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Terminal Pleistocene/Early Holocene human adaptation in coastal Ecuador: the Las Vegas evidence

Karen E. Stothert[a,*], Dolores R. Piperno[b], Thomas C. Andres[c]

[a] Center for Archaeological Research, The University of Texas at San Antonio, San Antonio, TX, USA
[b] Smithsonian Tropical Research Institute, Balboa, Panama
[c] Cornell University, Ithaca, NY, USA

Abstract

Preceramic sites located on the Santa Elena Peninsula in southwestern Ecuador and occupied in the Terminal Pleistocene and during the Early Holocene (10,800–6600 BP) have produced evidence of a durable Las Vegas adaptation focused on marine, estuarine and terrestrial resources. The Las Vegas people were among the earliest cultivators in America who participated in the domestication of useful plant species and progressively intensified their efforts in both fishing and horticulture.

Contents

1. Introduction

The earliest known inhabitants of the coast of Ecuador were the preceramic Las Vegas people who occupied sites located on uplifted Pleistocene terraces on the Santa Elena Peninsula (Fig. 1) between 10,800 and

*Corresponding author.
E-mail addresses: maur2stoth@earthlink.net (K.E. Stothert), pipernod@stri.org (D.R. Piperno), tom@Andres.com (T.C. Andres).

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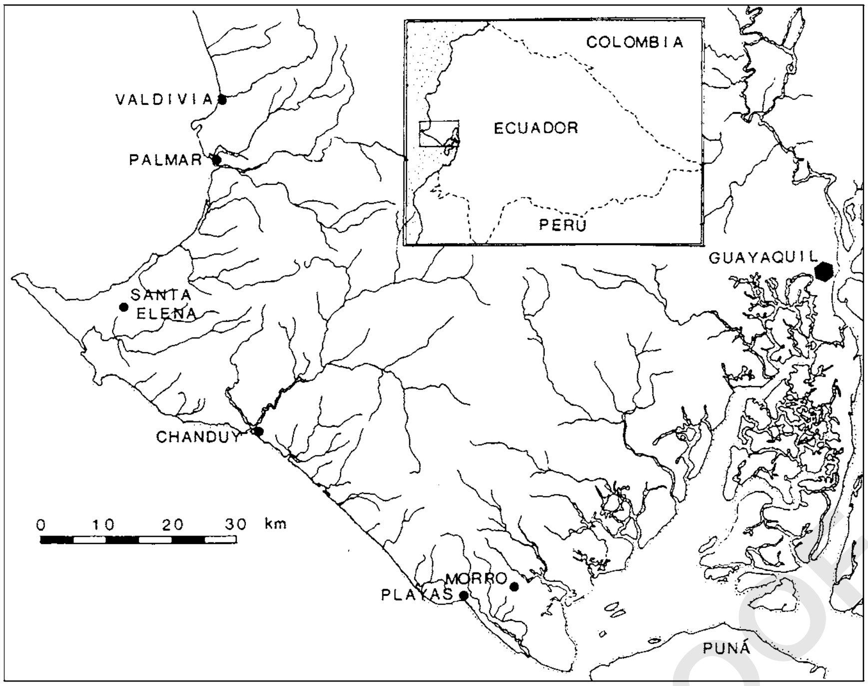

Fig. 1. Map of southwestern Ecuador showing the Santa Elena Peninsula, modern towns (small black dots), the city of Guayaquil (black hexagon), and the seasonal rivers of the peninsula.

6600 years ago (uncalibrated radiocarbon dates are used throughout). In this paper we review and update the interpretation of the paleoenvironments of the peninsula, describe the preceramic use of marine, estuarine and terrestrial resources, and report on new research which supports the idea that the Las Vegas people domesticated and adopted cultigens including squash and gourds (*Cucurbita* spp.) at the beginning of the Early Holocene period (10,000–7000 BP). The Las Vegas people were among other occupants of the Pacific littoral of South America who developed coastal adaptations at the end of the Pleistocene (Richardson, 1973, 1978, 1981; Llagostera, 1979; Sandweiss et al., 1989, 1996a, b, 1999a, b; Stothert and Quilter, 1991), but as early as the beginning of the Early Holocene Las Vegas people initiated an enduring pattern of plant cultivation.

2. Peopling the coast of Ecuador

The study of the origins and routes of dispersal of Paleoindians in South America is ongoing and controversial. The derivation of the first inhabitants of Ecuador cannot be specified, but it is clear that people were living in the highlands and along the southwest Ecuadorian littoral between 11,000 and 10,000 BP (Temme, 1982; Salazar, 1983; Stothert, 1985, 1988). The earliest denizens of the coast might have arrived by sea (Holm, 1986, 1987; see also Fladmark, 1978, and Sandweiss and Richardson, 2000).

If people entered Santa Elena in the Late Pleistocene, whether by land or by sea, they would have found a patchwork of biomes and an array of animals. The species identified in the Late Pleistocene fossil assemblages from Santa Elena (remains probably less than 25,000 years old) and from the Talara region of northern Peru (remains about 14,000 years old) include the following: mastodons, horse, camelids, deer, ground sloth, armadillo, capybara, opossum, fox, wolf, puma, saber-tooth tiger, snakes, lizards, turtles, crocodiles, gulls, ducks, doves, falcons, owls, vultures and condors (Hoffstetter, 1952; Edmund, 1965). The fossil evidence suggests that these terrestrial environments were relatively open grasslands with gallery vegetation along the river courses. Apparently there was sufficient moisture to maintain a high water table, standing pools of water, and vegetation along the drainage courses, but insufficient to support forests between the temporal rivers (Lemon and Churcher, 1961). Along the littoral, people would have found a teaming sea, as well as lagoons, bays and estuaries where fresh water pooled seasonally (Lemon and Churcher, 1961; Edmund, 1965; Campbell, 1973,1982; Richardson, 1978,1998a, b; Portais, 1983; Usselmann, 1989). The Late Pleistocene environments were affected by tectonic uplift (Sheppard, 1937; Edmund, 1965), changes in sea level (Fairbridge, 1960), and climate changes occurring on a global scale (Sherratt, 1997).

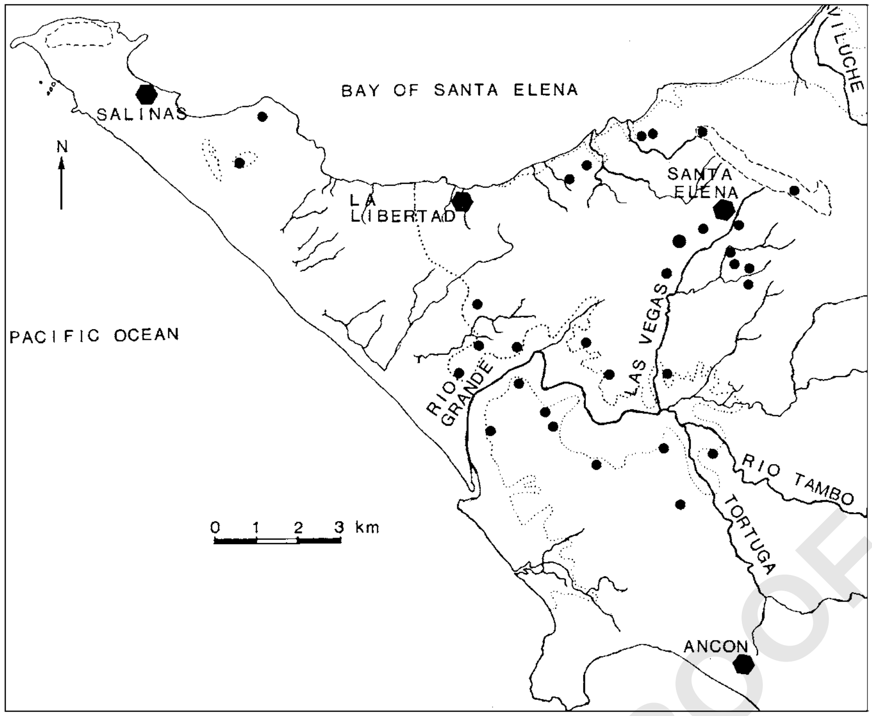

Fig. 2. Map of the western portion of the Santa Elena Peninsula showing the distribution of Las Vegas preceramic sites, the modern drainage pattern, the modern 10-m contour line (dotted line), modern towns (hexagons), Las Vegas Site 80 (larger dot near the town of Santa Elena), and 30 other Las Vegas camp sites (small dots).

In coastal Ecuador no association between fossil bones and diagnostic human artifacts has been described, and no credible Late Pleistocene cultural deposits are known (Stothert, 1983). The discovery of a few stone projectile points with no archaeological context is the only evidence that the Santa Elena Peninsula was occupied by Paleoindian hunters, but human predators are likely to have been attracted to the Ice Age herbivores before those animals became extinct in the Terminal Pleistocene Period.

3. The preceramic culture of the Santa Elena Peninsula

In contrast to the lack of information about Late Pleistocene peoples in coastal Ecuador, the Early Holocene Las Vegas way of life is known from a wide variety of evidence found in 32 sites on the Santa Elena Peninsula (Fig. 2). The reconstruction of this preceramic adaptation is based principally upon evidence from the Las Vegas type site, Site 80 (CT M5 A3-80, formerly OGSE-80, 2°13′S; 80°52′W), which is characterized by deep midden that accumulated for almost 4000 years (Stothert, 1976, 1977, 1979, 1985, 1987,1988; Ubelaker, 1980, 1988; Malpass and Stothert, 1992). Today the site is located about 3 km from the Bay of Santa Elena.

