carrying capacity, then anchoveta could support a maximum of some 6,626,772 persons per year (Osborn, *pers. comm.*). This figure is about half the traditional population estimate for the entire Andean culture area at the time of European conquest (Bennett 1946: 7–8), and represents a demographic maximum well above the level at which the rise of large, sedentary marine-based communities is a very viable, if not fully predictable, proposition.

A potential demographic ceiling measured in millions of individuals, and annual yields averaging 100 tons of small fish per square kilometre of nearshore waters are figures that stand in stark contrast to all anthropological claims that Peru's coastal resources are not productive enough to sustain extremely large populations. This difference exists because every such claim is predicated on systematic exclusion of all quantitative reference to the productivity of anchoveta netting, when in fact the role of the fishery is fully documented as a twentieth-century international economic mainstay (cf. Idyll 1973; Jordan 1980).

Anchoveta distribution

For anthropologists to contend that the present importance of the fishery has no bearing on Peru's past, it is necessary to posit that anchoveta schools were inaccessible to pre-Hispanic populations. Inaccessibility due to climatic or current changes cannot be invoked without concurrent change in the entire tropical Pacific ocean-atmosphere circulation system. Thus, if anchoveta are to be rejected as a prehistoric resource, then the reason should lie either with schooling behaviour of the fish or maritime technology of the fishermen.

The overall distribution of *E. ringens* is shown in Fig. 11.1, which also plots the location of major pre-ceramic architectural monuments and related sites. These sites are largely coincident with the richer northern portion of the fishery between the ports of Callao (12°S) and Chimbote (9°S), which is the northernmost harbour serving the modern anchoveta industry (although the anchoveta's spawning activity and larval distribution extend up to 6°S). The distribution of anchoveta is related to the productivity of upwelling currents, which is in turn influenced by sea-floor topographic variation related to proximity of the Peru–Chile trench to the Andean cordillera. Production of chlorophyll and phytoplankton is high but not uniform throughout the anchovy belt. The overall average for the Andean coast surpasses all other upwelling systems except for the smaller Benguela Current (Cushing 1969). However, the chlorophyll average of the latter is surpassed by specific Peruvian productivity maxima occurring around 8°, 11°, and 15°S. These localities are coincident with extremely high commercial yields measured on the order of 1000 tons/km^2/yr (Guillen 1980, Walsh 1981).

The MFAC proposition holds that the coastal co-occurrence, between *c.* 8° and 15°S, of the highest fishery yields and the largest pre-ceramic architectural complexes on the continent, is not a casual coincidence. Rather, it is considered an economic reflection of *E. ringens* schooling habits, with most fish swimming at depths of less than 25 m during most of the year, and at distances less than 20 nautical miles from the shore for most of their lives (Vestnes *et al.* 1965a, 1965b, Jordan 1980: 250). Although schools range from reported depths of up to 100 m and distances up to 210 miles, the greatest numbers of anchoveta are concentrated in nearshore shallow waters, with between 40% and 50% of the annual commercial harvest occurring within 10 miles of the coast. Indeed, during warm water El Niño intrusions the schools move closer than usual to the shore (Santander 1980) and 90% of the commercial catch can then be taken within 10 miles of land (Vildoso 1980). At times, masses of anchoveta will even beach themselves where great quantities can be scooped up in baskets (Jackson and Stocker 1982).

Under normal conditions the annual variation observable in schooling behaviour entails large concentrations of anchoveta close to the shore during the summer months, with winter seeing a dispersal into smaller schools over a larger area. Thus, more effort is required to net anchoveta during May, June and July than during the larger part of the year from September to March, when harvests are four to six times greater (Valdivia 1980). However, schools are present year-round. Until the early 1960s and the beginning of government-imposed regulations, the anchovy industry registered more than 290 fishing days during most years (Jordan 1980: 262).

In summary, anchoveta schooling behaviour brings large stocks of small fish into shallow waters within 20 miles of the shore on a year-round basis. The result is one of the most accessible major piscine resources known to man. From an anthropological perspective, the anchoveta fishery is both biologically more productive and technologically easier to exploit than the salmon or anadromous fisheries of the North American Pacific seaboard, which supported stable populations with advanced social systems.