The Las Vegas type site is found in the coastal zone, defined as the land lying between the Ecuadorian Andean massif and the sea. This diverse region measures between 70 and 200 km in width and some 700 km from north to south, and is characterized by wet tropical forest in the north and dry forests and open habitats in the south. A pattern of seasonal rainfall is characteristic of most of the coast, which results in a mosaic of compressed terrestrial zones with variable agricultural potential. Today the Santa Elena Peninsula is a biologically complex, dry, tropical ecotone, sometimes called the "abnormal appendage" of southwest Ecuador (Wolf, 1975 [1892]). The chronological framework for interpreting Las Vegas evidence is based upon numerous radiocarbon dates (Table 1) which inspire confidence because they form a coherent series, they agree well with independent stratigraphic interpretations, and because the assays were made at different laboratories using shell, charcoal, human bone, and by directly dating microfossil samples using AMS techniques.

Three radiocarbon dates associated with sparse cultural materials in the deepest levels of Site 80 are the only evidence of a pre-Las Vegas occupation between 10,800 and 10,000 years ago (Stothert, 1988, pp. 618–619). The subsequent Las Vegas occupation lasted from about 10,000–6600 BP. On the basis of a stratigraphic break in the midden at Site 80, the preceramic occupation was divided into an Early Las Vegas phase (10,000–8000 BP) and a Late Las Vegas phase (8000–6600 BP).

Las Vegas settlement strategies are poorly known and Las Vegas patterns of residential mobility have not been

Table 1
Thirty-two radiocarbon dates and calibrated ranges from Las Vegas cultural contexts (Stothert, 1988, p. 56, Table 3.1; 1988, p. 231, Table 12.2; Piperno and Pearsall, 1998, p. 186, Table 4.1)

	Site number	Measured radiocarbon age (BP)	Material assayed	Conventional radiocarbon age	95% probability dendrocalibrated age range in years BP (2-sigma)[a]
Rejected dates	80	15,850 ± 400	C	15,850 ± 400	20,160–17,750
	80	12,130 ± 70	P[b]	12,130 ± 70	Circa Cal 15,260–13,830
Pre-Las Vegas	80	10,840 ± 410	C	10,840 ± 410	Circa Cal 13,820–11,350
	80	10,300 ± 240	C	10,300 ± 240	12,950–11,210
	80	10,100 ± 130	S	10,510 ± 130	Circa Cal 12,310–10,850
Early Las Vegas	80	9800 ± 100	S	10,210 ± 100	Circa Cal 11,620–10,640
	80	9740 ± 60	P[b]	9740 ± 60	Circa Cal 11,220–10,890
	80	9550 ± 120	S	9960 ± 120	Circa Cal 11,310–10,300
	201	9460 ± 100	S	9870 ± 100	Circa Cal 11,150–10,290
	80	9080 ± 60	P[b]	9080 ± 60	Circa Cal 10,370–10,170
	80	8920 ± 120 [9330 ± 120]	S	9330 ± 120	Circa Cal 10,540–9560
	80	8810 ± 395	C	8810 ± 400	Circa Cal 11,090–8990
	80	8600 ± 200	S	9010 ± 200	10,290–8980
	78	8600 ± 100	S	9010 ± 100	Circa Cal 9930–9080
	80	8250 ± 120	HB	8350 ± 120	9540–9020
	80	8170 ± 70	S	8580 ± 70	Circa Cal 9410–8890
	38B	8100 ± 130	S	8510 ± 130	Circa Cal 9590–8770
Late Las Vegas	80	7960 ± 60	P[b]	7960 ± 60	9010–8610
	67	7480 ± 70	S	7890 ± 70	8460–8180
	66	7390 ± 60	S	7800 ± 70	8380–8120
	202	7780 ± 90	S	8190 ± 90	8940–8430
	80	7710 ± 240	HB	7810 ± 240	9290–8160
	80	7600 ± 100	S	8010 ± 100	8700–8290
	80	7440 ± 100	S	7850 ± 100	8500–8110
		7250 ± 150	S	7660 ± 150	8400–7810
	38A				
		7170 ± 60		7170 ± 60	
	80		P[b]		Circa Cal 8110–7860
	80	7150 ± 70		7560 ± 70	
			S		8160–7870
	203	6900 ± 80		7310 ± 80	
			S		7930–7610
	80	6750 ± 150		6850 ± 150	
			HB		7960–7440
	80	6600 ± 150		6700 ± 150	
			HB		7820–7310
Post-Las Vegas	213	5830 ± 80	S	6240 ± 80	6860–6490
	80	5780 ± 60	P[b]	5780 ± 60	6710–6430

Dated material includes phytoliths (P), shell (S), human bone (HB), and charcoal (C). Beta Analytic provided the Beta/Pretoria calibrations (Stuiver and van der Plicht, 1998; Stuiver et al., 1998; Talma and Vogel, 1993).

[a] In the case of each date that has multiple ranges, caused by the highly variable correlation between radiocarbon years and calendar years, the set of ranges has been collapsed into a single range [circa Cal xxxx–yyyy] for purposes of this discussion.

[b] AMS date.

modeled adequately. Nevertheless, people may have occupied Site 80 either continuously or re-occupied it repeatedly from the terminal Pleistocene until about 6600 BP. In the Late Las Vegas Period this possible base camp may also have served as a ceremonial center where its residents undertook elaborate funeral activities, which are understood as evidence of social intensification and growing economic complexity. Other sites, consisting of shallow deposits of preceramic midden dated to both the Early and Late Las Vegas periods, suggest that the preceramic people also occupied temporal campsites near the western tip of the peninsula (Fig. 2) while they exploited marine and land resources (Stothert, 1988, pp. 225–236).

4. Reassessing Las Vegas paleoenvironments

There is no paleoecological evidence from the Santa Elena Peninsula which would permit a fine-grained paleoenvironmental reconstruction for the region. However, numerous studies have demonstrated that the Late Pleistocene period in tropical America was characterized by drier and cooler climates and vegetation and faunal communities that differed substantially from conditions seen today (Piperno and Pearsall, 1998, Chapter 2). It is likely that the people of Santa Elena, like other Terminal Pleistocene peoples, were confronted with fluctuating environmental conditions and changing resource availability, which were influential factors in the development of food production. Although we lack direct evidence, it seems likely that the Las Vegas people manipulated the vegetation (including burning and clearing native vegetation before cultivation) and significantly altered their environment in the Early Holocene, as has been demonstrated for other tropical regions including Panama and in the Amazon (Stahl, 1996, pp. 113–114; Piperno and Pearsall, 1998; Athens and Ward, 1999).

After a review of recent literature, Stahl (1996, p. 118) concluded that "[a]t any given time and place, environmentally and/or anthropogenically induced alteration set both the numbers of different kinds of species and their respective proportions into a continuous flux." He further emphasized that the "Holocene record suggests a dynamic ecological history that impacted plants, animals, and native human populations on a hemispheric scale" (1996:109). Specifically, the end of the Pleistocene was characterized by "gradual and oscillating climatic amelioration" after which there were "greater seasonal extremes in temperature and moisture" that resulted in substantial change in the communities of plants and animals: "[I]n this scenario, local richness and evenness of any biota would be in a state of constant spatial and temporal flux as each component acted and reacted according to its own ecological needs depending upon changing circumstances" (1996:110).

Regrettably the Las Vegas midden deposits are too compressed to allow the documentation of climate processes and oscillations, but it is widely believed that these processes created long- and short-term environmental variations throughout the Early and Middle Holocene (Piperno and Pearsall, 1998, pp. 90–107). Plant and animal remains from the Vegas type site indicate the ancient Las Vegas environments varied across only a limited range, from thorn scrub to seasonally dry forest. This suggests that there was a persistent pattern of seasonal rainfall and a marked dry season in the region. Our current understanding of past environments will be summarized here in four discussions.

4.1. The Vegas littoral

In southwest Ecuador today marine resources are attractive due to their great diversity, the availability of a large biomass, and the absence of pronounced seasonality. These waters today are only slightly less rich in terms of carbon, phytoplankton, and zooplankton than those of coastal Peru (United Nations, 1972, maps 1.1, 1.2; Rand McNally Corporation, 1977, p. 86). The overall productivity of the marine biotopes of Ecuador is not drastically affected during periodic El Niño disturbances. While marine resources are irregularly distributed because of coastal morphology and the localized contribution of nutrients from river systems, the same species are available in differing proportions along the southwestern coast. The most attractive areas for prehistoric fishermen and modern artisanal fishermen are the shallow bays, shoals, lagoons, estuaries and mangrove formations (including the great ones of Esmeraldas and Gulf of Guayaquil). Most fishing communities are and were oriented to these resource areas. The Bay of Santa Elena continues to be productive for both commercial and artisanal fishing.

Conditions in the sea and along the littoral of Santa Elena were probably very different in the past. The change in fish fauna between the Early and Late Las Vegas phases might have been due to changes in the position of the Humboldt Current, geomorphological alterations of the coast and associated ecological changes, or to technological, social or economic innovations among the Vegas fisherpeople.

Recent research has shown that in the Early Holocene ocean currents in the Pacific operated differently than they do today (Sandweiss, 1996a; Sandweiss et al., 1996). The warm Equatorial Counter Current apparently penetrated as far as 9° south latitude along the coast of Peru, and the boundary between the tropical Panamic faunal province and temperate Peruvian province (characterized by cold water upwelling) moved to a position some 800 km south of the Santa Elena Peninsula (Rollins et al., 1986; Sandweiss et al., 1996). While the more southerly position of the warm current resulted in dramatic changes in the distribution of marine faunal species in Peru, it seems to have altered the tropical pattern in Santa Elena to a much lesser extent. The same species exploited by the Early and Late Las Vegas people are still available off Santa Elena today.

Another factor that determines the distribution and extent of littoral resources is eustatic change in sea level. Recent research has supported Fairbridge's contention that marine transgression was marked by reversals and changes in tempo, so we believe that Vegas people were confronted with a dynamic littoral, but the relationship between the sea and the land at particular geographical locations at various dates in the past cannot be

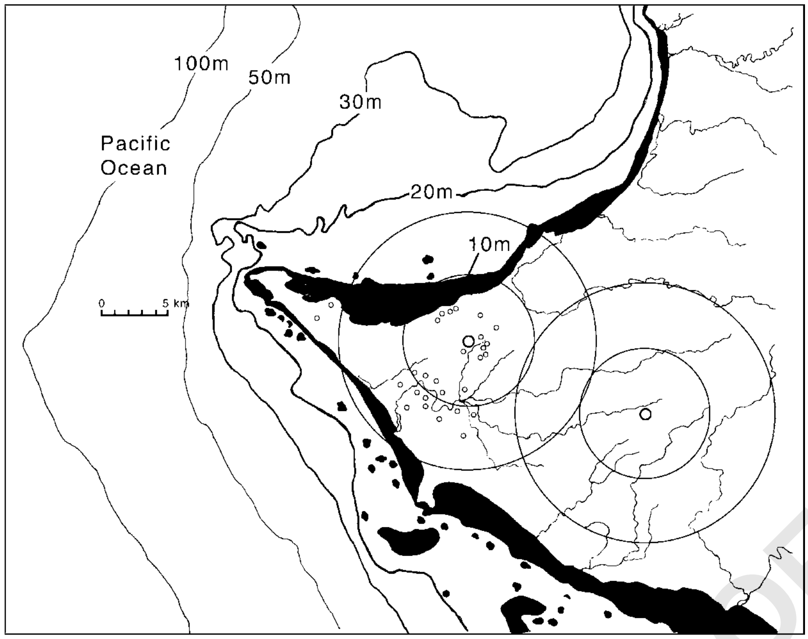

Fig. 3. Map of the changing coastline of the Santa Elena Peninsula as inferred from bathymetric readings of the modern sea bottom. When sea level was depressed 30 m, the paleocoastline may have approximated the 30 m isobath, and the continental shelf between that contour line and the present coast may have been dry land. The area between the 10 m isobath and the present coastline is marked in black. Thirty small Las Vegas camp sites are indicated by small circles, and Sites 80 and 67 are represented by larger circles. The catchment areas of these two large sites are represented by overlapping concentric circles 10 and 20 km in diameter.

Table 2
Extent of additional terrestrial zone exposed in the littoral of the Santa Elena Peninsula in the Early Holocene when world sea level was depressed (see Fig. 3)

Years before present (uncal. 14C years)	Sea level in meters below present level[a]	Amount of additional land exposed compared to today (in km^2)	Level of land (in meters) with respect to modern level	Difference in elevation (in meters) between modern shore line and sea level	Amount of land exposed given steady tectonic uplift of the land (in km^2)
10,000 BP	−30	600	−5	25	498
8000 BP	−20	450	−4	16	360
7000 BP	−10	97	−3.5	6.5	63
5000 BP	−5 to 0	20 to 0	−2.5	2.5 to 0	10
Present	0		0	0	—

If tectonic uplift occurred in coastal Ecuador at a steady rate of 0.5 vertical meters per 1000 years (as suggested for Peru by Richardson, 1998a, p. 4; Sandweiss et al., 1989, pp. 49, 53, then the distance between the modern shore and the paleocoastline might have been reduced as indicated.

[a] These levels are subject to both temporal and spatial fluctuations. For instance, in coastal Peru at 7000 BP the sea level may have been some 20 m below present sea level (Sandweiss and Richardson, 2000, p. 181).

reconstructed with surety. Although the Fairbridge curve, which models changes in historical sea level, is repeated in modern text books (Bird, 1993, p. 15), there is controversy about the deformations in the earth's crust which caused local variations in sea levels. Morner's plot of sea level changes (since about 20,000 years ago) from sites around the globe against "present geoid position" shows considerable non-conformity, which he attributes to regional geoid deformation (Morner, 1983, 2000; Donnelly, 2001). Nevertheless, Fig. 3 represents one attempt to model Early Holocene sea level change using bathymetric soundings from the modern sea floor off the Santa Elena Peninsula (INOCAR, 1980 [1989]) and information about change in sea level (Fairbrige, 1961; Bird, 1993).

About 10,000 years ago mean sea level was depressed 30 m below its modern level (Table 2). In this case, an additional 600 km^2 of land might have been exposed. Taking into account a modest rate of tectonic uplift, the extent of exposed continental shelf would have been around 500 km^2.

In Fig. 3, Site 80 might have been located as much as 13 km from the coast (Table 3), or perhaps a kilometer or two closer if the land were 5 m lower at that time. Depending upon local topography, the exposed areas of the continental shelf might have been characterized by wetlands, lagoons, and mangrove swamps.

According to Fairbridge's research on sea level change (Fairbridge, 1960, 1961, 1962), there was rapid upsurge between 10,000 and 9000 years BP, then, in the 9th millennium BP, the sea level may have reached about 16 m below its modern mean, only to fall again to below 20 m below present level by 8000 BP. The amplitude of short-term oscillations was greater in this period than in the Middle Holocene Period (7000–3000 BP). More recent research has supported the Fairbridge curve (Bird, 1993, p. 15). Fairbanks (1989) has strengthened the evidence for two episodes of marine surge, one between 14,000 and 12,000 BP, followed by a period of stable conditions, then a significant "melt-water pulse" between 10,000 and 7000 BP.

Table 3
Estimated distance from Las Vegas Site 80 to the seashore of Santa Elena at various moments during its occupation

Years before present (BP)	Sea level in meters below present sea level	Estimated minimum distance from Site 80 to north shore of peninsula (km)	Estimated minimum distance from Site 80 to south shore of peninsula (km)
10,000	−30	13	14.5
9000	−15	10	13
8000	−20	12	11
7000	−10	5.5	9
6000	−2	4	10
5000	0	3.5	10

Geographical relationships calculated from modern isobaths and by assuming depressed sea levels in the Early and Middle Holocene Periods (Fairbridge, 1961; Bird, 1993, p. 15). Tectonic uplift is ignored.

Around 8000 BP the fluctuating sea level might have been near the 20 m isobath. In this case, Site 80 could have been about 12 km from the north shore of the peninsula, and the people may have enjoyed some 360 km^2 of land, estuaries and mangrove formations that are today submerged on the continental shelf. By 7000 years ago, when sea level was depressed only 10 m, Site 80 would have been only 5.5 km from the north shore, and the amount of exposed continental shelf was reduced to only 63 km^2 (see black area in Fig. 3).

As the sea level rose and fluctuated in Santa Elena, people would have witnessed the creation and destruction of mangrove swamps, as well as the alteration of river courses, water tables, salt marshes, lagoons, and estuaries (Bird, 1993; Oyuela-Caycedo and Rodriguez Ramírez, 1991). One authority states that "[p]resumably life in lower river valleys was precarious until the rise in sea level decelerated at about 4000 BC [6000 BP]" (Donnelly, 2001).

Evidence recovered from a deep sea core from off the coast of Ecuador, which probably reflects conditions in the Gulf of Guayaquil, suggests that mangrove formations reached their maximum development between 12,000 and 7000 years ago (Heusser and Shackleton, 1994, p. 223). In fact, mangrove clams (*Anadara tuberculosa*) dominated the molluscan assemblages of the Early Las Vegas Period, but were less well-represented in Late Las Vegas assemblages after 8000 BP (Table 4). These numbers may track the changing extent of mangrove formations on the peninsula.

It has been suggested that a specialized adaptation to the vast and highly productive mangrove formations of the Late Pleistocene/Early Holocene developed in the

Table 4
Analysis of molluscan remains identified in excavated units from Las Vegas Site 80. Based upon a calculation of Minimum Number of Individuals in each sample, the occurrence of each category of mollusk is represented as a percentage of the entire sample

Las Vegas Phase	Level in unit F-H/8-11	Rock-Living species	Estuarine/Mangrove species	*Anadara tuberculosa*	Total[a]
Range of occurrence of species in three Late Las Vegas contexts	65–80 cm	5.3–8.6%	13.3–13.8%	57–70%	78.9–89.1%[a]
	80–90 cm				
	90–100 cm				
Range of Occurrences of species in 4 Early Las Vegas contexts	100–110 cm	0.8–1.5%	5.5–8.3%	81–87%	89.9–94.9%[a]
	110–120 cm				
	120–130 cm				
	130–140 cm				

The category of rock living species includes *Astrea* sp., *Fisurella* sp., and *Turbo saxosis.* The estuarine and mangrove species include *Cerithidea pulchra, Tagelus rufus*, and *Thais kiosquiformes.* The mangrove clam *Anadara tuberculosa* is described separately. Data taken from Stothert (1988, Chapter 9).