Technology

The technological prerequisites necessary for pre-Hispanic anchoveta exploitation can be assessed on the basis of documented present practices. The fishing industry proceeds upon the basis that anchoveta are most efficiently harvested by netting from small craft, and most economically processed by drying, grinding into fish meal, and then bagging for open-air storage. In the early 1950s the commercial fishery operated out of a few ports and was very simple, based on 126 small wooden boats (of 2400 tons gross registry) largely without mechanical equipment for net recovery and with little capacity for sailing long distances. The fleet modernised and the fish-meal industry expanded before producing its maximum harvests of 10 million metric tons annually (Jordan 1980). The point here, however, is that commercial yields are obtainable without motorised craft or net retrieval.

The MFAC proposition rests upon the premise that anchoveta exploitation in the past was basically similar to its present practice, which involves the use of small craft and the netting, drying, grinding and storing of the fish. Of these five factors, arguments against an early maritime adaptation have focussed upon the first (Wilson 1981). Indeed, unlike netting, grinding, and storing, no physical remains of pre-Hispanic watercraft have been recovered from excavated coastal sites. Therefore the sea-going abilities of the early coastal population must be inferred from other lines of evidence.

Valdivia- and Machalilla-phase occupational midden deposits on La Plata Island (Ecuador) establish a minimal 20 km off-shore voyage capability prior to 1000 bc in the area north of the anchoveta belt (Donald Lathrap and Jorge Marcos, *pers. comm.*). Within the anchoveta belt, voyages of 9, 14, and 16 km are established for the first millennium AD by artefacts recovered in guano deposits on the Macabi, Guañape, and Chincha Islands (Kubler 1948). By the first centuries AD, two varieties of sea-going craft are represented in Moche iconography of the desert coast. These are totora reed boats of one- and two-man size, and balsa-log sailing rafts (Donnan 1978). Both vessels were described more than a millennium later in various ethnohistoric sources. These references range from Francisco Pizarro's ships encountering balsa sailing rafts on the open ocean, far beyond land sight (Fonseca and Richardson 1978), through Cieze de Leon's account of regular voyages to the Tarapaca guano islands, apparently by reed boats, and definitely for the purpose of procuring fertilisers (Kubler 1948). More recently, the transoceanic feasibilities of both balsa rafts and reed craft have been popularised by Thor Heyerdahl's Kon Tiki and Ra expeditions. Within these parameters, if pre-ceramic reed or balsa craft can be legitimately inferred, then a simple one- or two-man capacity for shallow-water netting up to 10 km offshore would fall within native sailing capabilities of totora boats inferred archaeologically and demonstrated ethnohistorically, yet would effectively place more than 40% of the anchoveta stock within exploitable reach of the early maritime populace.

Unlike watercraft, pre-ceramic netting practices are not inferential. Pre-pottery midden deposits dating to after *c.* 3000 bc characteristically produce net fragments in such abundance as to dominate numerically all other food-procurement artefacts, either marine or terrestrial related. Net fragments rank second only to twined cotton textile fragments as the most common and diagnostic of all pre-ceramic manufactures (Moseley 1968). The practice of float-netting is documented by excavated nets attached to gourd floats (Bird 1948, Bird and Hyslop 1985), as well as by the general co-occurrence of gourds and unattached net fragments in the same deposits.

Net mesh size is an important indicator of the size of fish caught. Analysis of 77 net fragments from pre-ceramic sites in the Ancon–Chillon region demonstrated that all of the specimens had apertures of less than 2.5 cm, with 75% of the sample falling in the 0.5 to 1.5 cm mesh range (Moseley 1968: 135). This small mesh size is not appropriate for gill-netting of large fish, rather it is structured for the float-netting of small fish. Further, pre-ceramic aperture dimensions fall within the mesh range employed by the modern anchoveta industry.