[a] Other mollusks not listed make up only 5.1–10.1% of the Early Las Vegas assemblages. In contrast, other species make up 10.9–21.1% of the Late Las Vegas samples.

Gulf of Guayaquil (Spath, 1980), but this hypothesis is poorly supported because any archaeological sites located in or near the former mangrove swamps were later submerged during continuing marine transgression. Our inventory of Vegas sites lacks any specialized Vegas extraction camps that might have been located nearer the former littoral. The Las Vegas base camps, apparently lying inland from the sea, may represent only the terrestrial aspect of the ancient subsistence system. This interpretation has been suggested also by investigators in Peru who also deal with the more inland camps of preceramic people who also exploited the sea, perhaps seasonally (Richardson, 1998b, p. 3; Chauchat, 1992).

Returning to the issue of tectonic uplift. A conservative estimate of uplift falls in the range of 0.1–0.5 m per 1000 years (Clapperton, 1993, p. 71; Richardson, 1998a, p. 4, citing Sandweiss et al., 1989, pp. 49, 53), but it is also true that Santa Elena lies in a "subduction coast" where uplift is notoriously variable, "rising at different rates and by different amounts than neighboring sections; [and] differential vertical movements may occur even within a segment [of the coast] because of deep fractures" (Clapperton, 1993, p. 618). More troubling still is that Santa Elena rests within a degree of the Carnegie Ridge, an aseismic sub-marine ridge responsible for the extraordinary "flights of Quaternary marine terraces" observed along the coast. The height of the terraces in Ecuador and northern Peru is indicative of "rapid tectonic uplift compared to other parts of the Pacific coast where the terraces are lower" (Clapperton, 1993, p. 618). Some estimates suggest that uplift in the Northern Andes approximated 150 m in 70,000 years (Clapperton, 1993, p. 37), which is a rate of more than 2.0 m per 1000 years. Because of uncertainty about local tectonic changes, the conformation of the coastline in Vegas times remains a mystery.

The most important implication of this modeling of the Early Holocene littoral is that the ancient configuration of coastal resources was constantly changing. Estuaries and extensive mangrove formations would have been repeatedly created and destroyed, and all the evidence of these events has been scoured away or now lies underwater. The Santa Elena Peninsula lies within the tropical belt where the formation of mangrove swamps depends upon local geomorphology. Persistently rising sea level may have created the conditions that allowed mangroves to reach their greatest extent on the Santa Elena Peninsula in Vegas times. The mangrove formations which characterized Santa Elena early in the 20th century were destroyed altogether by bulldozers and dams (Ferdon, 1981; Stothert, 1988, pp. 243–244).

Even without specifying which physiographic changes took place precisely when, it is clear that plant and animal communities living along beaches, rocky points, and in bays and estuaries would have been affected by both sea level fluctuations and tectonic uplift. Similarly, in the terrestrial zone, changes in water table, in river gradients, and sedimentation rates can be inferred.

The long-term settlement of some sites in western Santa Elena may reflect the formation and persistence of productive embayments, estuaries and mangroves during the period of dramatic marine emergence (Bird, 1993, p. 15). Cultural change in the archaeological record may reflect human responses to the instability of highly productive estuarine resources, particularly mangrove swamps (Oyuela-Cacedo and Rodriguez, 1991).

4.2. Terrestrial animals and Vegas environments

The remains of terrestrial animal species found in midden deposits at Site 80 are the basis for the reconstruction of the Las Vegas environment and climate regime (Table 5). Regrettably neither the paleoenvironmental reconstructions based on Pleistocene fossils, nor the interpretation of the Las Vegas remains is sufficiently fine-grained to identify climate oscillations and environmental shifts, even those that may have lasted a few centuries or more. The Vegas bioindicators were recovered from "time-averaged assemblages [which] could easily mask environmental variability, particularly in sensitive ecotonal areas like southwestern Ecuador" (Stahl, 1991, p. 356).

Assemblages of terrestrial vertebrate animals that accumulated for over 3000 years in Las Vegas midden deposits showed only species that are found today in the sub-humid and arid environments of southwestern Ecuador. In Vegas times, the region was probably a semi-arid ecotone: as the Vegas people moved just short distances across the landscape they would have found distinct plant and animal communities, but little wet forest. Despite a potential for radical environmental change (caused by shifts in global climate), species characteristic of moist tropical forests are missing from the Vegas fauna, so we conclude that moister conditions were never established.

In summary, the bones of terrestrial animals suggest that conditions were always sub-humid on the western peninsula. Similarly, the remains of fish and shellfish which accumulated in the Vegas midden showed that the same marine species that are present today were important in Vegas times (although today mangrove clams are locally extinct).

4.3. Plant remains and Las Vegas conditions

Today precipitation on the peninsula is concentrated in one short season, followed by eight relatively dry months. This climate pattern does not necessarily create desert-like conditions. The modern desert characteristic of the western portion of the peninsula is the result of deforestation and other human interventions. Ferdon

Table 5
Composite list of animal species identified in both Early and Late Las Vegas faunal assemblages excavated from Site 80[a]

Family or species	Common name, Spanish	Common name, English	Habitat
Fish			
Carcharhinidae	Tiburón	Sharks	Off and in shore
Mustelus sp.	tollo, cazón de leche	Requiem shark	—
Dasyatidae	Raya	Stingrays	In shore
Ariidae	Bagre	Sea catfish	Estuaries and in shore
Bagre sp.	Bagre	Sea catfish	Estuaries and in shore
Centropomus sp.	Robalo	Snook, robalo	Off shore
Serranidae	Guato, cherna	Sea basses, groupers	Estuaries and in shore
Batrachoides sp.	Bruja	Toadfish	rocks
Scombridae	Atún, bonito, sierra	Tunas , mackerels	Off and in shore
Caranx sp.	Jurel, caballa	Jack, yellow caranx	Estuaries and in shore
Chaetodipterus sp.	Leonora, chavela	Spadefish	Rocks
Mugil sp.	Liza	Mullet	Estuaries and in shore
Trachinotus sp.	Pámpano	Pompano	Beach
Lutjanus sp.	Pargo	Snapper	Estuaries and in shore
Diapterus sp.	Mojarra, palometa	Mojarra	Beach
Orthopristis sp.	Teniente, presidents	Grunt, pigfish	—
Isacia sp.	—	Grunt	—
Micropogonias sp.	Corvina , roncador	Croaker	In shore
Odontoscion sp.	—	Drum, croaker	—
Scianidae	Corvina, chogorro	Drum, croaker	Estuaries and in shore
Conodon sp.	Limona	Drum, Barret grunt	Beach
Paralonchurus sp.	Rayado , ratón	Drum, croaker	Beach
Sciaena sp.	Corvina, roncador	Drum	—
Sphaeroides sp.	Tamborín, tambulero	Swellfish, puffer	Beach
Cynoscion sp.	Corvina	Weakfish	In shore
Amphibians			
Ranidae	Rana	Frog	Cosmopolitan
Bufonidae	Sapo	Toad	Cosmopolitan
Anuran	Rana, sapo	Toads, frogs	Cosmopolitan
Reptiles			
Cheloniidae	Tortuga	Sea turtles	Sea
Emydidae	Tortuga	Box and water turtles	—
Dicrodon sp.	Lagarto	Lizard	Thorn-scrub
Boa sp.	Boa	Boa constrictor	Cosmopolitan
Drymarchon sp.	Culebra	Indigo snake	Cosmopolitan
Birds			
Psittacidae	Loro	Parrots	Cosmopolitan
Mammals			
Didelphus sp.	Zarigueya/zorro	Opossum	Cosmopolitan
Sylvilagus sp.	Conejo	Rabbit	Cosmopolitan
Mustela sp.	Chucuri	Weasel	Cosmopolitan
Dusicyon sp.	Lobo de selva	Fox	Cosmopolitan
Mazama sp.	Chivicabra, mazama	Brocket deer	Cosmop/mangrove
Odocoileus Virginianus	Venado	White-tailed deer	Cosmopolitan
	Saíno, javelina	Peccary	Cosmop/thorn scrub
Tayassu sp.	Ratas, ratón de campo	Rats and mice	—
Cricetinae	Rata	Cotton rat	—
Sigmond sp.	Rata	Spiny rat	—
Proechimys sp.			
Other rodents	Roedores	Rodents	—
Tamandua t.	Oso mielero, tamandua	Anteater	Cosmopolitan
Sciuriade	Ardilla	Squirrel	Cosmopolitan
Canidae	Perro, lobo	Dog/wolf	—
Felis sp.	Tigrillo (?)	Cat	—
Marine mammal	Mamífero marine	Marine mammal	Sea, beaches

Table 5 (*continued*)

Family or species	Common name, Spanish	Common name, English	Habitat
Crustaceans			
Decapods	Cangrejo	Crab	Rocks and mangroves
Mollusks			
Anadara tuberculosa	Concha prieta	Clam	Abundant in mangrove
Anadara grandis	Pata de burro	—	Sand banks/low tide line
Astreae buschii	Colón	—	Rocks in tidal zone
Cerithidea pulchra	Churo, jeringaolorra	—	Mangrove/high tide line
Chione subimbricata	Concha	—	Bays and swamps
Chiton plates			Rocks
Fissurella sp.	Conchalagua	—	Rocks in tidal zone
Hexaplex regius	Churo zambo	Royal murex	Tidal zone
Lyropecten subnodosus	Concha de abanico	—	Shallow and deep waters
Argopecten circularis	pinganilla	—	Shallow and deep waters
Malea ringens	Churo	Grinning tun	Sand banks and rocks in tidal zone
Melongena patula	Caracol	—	Shallow and deep waters
Modiolus capax	Mejillón	Mussel	—
Natica sp.	Caracol	—	Deep waters
Ostrea columbiensis	Ostion	Oyster	Abundant in mangrove
Pinna rugosal Atrina maura	—	—	Sand banks and bays
Pinctada mazatlanica	Concha de perla	Pearl oyster	Shallow waters
Pteria sterna	Concha de perla	Pearl oyster	Shallow waters and tidal zone
Pitar catharius	—	—	Deep sea
Protothaca ecuatoriana	Concha	—	Tidal zone
Tagelus dombeii	Michulla	Razor clam	Tidal zone, mangrove
Thais kiosquiformes	churo	—	Tidal zone, mangrove
Trachycardium sp.	Concha	Cockle	Shallow and deep waters
Turbo saxosus	Guerere soñador	—	Rocks in tidal zone
Strophocheilus sp.	Caracol de monte	Tree snail	Trees and bushes

[a] Data from Byrd (1976), Chase (1988), Stothert (1988), and Wing (1988); see also Cobo and Massay (1969), Patzelt (1978), and Keen (1971).

(1981) argued that geomorphological forces in Santa Elena caused environmental change in the past, and Spath (1980) working near the Gulf of Guayaquil has concluded that the differences between the preceramic period environment and the modern environment can be attributed to human degradation of the plant communities and not to climate change. Pearsall (1979, pp. 55–64, 1988) reconstructed the environments of the Valdivia and Machalilla periods and concluded that the climate patterns and currents of the western peninsula during between 5000 and 3500 BP were similar to the present day.

Past environments, unaffected by recent depredation, would have been more attractive to people with or without a moisture budget more generous than today's. Based on contemporary observations of more humid conditions in areas to the north and east of Santa Elena, we can imagine a scenario in which the peninsula received greater rainfall, but the evidence from Las Vegas sites shows that tropical forest conditions were never produced in the immediate vicinity of the Las Vegas sites. Documented shifts in the position of the Intertropical Convergence Zone (from north of the Equator toward the south) might have increased the amount of rainfall southwestern Ecuador, and global phenomena such as mid-Holocene warming and eustatic rises in sea level might have affected the moisture budget in Santa Elena. However, the Las Vegas remains have lead to the conclusion that the Early Holocene environment of the peninsula was seasonally arid.

Missing from the Las Vegas sediments are palm phytoliths which are found commonly in archaeological soils in moist tropical habitats. In contrast, the abundance of grass and shrub phytoliths in Las Vegas soil samples is additional evidence that the ancient environment was dry. The western part of the peninsula probably was characterized by thorn scrub and wooded savanna vegetation in the Early Holocene (Piperno and Pearsall, 1998, Chapters 2 and 4, Figs. 4.1a, b).

4.4. Climate change

The paleoclimatic history of northwestern South America is based on several pollen cores and on global climate models. It is not sure that general climate models accurately describe conditions in local areas, such as Santa Elena, because paleoclimatic patterns have been regionally very differentiated since about 12,000 years ago (Markgraf, 1993, pp. 377, 381, 357–358). Nevertheless, one general paleoclimate history for lowland South America states that conditions "…at 12,000 yr BP were cold and dry, in a continuation of the glacial mode.

By 9000 yr BP moisture levels had reached or even surpassed modern levels, but temperatures were probably still lower than today. After 8500 yr BP moisture levels fell, reaching a minimum at 6000 yr BP" (Markgraf, 1993, p. 364).

Because there is little evidence for ancient climatic conditions in southwestern Ecuador during the Late Pleistocene and Early Holocene (Sarma, 1974; Spath, 1980; Stothert, 1987; Stahl, 1991), late glacial moisture patterns in Santa Elena can not be inferred directly, but it seems likely that less precipitation fell in the Late Pleistocene than in the Early Holocene. Temperatures were probably significantly reduced as well, as has been shown for elsewhere in tropical America (Colinvaux et al., 1996; Piperno and Pearsall, 1998).

Today the aridity of the Santa Elena Peninsula is attributed to the action of the cold Peru (Humboldt) Current. If this cold current had a more southerly position in the Early Holocene (Sandweiss, 1996a), and if the warm Equatorial Counter Current permanently bathed the peninsula, then the region may have experienced more rainfall, even without the effects of the ENSO phenomenon, which seems to have occurred much less frequently before 5000 years ago (Sandweiss et al., 1996).

Despite the possibility of a wetter regime in the Early Holocene (as predicted by the general paleoclimatic model), the Las Vegas environment inferred from midden remains was shaped by a pattern of low rainfall or seasonal precipitation. The plant and animal communities found near the Cape of Santa Elena in the 3000 year-long Las Vegas period apparently are the same ones found in sub-humid and semi-arid southwest Ecuador today. Even if there was greater precipitation in the Early Holocene epoch, nevertheless, palms, bamboo, monkeys and other canopy animals were never present.

Because the Southern Hemisphere in general experienced decreased seasonality in the Early Holocene (Markgraf, 1993, p. 379; Piperno and Pearsall, 1998), it is possible that precipitation in Las Vegas times was more evenly spread throughout the year (as compared to the Middle and Late Holocene periods after 7000 BP). Markgraf suggests that in South America only after 8500 years BP was there an increase in "seasonally dry periods" (1993:364). Dry southwesterly winds in the Early Holocene might have increased evaporation (Svenson, 1946) which prevented the formation of moist forests in southwestern Ecuador, but it seems likely that plant cultivation was always possible on a small scale in Santa Elena. While this activity could have been limited by low annual rainfall, it might have been favored by a more robust water table and lower rates of evaporation than observed today.

While environmental conditions in both the Early and Late Las Vegas periods seem to have been within the range of modern ones, this does not mean that they were unchanging. On the continental scale there is growing evidence that past climate regimes were different from present ones, and scientists are now convinced that Neotropical environments were unstable in the Late Pleistocene and Early Holocene periods (Markgraf, 1993; Piperno, 1994, p. 638; Piperno and Pearsall, 1998; Athens and Ward, 1999). According to Markgraf (1993, p. 364), "[b]etween 10,000 and 8500 yr BP those records with sufficient paleoenvironmental detail show a rapid stepwise succession of vegetation types, replacing the Late Pleistocene grasslands.... This succession suggests a stepwise warming and increase in precipitation."

Pollen data from a site on the Galapagos Islands off Ecuador shows that toward the middle of the Early Holocene there was an environmental transition, from grassland with a few savanna trees and extensive marshes at 9000 BP to a grassland with more savanna trees and much reduced marshland at 6000 BP (Markgraf, 1993, p. 365, Fig. 143). Subsequently people may have witnessed intervals of "moisture stress" beginning as early as 8000 BP and continuing after 6000 BP (Markgraf, 1993, p. 377). In other words, in South America after 8500 years BP there may have been an increase in "seasonally dry periods" (1993:364).

Temporal and regional details are missing for the Santa Elena Peninsula, but if there was a drying trend late in the Early Holocene, this would have increased the attractiveness of risk-averting subsistence strategies, including plant cultivation and fishing. It is intriguing that ecologists expect to find "the wild ancestors of many important crop plants" in environments with dry seasons, such as those of ancient Santa Elena in Vegas times. These are the probable areas of origin of plant husbandry (Piperno and Pearsall, 1998, pp. 46; 50–52).

5. Las Vegas settlements and adaptation

The 32 known Vegas settlements (Fig. 3) reflect the adaptation of a group of people who harvested a wide variety of species from several sub environments on the western peninsula and in the Bay of Santa Elena. These Vegas sites are found today between 10 and 60 m above modern sea level. In the Early Holocene they must have been located on low hills overlooking the courses of seasonal or permanent rivers. In Vegas times the distance from these camps to littoral resource areas must have been greater.

The locations of the two larger Vegas sites, Sites 80 and 67/66, and of all the smaller sites (Fig. 3) indicate that both terrestrial and marine resources were attractive: these sites offer access to river bottom, to inland terrestrial environments, including higher hills east of Site 80, and to the diverse biomes of the littoral which, in the Early Holocene, may have lain between 5 and 20 km from Site 80, and even further from Site 67/66 (Fig. 3). Permanent residence in these settlements may have been desirable because of the juxtaposition of tropical marine and terrestrial resources. However, given the mosaic of resources available within the 10 km catchment zone of these settlements (Fig. 3), it seems possible that people might have moved freely from camp to camp depending upon the season or upon personal preferences. At this time it is not possible to weight the relative importance of resources in the Vegas subsistence system at any moment in time.

In the Early Las Vegas Period the local community may have consisted of tiny, independent household groups: the only known Vegas is a shelter less than 2 m in diameter (Stothert, 1988; Malpass and Stothert, 1992). Perhaps the basic social unit of production, distribution and consumption was the small, relatively self-sufficient family, flexibly organized for carrying out a wide variety of subsistence tasks using a few generalized tools and facilities. It is possible that this basic economic unit changed in Late Las Vegas times, and that people grew less mobile and more committed to plant cultivation.