If qualitative characteristics of pre-ceramic netting – mesh size and float suspension – are indicative of small fish capture, then other characteristics of the early maritime technology need not be inconsistent with the potentials of anchoveta harvesting. The subsistence technology demonstrable through artefact recovery includes a very high incidence of netting, but a low incidence of other tackle or food-procurement gear (Moseley 1978b: Table 1). This all but exclusive focus upon float-netting is without analogy among other native maritime societies of the Pacific seaboard that lie outside the anchoveta belt. However, technological analogies for exclusive reliance upon small mesh netting can be found with commercial anchoveta fishing of the early 1950s.

Fish-hooks are present at certain early pre-ceramic sites, particularly where angling could take place by hand-line off rocky headlands (Moseley 1968). However, after about 2500 bc their frequency of occurrence declines, as do sites oriented toward headland angling. Netting reflects a quantitative change opposite that of hooks: fragment recovery becomes more common through time, as do the number and sizes of communities located by open sandy bays. In overview: 'Thus, the maritime technology developed little qualitative change, but quantitative modifications did occur. Float netting used to capture small schooling fish was the most productive component of the pre-ceramic economy and received progressively more emphasis through time by increasing numbers of people' (Moseley 1978b: 10).

In the technological chain of fish-meal production proceeding from small craft-netting of the anchoveta through their drying, grinding, and storage, the latter processing aspects have no mechanical requirements that preclude early exploitation. Indeed, recent identification of abundant dried fish deposits at the pre-ceramic settlement of La Paloma on the central coast unequivocally documents intensive processing of small schooling fish (Engel 1980, Quilter and Stocker 1983).

Demonstrating the production of fish meal is relatively simple in comparison to quantifying its consumption. Coprolites and skeletal bone chemistry, however, provide important insights. Study of faecal samples from the pre-ceramic site of Aspero established that small fish bones were the dominant recognisable organic constituent in the coprolites (Popper 1978, Feldman 1980). These samples, however, need only represent the consumption of whole fish in fresh or dried form, since ground fish meal leaves few recognisable remains. We can get an indication of the total animal protein consumption by measuring strontium levels of bone, which reflect dietary intake of animal protein versus plant nutrients. The Paloma settlement has provided the largest pre-ceramic population yet sampled. Significantly, strontium levels in Paloman bone are very low – lower than any other reported population – suggesting a very high protein diet. Corresponding studies of intestinal contents and coprolites have identified sea foods as the source of this protein (Benfer 1986: 57).

In overview, the physical evidence for exploitation of small schooling fish ranges from fish nets through fish meal to coprolite content and bone chemistry. Although quantifying fish and fish-meal consumption remains difficult, it seems evident that early Andean maritime societies exploited a rich and abundant resource base in which anchoveta played a role akin to an agricultural staple with capabilities of supporting millions of people.

Agricultural productivity

Peru's desert coast is crossed by some 57 streams and rivers that support farming and form the core of the nation's commercial agriculture (Robinson 1964). The productivity of well-watered coastal land is exceptionally high, with harvests averaging 3200 kg/ha for maize, 13,000 kg/ha for sweet manioc, and 136,000 kg/ha/yr for sugar cane (ONERN 1973). These per-unit area yields are substantially above world averages, and the irrigated coastal valleys are similar to the highly productive Imperial and Coachella Valleys of California's Mojave desert. The favourable combination of sunshine, mild but constant temperatures, and well-drained soils makes the Pacific desert one of the most productive agricultural settings in the New World, and the well-watered lands are monopolised by mechanised, agro-industrial complexes serving the international export market.

Because crop yields are exceptionally high, anthropologists have argued that farming is more productive than fishing (Wilson 1981, Raymond 1981). During the present century, however, the returns from commercial farming have never matched the high returns from commercial fishing set by the anchoveta industry. This situation simply reflects the fact that what limits agricultural productivity is not yield per unit area, but the relatively small total area of the desert watershed that is agriculturally productive.