When Lanning originally defined Vegas he suggested that there were "riverside camp sites" and "shell middens along the shore and near ancient estuaries" (Lanning, 1967, p. 13). Subsequently no true "shell midden" sites have been identified. Site 38 (located just east of modern Salinas and occupied as early as 8000 BP) might have been located closer to the shore and the mangrove swamps than Site 80, but the accumulated midden showed about the same density of shell remains as seen at Site 80 (Stothert n.d. [1971]).

While marine and estuarine resources contributed significantly to the diet of the Vegas people, it is now clear that plant cultivation also was a key aspect of their way of life. Newly excavated Site 67/66 (Fig. 3), located 15 km further inland from Site 80, has been interpreted as another base camp where Vegas people resided and buried their dead (Stothert, 2000).

Although the length of occupation of Site 67/66 has not been estimated, the first two radiocarbon dates confirm that midden accumulated there at the beginning of the Late Las Vegas Period (Table 1). Based on preliminary observations, it seems that the density of molluscan remains may be lower at Site 67/66 than at Site 80, and the ratio of deer bone to fish bone may be higher. Initial analysis of sediments from Site 67/66 show that squash was being consumed there. Midden contents support the idea that this was a habitation site, but both Site 80 and 67/66 are distinguished from all the smaller Vegas settlements by the presence of graves. The recovery of human remains in both primary and secondary burials at both Site 80 and Site 67 is evidence of burial ceremonialism which may have been a mechanism by which members of the Vegas community achieved greater social integration or expressed their claims to resources and territory (Stothert, 1985, 1988, 2000).

These two sites indicate a Late Las Vegas pattern: families apparently occupied base camps located some kilometers inland near small seasonal rivers whose valleys served as a conduit for people moving between littoral extraction camps and inland areas. People may have settled in these base camps seasonally in order to cultivate crops and undertake celebrations that involved members of the larger community. People may or may not have exploited marine/estuarine resources on a daily basis, but they did carry seafood to these inland sites at intervals.

6. Evidence of change

A remarkable pattern of change has been described from the study of Las Vegas zooarchaeological and paleobotanical evidence.

6.1. Faunal remains

Remains from Las Vegas midden indicate that the ancient people exploited 25 categories of marine fish, one marine mammal, crab, a wide variety of mollusks, several species of reptiles and amphibians, scant bird, and 15 categories of terrestrial mammals (Table 5). More important is that when a comparison is made between the Early Las Vegas midden levels (9800–8000 BP) and the Late Las Vegas levels (8000 and 7150 BP), a pattern of change is revealed.

Table 6 shows that the relative contribution of fish increased significantly in the Late Las Vegas period as

Table 6
Comparison of the occurrence of bony remains of fish and mammals (expressed as a ratio of fish to mammals) from Early and Late Las Vegas deposits at Site 80

	Early Las Vegas contexts	Late Las Vegas contexts
Minimum number of individuals (fish/mammals)	30.5/55.2 = 0.55	48.4/38.5 = 1.26
Number of elements (fish/mammals)	11.2/22.2 = 0.50	22.2/21.4 = 1.04

Calculations are based on both the minimum number of individuals and number of elements identified in combined samples. Data from Chase (1988) and Stothert (1988, p. 194, Table 9.2).

sea level fluctuated and approached its modern level. Although fish may not have contributed more calories to the diet than terrestrial vertebrates in either of the Las Vegas phases, the evidence indicates a change in the valuation of fishing and an intensification in some fishing activities which might have involved technological change, or reorganization of labor or increased labor investment. All the Las Vegas fish could have been taken with hooks in near-shore waters or estuaries (Byrd, 1976; Chase, 1988), although netting, trapping, and the use of fish poison are possible alternative strategies for harvesting these resources. The Las Vegas artifacts that were preserved do not offer clues about either fishing or hunting techniques: neither fishhooks nor projectile points were found. It seems likely that rafts and canoes were in use by Las Vegas people for fishing and travel: the faunal species identified could have been taken by fishermen who lacked skill in offshore navigation, but logically that skill could have developed over time (Stothert, 1977).

A comparison of the Early and Late Vegas faunal remains also shows that terrestrial animal exploitation changed by species (Stothert, 1988). The Early Las Vegas people consumed both large mammals (principally deer), smaller ones (rodents and opossum), and fish, but in Late Vegas times while the same larger mammals were exploited, the smaller ones were sought less frequently, and, at the same time, people took more fish, including more small fish.

An analysis of shellfish remains from the midden at Site 80 shows a contrast between the Early and Late Las Vegas levels (Table 4). While the Early Vegas folks brought home principally *Anadara* clams from the mangrove swamps, the later peoples consumed a wider variety of shellfish from rocks and other habitats. Shell artifacts were recovered from Late Vegas tombs, but no Early Vegas period graves were investigated and no shell artifacts were reported. The apparent change in shellfish exploitation may have tracked fluctuations in the estuarine/mangrove resources caused by sea level change. Feedback from other subsystems such as technology, short-term climate oscillations, the need to cope with population growth, or the expansion of other socio-ceremonial activities also might have inspired the ancient Vegans to intensify their use of certain animal resources at the expense of others.

One aspect of the Late Las Vegas diet was reconstructed by estimating the amount of edible biomass (expressed in calories) represented by the number of individuals of each animal species identified in a small sample of fauna remains (Byrd, 1976, p. Table 30; Stothert, 1988, pp. 199–201). This reconstruction was based only on vertebrate sources, whereas the ancient people surely consumed large quantities of terrestrial and marine plants, as well as terrestrial and marine invertebrates, like insects, grubs, shrimp, and octopus, whose remains are not preserved in Las Vegas soils. The dietary estimate suggests the relative contribution of terrestrial mammals, marine fish and shellfish to subsistence over as much as 1000 years in the Late Las Vegas period.

In the sample studied, terrestrial animals (primarily deer) accounted for about 54% of the calories consumed from animal sources, fish contributed about 35%, and mangrove clams contributed about 11%. The proportion of shellfish may be over-estimated because of the excellent preservation of shell, while the quantity of small fish is probably underestimated in the calculations because the tiny bones which passed through the 0.5 cm screen have not been analyzed.

In summary, the study of faunal remains suggests that the Las Vegas people, living in villages inland from the sea in an area of tropical ecotone with little seasonal variation in the availability of animal resources, probably exploited a wide variety of terrestrial and marine species and enjoyed a constant supply of animal protein. In the Late Vegas period fishing practices apparently were intensified, and at that time half of all food from animal sources was sought in the marine and estuarine environments, while the other half came from the terrestrial zone. The human skeletal remains showed that people were healthy, free of anemia, and relatively long-lived (Ubelaker, 1980, 1988; Stothert, 1985, 1988).

6.2. Paleobotanical remains

Today, the seasonally dry tropical forest and savannas have a variety of useful and edible plants which probably were important to Vegas people (Svenson, 1946; Valverde et al., 1979; Lindao and Stothert, 1994), but poor preservation of plant remains initially frustrated the reconstruction of the vegetal aspects of Las Vegas subsistence (Stothert, 1985, 1988).

New evidence from the study of plant microfossils has altered strikingly our understanding of the Las Vegas adaptation, and now confirms that since early in the Holocene Las Vegas people were involved in plant cultivation. This result corresponds to the predictions of David Harris (1972), who argued that early populations in tropical ecotonal regions of northwestern South America would be among the earliest American horticulturists. It is also clear that several domesticated root plants were developed from wild ancestors native to the seasonally dry Neotropics, and that the cultivation and storage of maize and other seed crops is favored in regions, such as Santa Elena, with distinct and long dry seasons (Pearsall and Piperno, 1990, p. 335).

6.2.1. Phytolith chronology

The study of change in the use of plants in the Las Vegas period has been made possible by the development of methods for identifying plants from the microscopic silica bodies which originally formed in their cells and which are preserved in archaeological sediments (Piperno, 1988a, 1998). Not only may some ancient plants be identified to genus or species, but recently AMS dating procedures have been employed to assess directly the age of decoctions of phytoliths extracted from archaeological soils (Mulholland and Prior, 1993). This approach has verified that the Las Vegas phytoliths were deposited in the preceramic period and are of preceramic age. Furthermore, the Vegas phytolith assemblages have dates similar to those from samples of bone, shell and charcoal from the same midden contexts.

6.2.2. *Plant use in Vegas times*

Even though bottle gourd *(Lagenaria siceraria)* produces very few phytoliths, silica bodies from this plant are present at Site 80 in archaeological deposits dated as early as 9000 BP. They continue to appear in later levels (Piperno, 1988a, 1988b; Piperno and Pearsall, 1998).

Phytoliths from the seeds of *Calathea allouia* have also been identified. This is a tropical root crop, called leren, which is grown today in northern South America and the Antilles, and which probably was introduced into coastal Ecuador. Its diagnostic phytoliths appeared first in a 9000 BP level at Site 80, and they are common in later levels. The economic importance of this plant in Vegas times is unknown, but the occurrence of a few edge-ground cobbles and other simple, stone grinding tools is evidence that the Las Vegas people, like other preceramic groups, were processing tropical root foods (Ranere, 1972, 1976; Piperno and Pearsall, 1998, p. 283).

Vegas soil from all levels showed a high concentration of phytoliths from the epidermal cells of grass. Samples from the pre-7960 BP deposits show only phytoliths from wild grasses but maize phytoliths (*Zea mays*) were identified in soils from Late Las Vegas levels and some features (Pearsall and Piperno, 1990). Two samples containing phytoliths identified as those of maize yielded uncorrected dates of 7170 and 5780 BP. Maize apparently was not a staple in Las Vegas times, but the inhabitants of Site 80 began cultivating a primitive variety shortly before 6600 BP. No later preceramic sediments have been recovered from Site 80. The cultivation and storage of maize and other seed crops is favored in regions with distinct and long dry seasons (Piperno and Pearsall, 1998, p. 335).

Primitive maize, which is easily transported, would have been well adapted to the seasonally dry habitats of coastal Pacific Central America and the interior Cauca and Magdalena valleys of Colombia. People may have carried seeds out of West Mexico and dispersed them into northern South America along this route. There probably existed a network of interacting preceramic peoples who, in Vegas times, passed useful plants from hand to hand (Stothert, 1977, 1985, 1988).

The Las Vegans also may have cultivated beans, cotton, peanuts, and other tropical root crops like manioc, arrowroot, achira (*Cana edulis*), and perhaps species of *Xanthosoma* and *Dioscorea.* No direct evidence for these crops was recovered from Vegas sites, but several of these cultigens were positively identified, from both phytoliths and macrofossil remains, in later (Early Formative period) contexts in coastal Ecuador (Pearsall, 1979, 1988; Damp et al., 1981; Damp, 1990; Damp and Pearsall, 1994). Manioc and other tropical food species are difficult to identify, but manioc starch grains have recently been recovered from plant grinding stones dating to ca. 7000 BP at the Aguadulce Rock Shelter in Panama, evidence of its early domestication and spread from its domestication hearth in South America (Piperno et al., 2000a, b). Other evidence of domesticated squash, leren and bottle gourd were found in association with abundant remains of palm fruits at the Peña Roja site in eastern Colombia, in contexts dating to 8090 ± 60 BP (Gnecco and Mora, 1997; Piperno and Pearsall, 1998, pp. 303–04).

6.2.3. *The domestication of squash (Cucurbita)*

Recently botanical, paleobotanical and archaeological evidence has been employed to reconstruct the origin and development of domesticated squash (Andres, 1990; Andres and Piperno, 1995; Piperno et al., 2000a, b; Stothert et al., 2001). An analysis of the size of modern *Cucurbita* phytoliths has allowed Piperno to distinguish domesticated from wild squashes (Piperno and Pearsall, 1998, p. 191, Table 4.2; Stothert and Piperno, 2000, Table 5). Modern-day wild squashes have short phytoliths, while domesticated species have longer ones. The phytoliths of *Cucurbita ecuadorensis* are intermediate in size between those of wild species and domesticated species (*C. moschata* and *C. ficifolia*), a result supporting the semi-domesticated status of *C. ecuadorensis* (Nee, 1990).

Furthermore, it has been shown that as squash fruit and seeds increase in size, so do the phytoliths recovered from the remains of their fruit rinds (Figs. 4 and 5; Piperno and Pearsall, 1998, Chapter 4). This means that there is a method for assessing the size of ancient *Cucurbita* fruit and seeds directly from phytolith measurements (Piperno and Pearsall, 1998, Fig. 4.7a).

Cucurbita phytoliths are ubiquitous in preceramic midden at Site 80. Samples of phytoliths from the oldest midden deposits were dated by associated shell and charcoal, while the later phytolith assemblages were dated directly. The study of these samples demonstrates that the size of the phytoliths increased regularly through time (Table 7).

In brief, soil samples dating before 10,000 BP yielded a population of *Cucurbita* phytoliths whose measured mean was small: it is very likely that the fruit and seed size had not been subject to significant selection by human beings. These probably were wild squashes.

The phytoliths from a context dated 9740 BP showed a greater mean length than those of the pre-10,000 BP deposit, although phytolith thickness did not increase. These phytoliths were within the size range of some modern, wild species, and were slightly smaller than those of modern *C. ecuadorensis*.

The assemblage of phytoliths with a direct phytolith date of 9080 BP yielded a mean length more than 20% greater than that of the next older sample, and the recorded phytolith thicknesses were significantly greater. Data suggest that the squashes of the early 9th

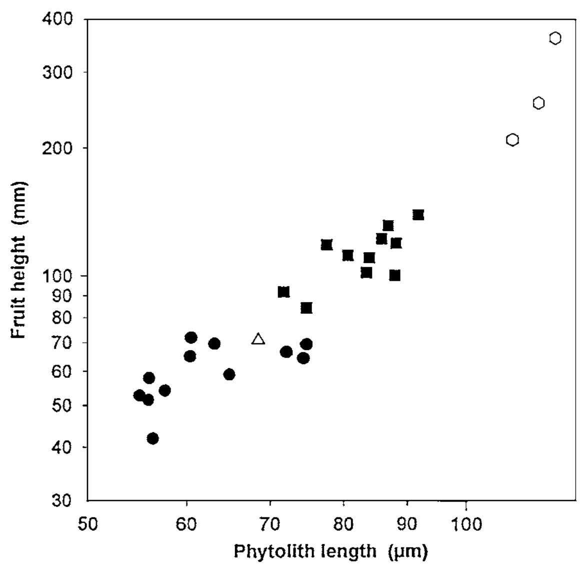

Fig. 4. The relationship between phytolith length (microns) and fruit height (millimeters) in modern species of *Cucurbita.* Black circles are wild *C. argyrosperma* ssp. *sororia* from Panama; open triangle is wild *C. pepo* ssp. *texana*; black squares are semi-domesticated *C. ecuadorensis*; and open hexagons are domesticated *C. ficifolia* (data from Piperno and Pearsall, 1998, p. 194, Fig. 4.7a).

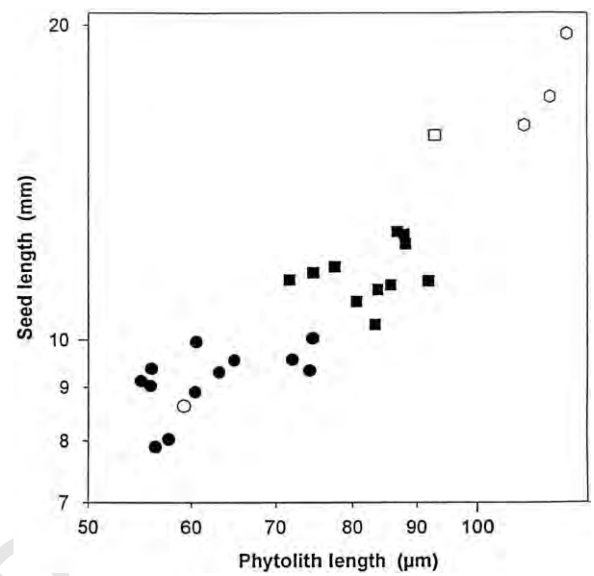

Fig. 5. The relationship between phytolith length (microns) and seed length (millimeters) in modern species of *Cucurbita.* Black circles are wild *C. argyrosperma* ssp. *sororia* from Panama; open circle is wild *C. foetidissima*; black squares are semi-domesticated *C. ecuadorensis*; open square is domesticated *C. moschata*; and open hexagons are domesticated *C. ficifolia* (data from Piperno and Pearsall, 1998, p. 195, Fig. 4.7b).

Table 7
Mean lengths and thicknesses of assemblages of squash phytoliths (*Cucurbita*) from dated archaeological contexts in Las Vegas Site 80. The pre-10,000 BP context was dated by associated shell and charcoal, but all the other contexts were dated by AMS dates from phytoliths

14C Phytolith age in years BP	Mean length in microns	Range	Number of length measurements in sample	Mean thickness in microns	Range	Number of thickness measurements in sample
5780±6 Feature 1, 112 cm	96	72–120	8	74	56–88	4
7170±60 GH8–9, 105–110 cm	94	64–116	12	78	64–95	6
7960±60 G10–11, 130–140 cm	78	56–108	52	63	40–76	41
9080±60 E8–9, 110–120 cm	86	56–120	65	68	42–93	31
9740±60 F8–9, 110–120 cm	72	48–108	51	55	36–76	45
> 10,000 Feature 95, 200 cm	64	52–92	9	55	41–80	3

For calibrations see Table 1. Data from (Piperno and Pearsall, 1998, p. 186, Table 4.1; and Piperno et al., 2000a, b, p. 206, Table 5).

millennium BP had fruits and seeds larger than those of any wild species that have been investigated. The ancient fruits likely were from a genetically and morphologically altered form of *Cucurbita*, and they likely measured at least 12 cm long.

The sediment sample dated 7960 BP showed phytoliths which were substantially larger than those in the 9740 BP context, but the means were not as high as the 9080 BP sample. In fact, the mean fell within the range of modern *C. ecuadorensis.* More than one type of squash may have been under domestication at Site 80 at this time.

The microfossil sample directly dated to 7170 ± 60 BP contained both maize phytoliths and an assemblage of squash phytoliths with the greatest mean length of any Vegas assemblage. The mean phytolith size overlapped that of modern *C. moschata.* The Late Las Vegas fruits may have been around 16 cm long, which is double the size of the 9700 year old squashes from the site. Squash phytoliths of this size also occur in the later sample dated 5780 ± 60 BP.