Fishing can take place continuously along the 2000 km length of the coastline, but farming cannot. Extreme aridity confines agriculture to the river valleys spaced along the coastal plain at intervals of roughly 40 km; less than 10% of the desert is farmed (Robinson 1964). This creates a situation in which fishermen exploit far larger productive areas than farmers. For example, the Santa Valley with 8643 ha under irrigation and the nearby Nepeña Valley with 8333 ha both support large-scale mechanised commercial farming, yet monetary returns from either or both combined have never approximated the higher returns from the fish-meal industry at the adjacent port of Chimbote (*ibid.*, ONERN 1972). This situation is not unusual. By the late 1960s irrigation systems in the valleys below 9°S were all being commercially out-produced by the anchoveta fleets of their local ports. Considering the desert coast as a whole, only the largest northern agricultural complexes, such as Lambayeque (6°S), have commercial importance comparable to that achieved by large anchoveta ports such as Chimbote. The point to be drawn from such commercial comparisons is simply that, even with exceptionally high crop yields, very large irrigation systems are required to reclaim sufficient desert land for agriculture to out-produce anchoveta yields from small-craft and netting technology based out of small ports.

Agricultural technology

The majority (90%+) of arable coastal land is irrigated by river-fed canal systems and corporately worked. A variety of techniques, however, supports smaller scale, more entrepreneurial agriculture. These are tied to so-called 'self-watering' desert lands, primarily lower valley areas where river runoff creates surface saturation or high water-table conditions (Moseley 1978a: 18); and secondarily *lomas* stands of fog-supported vegetation (Quilter 1981). In seasonally inundated river flood-plains, flood-water farming can produce crops without large expenditures in construction and maintenance of water management structures, while in high water-table settings, such as near springs or lagoonal areas, small to moderate labour investments can open land to farming (West 1979, Parsons and Psuti 1968). In comparison with irrigation agriculture, such farming is of very minor commercial significance because there is very little self-watering land. Due to high rates of tectonic uplift, the Pacific watershed is in an erosional downcutting regime, confining the coastal rivers to entrenched channels with narrow flood-plains (Moseley *et al.* 1983), and restricting most high water-table settings to nearshore valley-mouth areas or areas charged by irrigation runoff (Rowe 1969). These factors greatly restrict the areal scope of small-scale farming in most valleys. Thus, for example, in the Viru drainage, where water-table farming and alternatives to canal irrigation are well developed, river and pump fed irrigation agriculture still account for 99% of all cultivation (West 1981). The point here is simply that there is insufficient self-watering land along the perpetually arid Pacific watershed to support either large populations or early civilisations.

The MFAC hypothesis contends that it is far easier to fish than it is to farm along the Andean coast because securing agricultural yields that surpass anchoveta yields requires irrigation on a large scale. The scale of canal delivery systems reflects the fact that watering the world's driest desert with highland runoff from the hemisphere's most rugged cordillara requires large engineering and labour investments. Great topographic inequities in the natural distribution of arable land and fresh water – ones far more extreme than any faced by ancient agriculturalists in the Fertile Crescent – must be overcome. Indeed, the largest canal systems ever built in the continent are open-flow channel networks carrying runoff to irrigated fields of the coastal desert in the zone from *c.* 6° to 15°S. Significantly, the canal systems in current use are basically atrophied central-valley portions of far larger irrigation networks of pre-Hispanic construction (Kosok 1965, Moseley 1978a, Moseley and Deeds 1982). Thus, information on the performance of present irrigation agriculture is not unrelated to questions of past productivity.

Mechanisation of coastal fishing and farming has changed absolute productivity, but it has not affected the relative structural contrast between the technology of obtaining high yields from anchoveta and that of obtaining high agricultural yields. The former requires large numbers of small craft carrying nets, while the latter requires few but large canal delivery systems. Thus, the argument that it is easier to fish than to farm is not simply a statement about the effort of individual fishermen versus farmers, but a statement about ease of economic organisation that contrasts entrepreneurial with corporate technologies.

Implications

These basic contrasts in technology and economic organisation carry interesting, if hypothetical, political implications. High yields from an entrepreneurial subsistence system, such as anchoveta netting, are potentially compatible with a scenario of 'Balkanised' political development and the rise of multiple independent, competing polities of medium density, substantially larger than, yet perhaps not dissimilar to, the maritime polities of the North American Pacific seaboard.

Alternatively, securing comparable caloric yields from farming is compatible with a Wittfogel-type scenario and the rise of centralised, bureaucratic polities. High agricultural returns require large areas of reclaimed land, which require large-scale labour investments and corporate organisation, not simply because the Peruvian desert is the world's driest, but because the 'over-steepened' watershed involves some of the highest mountains and the most broken topography in the world. These global extremes in topography are no less important than global climatic extremes in aridity in structuring coastal irrigation (Ortloff *et al.* 1982). Local village- or clan-level labour and organisation may well be sufficient to make the Nile flood-plain or the flat Tigris–Euphrates basin agriculturally verdant (Butzer 1976, Adams 1965). However, such a level of investment cannot overcome the topographic irregularities in the natural distribution of land and water to an extent that would allow reclamation of sufficiently large areas of the Andean desert for agriculture to out-produce yields from anchoveta exploitation.

Because topographic and climatic constraints do not allow small-scale investments to reclaim large areas of land, it has been argued that the maritime adaptation effectively 'pre-adapted' coastal societies to the rapid development of large-scale irrigation after *c.*1800 bc (Moseley 1974, 1975, Feldman 1980). The contention here is that marine resources underwrote the rise of large sedentary populations, which organised and engaged in monumental construction, and while this effort was initially focussed upon erecting large architectural works, labour and organisation were subsequently redirected to more mundane concerns of canal construction.

Environmental dynamics

The productivity of farming, as well as fishing, on the Peruvian coast is high because both go on year-round, year after year. However, both are subject to short-term and long-term downturns due to alterations of environmental conditions. Rare, but recurrent alterations occur with El Niño perturbations, while long, ongoing alterations are associated with orogeny and tectonic parameters.

Orogeny and tectonic change

The Andes are the world's most actively growing major mountain range. This fact confronts anthropological expectations with yet another condition of global extremes. Throughout the Quaternary and continuing into the present, the Nazca Oceanic Plate has been underthrusting the Pacific watershed at rates averaging 100 mm per annum or greater. Consequently, the watershed is undergoing vertical displacement and cumulative slope change – both gradually at short-term rates measured in excess of 10 mm per annum (Wyss 1978) and radically as seismic events producing one to three or more metres' displacement (Darwin 1839, Herd *et al.* 1981, Moseley *et al.* 1981).

The hydrological regime of the entire Pacific watershed changes in mechanical response to tectonic changes. As the land surfaces rise and ground slopes increase, rivers must downcut their channels to maintain equilibrium with sea-level, which has not significantly changed during the last five millennia (Richardson 1981). River response is rapid because the watershed is the shortest and steepest in the world. Inland groundwater-level is set by the littoral zone, and in the context of extreme aridity, recharged by river runoff. Therefore, as rivers entrench and the littoral lowers relative to the uptilting land surfaces, groundwater lowers and the entire hydrological regime contracts and constricts (Moseley *et al.* 1983).

Economic consequences

The mechanical consequences of tectonic uplift and a constricting hydrological regime are erosion and 'desertification', to which large-scale irrigation is directly tied by canal intakes (Moseley 1983). As rivers downcut, intakes lose efficiency and eventually become stranded above the entrenching water-flow (Moseley and Feldman 1982, Moseley *et al.* 1983). It is possible to design and construct canals with the hydraulic capacity to be largely 'self-maintaining' insofar as most suspended sediment can be carried to planting surfaces rather than being deposited in the canals, thus requiring cleaning (Ortloff *et al.* 1985). However, ongoing river downcutting and lateral course change leads to chronic canal intake problems requiring canal mouth and intake channel recutting to such a degree that the original hydraulic efficiency of the system is eventually lost and consequent silting of transport channels gradually strangles the flow. This purely mechanical process has social consequences that can be measured as successively larger annual labour investments in the maintenance of progressively smaller irrigation systems. Agrarian abandonment is a pervasive and ongoing process in the Andes. Far larger labour investments than those that initially establish irrigation systems cannot maintain and keep the systems in operation indefinitely in the context of a constricting hydrological regime. The long-term rate of agrarian abandonment has been measured as a 25% loss of arable land per millennium in the Rio Moche drainage (8°S), and collapse of comparable magnitude is predictable for canal systems throughout the desert watershed (Moseley *et al.* 1983).