In summary, the pattern of change in the size of squash phytoliths from these contexts appears to document the progressive domestication of the plant. These data support the argument that domestication was underway by 9000 BP in Santa Elena, and provide evidence for independent domestication of squash species in lowland tropical South America during the earliest Holocene (Piperno and Pearsall, 1998, Chapter 4). Recently Smith (1997) also has shown that early domesticated squash seeds were present in Mexico by 8990 ± 60 BP.

6.2.4. *Starch grains*

There have been several fruitless attempts to use trace elements in human bone samples to assess the diet and plant intake of the Late Las Vegas people (Stothert, 1988, pp. 219–224; Van der Merwe et al., 1993), but a new approach to the reconstruction of ancient diet has resulted in evidence that supports the hypothesis of early cultivation in coastal Ecuador. Starch grain analysis provides information about the presence in ancient sites of elusive root crops and other starchy plants like maize. This technique depends upon the fact that the starch grains found in roots, tubers and seeds may be preserved in archaeological contexts, and that the form of these grains, which is under genetic control, permits the identification of tropical cultivars such as manioc, maize, and arrowroot.

Paleobotanists are now recovering starch grains from the working surfaces of stone tools and from the teeth of prehistoric skeletons (Piperno and Holst, 1998; Piperno et al., 2000a, b, 2001). Both starch grains and phytoliths recovered from the plaque of teeth sampled from Late Las Vegas contexts have been identified as follows: 6 phytoliths are indistinguishable from those of maize glumes, 6 grains of starch compare favorably in size and morphology to grains from seeds of modern varieties of maize, and two other grains correspond to roots and tubers. This evidence supports the argument that maize was used by the Late Vegans by 7000 years ago.

7. Marine resources and early agriculture

In the Early Holocene the people of the Santa Elena Peninsula developed a pattern of broad-spectrum collecting, focused on both terrestrial and marine resources. This subsistence strategy may have compensated them for the loss of Pleistocene resources (such as giant Ice Age animals), and provided them with a subsistence system that adequately buffered the local community against instability and fluctuations in the environment. Relatively sedentary settlement may have been favored because of the economic benefits of exploiting both predictable terrestrial and marine/estuarine resources. The Las Vegas people became progressively more committed to exploiting the rich marine/estuarine fish resources while also feeding themselves with products from their gardens.

Innovating a subsistence strategy that included the cultivation of plants in the early stages of domestication, and others more fully domesticated, proved to be a successful and enduring adjustment in a complex tropical, coastal ecosystem. One can argue that the Las Vegas preceramic people were the innovators of the successful farming and fishing adaptation which was characteristic of the succeeding Formative period and which was the basis for life in all subsequent peoples in coastal Ecuador. Later coastal people developed more complex social arrangements upon the foundation of this mixed economic strategy (Stothert, 1992): ultimately they combined several maritime activities (fishing, shell fish harvesting, seafaring and trading) with terrestrial pursuits (especially agriculture, forest product extraction, mining, and craft production). This adaptation has been durable and well-suited to an unstable environment in a region where agriculture is risky.

The Las Vegas case demonstrates that as early as 9000 BP both seed plants (*Cucurbita sp.* and *Lagenaria siceraria*) and root crops (*Calathea allouid*) were cultivated in local gardens. By 7000 BP the Las Vegas farmers had domesticated or acquired more productive species of squash, and added primitive maize to their list of cultivars. These Late Las Vegans who practiced both intensified fishing and an evolved form of gardening, also undertook some social changes, including the development of elaborate communal burial activities.

One of the intriguing issues in the study of Las Vegas is what motivated the evolution of the Las Vegas adaptation. In one scenario, change may be viewed as a mechanism for adjusting to environmental alterations.

Given the probability that there were significant environmental fluctuations in the Early Holocene in Santa Elena, it is likely that short-term changes in the climate and biogeography of the Santa Elena Peninsula were factors that shaped the Las Vegas adaptation. For instance, the evolution of shell fishing between the early and late Las Vegas phases may reflect the replacement of mangrove formations by lagoons, beaches and rocky points. However, in order to test this explanation, and in order to model change successfully, geomorphological and paleoenvironmental studies designed to reconstruct the paleoenvironments of the peninsula are required. We need to know how cultural and environmental changes were correlated in order to improve the Las Vegas case study.

Other interpretations are attractive, too. People may have chosen to reallocate the labor of men or women for a variety of reasons not directly related to the loss of mangrove formations or climate instability. Other incentives to change may have included the perceived benefits of new technologies or the rise of social demands, which might have been satisfied by investing more food and other products in building alliances, engaging in reciprocity and undertaking regional and extra-regional exchange. Plants figure widely into human exchange activities (Hastorf, 1998).

Another intriguing issue in the study of the Las Vegas adaptation is modeling plant cultivation in the early and mid-Holocene periods. The Vegas case contributes an important corpus of data to the study of the origin of horticulture in the Neotropics. The Vegas data support the model that cultivation originated as foragers, familiar with a wide variety of species within a few kilometers of their stable settlements, manipulated complex tropical ecosystems (Harris, 1972). Harris predicted that the most "propitious areas" for early cultivation in the tropics "may have been marginal transitional zones, or ecotones, between major ecosystems" (1972:184), and he also suggested that sedentary foraging people would be most likely to undertake cultivation. On the Santa Elena Peninsula, the Las Vegas people, who developed horticulture in the Early Holocene, lived in just the kind of zone described by Harris and apparently occupied some relatively stable settlements.

Harris also suggested that early cultivation in the tropics was vegeculture, focused on tropical root crops, which are starch-rich cultigens. Because the wild ancestors of plants like manioc, leren and some species of *Xanthosoma* were adapted to seasonally arid regions, they would have been domesticated in tropical zones with marked dry seasons. The Vegas data support this interpretation.

In their comprehensive model of the origin of cultivation in the tropics, Piperno and Pearsall (1998, Chapters 1, 2 and 4; see also Piperno, 1989) argue that broad-spectrum collecting developed as people found more energetically efficient adjustments to the changing resource patterns of the Late Pleistocene and early post-Pleistocene periods. In particular, because people operated in an ecosystem poor in starchy wild plants, they would have found it desirable to inject more calories into their diet. Evidence from several regions, including southwest Ecuador, supports the idea that plant cultivation was a low-cost subsistence strategy innovated in seasonally dry tropical forest areas. Contrary to popular belief, in tropical forested biomes plant cultivation is a more energetically efficient subsistence activity than wild plant collecting. Not surprisingly, horticulture developed in Central and South America before 9000 BP, during a period when there was much more environmental instability than was experienced by people later in the Middle Holocene (Piperno, 1994, p. 638).

The Las Vegas economy evolved as people intensified their investment in fishing and added a progressively greater number of cultigens to their subsistence system. This may indicate that the Vegans found ways to pool their labor in order to improve their economic returns.

Late Las Vegas people, compared to their ancestors, consumed more fish, trapped fewer small animals, hunted large animals, and cultivated improved squash, maize, and root crops (like leren). Perhaps Late Vegas Period men hunted deer as before, but also parties of kinsmen developed ways of fishing together, improving the productivity of their lines and nets. Women may have gardened in the bottom land along the Las Vegas River (Hastorf, 1998; Bruhns and Stothert, 1999), an activity viewed as more productive than only foraging in the bush for wild plants and small animals. If Las Vegas women traditionally were responsible for collecting plants and small animals, and if they were also the farmers, then their growing specialization in cultivation in the Late Las Vegas phase may explain the decrease in the utilization of small animals in that period.

Late Las Vegas burial ceremonialism indicates that people invested more time and effort in community social activities. One imagines that groups of families developed integrative mechanisms, including the mortuary rituals inferred from the Vegas graves, which might have helped them to share food on a regular or irregular basis and to field larger work groups.

Ceremonial gatherings imply both the consumption of special foods and the giving of food as gifts (Hastorf, 1998). Growing food and producing quantities offish in order to share is another way that people insure themselves against resource fluctuation. Food sharing is an important strategy for minimizing risk (Rossen, 1991; Piperno and Pearsall, 1998). The intensification of both fishing and farming may have underwritten the development of ceremonial activities, alliance building, and reciprocal exchange. In fact, spreading one's social net more widely would have been a risk-management strategy, which accounts for the strong pattern of interconnectedness observable among ancient Native American peoples.

The Las Vegas research demonstrates that some of the earliest horticulture in America took place among people who also fished for a living. While on the one hand the exploitation of the productive resources of the sea and mangrove estuaries may have favored stable settlement, by the same token gardening may have increased the availability of vegetable food, permitting people to live at the shore and enjoy the exquisite fruits of the sea. The Early Holocene people worked out a system in which the exploitation of several sub environments was the basis of a successful adaptation that persisted for more than 3000 years despite changing coastlines and fluctuating climates. This mixed economy allowed the Las Vegas people to tap the rich resources of the sea and the land, to adapt successfully to the instability of the resources of the littoral and the changing terrestrial conditions of the ''abnormal appendage'' of southwestern Ecuador.

The Late Las Vegas way of life can be seen as a pre-adaption for the development of fully agricultural, village life. By 5000 years ago the tropical regions of America peoples who cultivated a wide variety of useful domesticated plants were ubiquitous. Some of them also fished.

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