Tectonically induced sea-to-land level changes operate below as well as above the ocean surface and an emergent geological regime moves marine habitats and niches seaward and away from the rising littoral. There is abundant evidence of deep-to-shallow water molluscan faunal changes at maritime pre-ceramic settlements (Craig and Psuty 1971, Lanning 1965, Moseley 1968, Cardenas 1977–78; Sandweiss *et al.* 1983). If the seafaring capabilities of the pre-ceramic population were limited, then gradual seaward shifting into deeper more distant waters by anchoveta schools, in response to littoral emergence, might have stranded small craft-netting just as it strands canal intakes; and have had an adverse effect upon the early maritime adaptation (Feldman 1977, 1980, Moseley 1978b). Yet, insofar as coastal agriculturalists were regularly using small fish for plant fertilisers at the time of the Spanish Conquest, it seems doubtful that tectonic uplift affected fishing to the degree that it did farming (Cieza de Leon 1922: 242, Vasquez de Espinosa 1948: 440). The impact upon the former would be in terms of sailing distances, not entrepreneurial organisation, whereas impact upon farming would be organisational in terms of requiring more sophisticated corporate labour regimes. Thus, it is not only easier to fish than farm, but through time farming becomes progressively more difficult than fishing – at least in the context of Peru's global tectonic extremes.

El Niño perturbations

El Niño is a perturbation in the normal distribution of solar energy within the Pacific basin that travels eastward across the Equatorial counter-current as a wind- and water-borne wave of high temperatures. Encountering the north Andean landmass, the temperature pulse splinters and in part is deflected southward along the Peruvian seaboard into the normally cool, north flowing marine and meteorological regime (Cromie 1980). There are both weak and strong intrusions, and the latter have a statistical frequency of about once per 15 to 16 years at *c.* 8°S. They constitute phenomena of graded intensity, diminishing southward but reaching well below 15°S in several severe cases witnessed in the twentieth century (Nials *et al.* 1979, Lischka 1982).

The most severe historic El Niño occurred in 1925, the most devastating (in terms of its impact on the fish populations) in 1972, and the most recent in 1982–3. All were accompanied by torrential rains as well as disruption of normal marine currents. Not all strong perturbations are accompanied by showers, but all torrential desert rains, such as those of 1982–3, 1972, and 1925, are associated with El Niño conditions. Because the desert is both unvegetated and topographically rugged, rains cause flash flooding, land-slides, and geological mass wasting. The great rains of 1925 fell principally during March. In the Moche valley, 226 mm of precipitation fell within three days, and by the end of the month the city of Trujillo, in the lower valley, was awash under 395 mm of rainwater. There are no accurate records of what the cloudbursts released in the surrounding foothills and mountains, but observers reported walls of water sweeping down normally dry drainages that had not flowed in decades. Runoff swelled the Rio Moche, and like other rivers as far south as Pisco, it rose to its highest and most violent level in memory, spilling over vast tracts of farm land, destroying irrigation systems, and washing away roadways and bridges. Although El Niño showers rarely continue for more than a month, their impact upon canal systems requires substantial repair time and results in marked decline in agricultural productivity for a year or more (Nials *et al.* 1979, Feldman 1983).

Because rains are particularly conspicuous and destructive, they are the better documented aspects of severe El Niño occurrences during the Spanish occupation, and noteworthy rains fell at least four times in the 1700s. In 1891, El Niño storms drove coastal rivers to flood stages surpassed only in 1925. El Niño flooding and environmental disruptions of far larger magnitude than that of 1925 have been identified archaeologically in the Leche and Moche drainages and dated to the earlier part of the Chimu Phase occupation at *c.* 1100 ad (Shimada 1981, Nials *et al.* 1979). In the Moche valley, evidence of El Niño disruption during Chimu times includes large-scale washout of the pre-Hispanic canal system. This destruction is thought to represent the cataclysmic El Niño described in the 'Naymlap' legend of the Chimu dynasty ruling in Lambayeque (Kosok 1965, Moseley and Deeds 1982). The legend holds that one potentate incurred the gods' wrath, bringing on rain for 30 days and nights. Devastating floods only ceased when the populace rose up, seized and bound the king, and threw him into the ocean. There followed great famine and pestilence, lasting for years and eventually culminating in foreign invasion and conquest of the land. Famine and pestilence following a great rain are consequences not incompatible with the magnitude of canal washout and destruction that is archaeologically documented for the Chimu occupation of the Moche valley. Indeed, ethnohistorical sources document coastal agriculturalists being forced to turn to wild refuge foods following the disastrous El Niño rains and floods of 1578 (Netherly 1977: 106).

Because major rains like those of 1925 are so rare, when they do fall it is upon an unvegetated landscape that has experienced a century or more of ongoing tectonic displacement, and the normally dry desert drainages are out of equilibrium with the coastal rivers and land-to-sea-level changes. Thus, when a major deluge does supercharge the unstabilised hydraulic regime, geological mass-wasting occurs on a scale so large that Holocene occurrences have been misinterpreted as products of Pleistocene glacial epochs (Moseley *et al.* 1981). Flooding aggravated by uplift exacerbates erosional downcutting by rivers and their affluents. Downcutting may be postulated to exert greater negative selective pressure on small-scale canal systems and the farming of self-watered lands than upon large-scale systems. The former are in or adjacent to river flood-plains where El Niño-induced erosion is greatest, whereas larger systems spread laterally out to lands less severely disrupted by flooding.

While El Niño rains are deleterious to irrigation agriculture, they do make the desert *lomas* vegetation bloom, thereby opening subsistence options, particularly for animal pasturage. After the deluges of 1925 and 1982–3, thousands of cattle were brought to the desert to graze on wild vegetation. Thus, not all aspects of El Niño perturbations are negative, and exploiting the unusual opportunities presented by rains was no doubt significant in the distant past (Lischka 1982). However, accounts of the coastal populace being forced to exploit wild refuge foods after the rains and floods of 1578 do not suggest wild vegetation fully compensated for agricultural losses. Indeed, famine would be absent from the historical record if this were the case.

Traditionally, rains and flooding drew more attention than other aspects of El Niño perturbations. However, the economic rise of the guano industry in the late 1800s followed by the anchoveta industry in the 1900s focussed international scientific and commercial attention on the deleterious maritime effects of strong perturbations. This shift of attention culminated with the 1972 intrusion of warm sea and air temperature. Although rains and flooding disrupted agricultural production, washed out roads, and inundated settlements, these problems were overshadowed by the fact that the warm sea currents swept down the coast at a time when the anchoveta industry was over-fishing the stock, with a production of 12 million metric tons of fish meal. The combined forces of man and nature decimated the reproductive stock, which still after almost fifteen years has not recovered. The resultant loss of one of the world's major sources of cheap protein brought international attention to the El Niño phenomenon. Within a decade it became the only natural disaster science could successfully predict prior to its occurrence, but by that time mankind had lost one of the greatest renewable resources of all times (Hartline 1980).

The anchoveta stock and other marine fauna survived the far more severe 1925 perturbation, and there is consensus among marine biologists that the disastrous consequences of the 1972 El Niño were caused by commercial overfishing above the 10 million ton level (Walsh 1981, Jordan 1980). However, the 1965 and 1972 events had provided a precedent of sorts for anthropologists to argue that El Niños represent a recurrent 'limiting factor' curtailing an early successful maritime adaptation (M. Parsons 1970). More specifically, it has been argued that,

> As we have seen, early maritime groups probably experienced a continual occurrence of lean periods brought about by El Niño. . . . The agricultural system, of course, was also subject to limiting factors such as total supply and seasonal availability of water, amount of cultivable land, salinization, and technology. But it was clearly less limited than the maritime system (Wilson 1981: 114).

The intent of systematically dismissing all references to El Niños as dramatically documented agricultural limiting factors, while selectively emphasising postulated effects of the interruption of normal marine productivity, is to deliberately negate the sustaining capacity of marine resources for the purposes of making a romantic appeal that farming was the only viable economic adaptation open to early residents of the Andean coast. However, this romantic appeal does raise questions about the impact of El Niño upon the large early maritime societies sustained by anchoveta harvesting. Fortunately, a UNESCO report (1980) provides answers, by way of analogy with its modern impact, for most questions of archaeological concern.

First, so long as pre-ceramic population levels did not exceed five or six million (the carrying capacity of anchoveta), there is no reason to suppose the long-term sustaining capacity of the stock would be impaired by El Niños of 1925 or lesser magnitude. Second, insofar as anchoveta move closer to shore during perturbations, and 90% or more of the commercial harvest occurs within 10 km of land (Santander 1980, Vildoso 1980), El Niños could well have represented a boon rather than detriment to dependent maritime populations. Third, insofar as warm-water intrusions are accompanied by a southward migration of equatorial fish and fauna into the Peruvian province (Vildoso 1980), El Niños entail a redistribution and replacement, not disappearance, of marine foods. And fourth, in the form of dried and ground fish meal, anchoveta can be stored against lean periods equally as long as most agricultural products. These considerations do not imply that a maritime adaptation would be immune to the effects of a severe perturbation any more than an agricultural adaptation. They do, however, negate the romantic presumption that in a non-industrialised context El Niños exert selectively greater limits upon fishing than upon farming.

Conclusions

In overview, the MFAC hypothesis holds that the recent and distant economic past of Peru represent a consistent set of subsistence adaptations to global environmental extremes, the nature and dynamics of which are specified by emerging paradigms of the Ocean-Atmosphere Connection and the Theory of Plate Tectonics. These predictive models of the Andean environment carry economic implications about fishing and farming that make an early maritime adaptation probable. Yet the paradigms are quite new, whereas the axiom of civilisation's agricultural origins is old. Thus, development of a viable maritime hypothesis has been gradual because it must confront firmly entrenched preconceptions. Indeed, the first monumental maritime architecture was excavated almost four decades ago but dismissed as strangely anomalous (Moseley and Willey 1973). Subsequent excavations first documenting an early marine subsistence base unfortunately lay north of and outside the zone of commercial anchoveta fishing (Bird 1948, Bird and Hyslop 1985). When the concept of a maritime middle stage in coastal civilisation was first put forward (Lanning 1963; 1965) and the socio-political connotations elaborated (Fung 1969, 1972), the economic role of small-fish netting was not clear. Even in 1975, the first synthesis of the pre-ceramic adaptation failed to identify and correlate early construction of monumental architecture and production of anchoveta fish meal (Moseley 1975).

Subsequently, documentation of pre-ceramic fish meal production and small-fish consumption in coprolites and bone chemistry have emerged, as have the paradigms that make the Andean economic environment intelligible and predictable. These developments have been the focus of this essay, and they move the MFAC hypothesis into a more refined and mature state. Contributors to the process of ongoing refinement regard the hypothesis basically as an exploratory scenario of human adaptation to environmental extremes, one that allows articulation of the archaeological record with conditions called for by models emerging in the physical and natural sciences. Critics of the hypothesis, unfortunately, regard it a contrived affront to the anthropological axiom of civilisation's agricultural origins, one that is most conveniently rejected by systematic refusal to consider the anchoveta or the agricultural impact of El Niño and other environmental dynamics. In so doing, the defenders of the discipline's orthodoxy reject not only the MFAC proposition, but science in general, and simply reiterate a methodology of narrow perception that has bound anthropology to the arts and humanities ever since Morgan and Taylor first decreed that only an agricultural society can make monumental architecture.

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