

Paleoenvironmental Change at Elkhorn Slough: Implications for Human Adaptive Strategies

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SINCE the early 1900s when the results of the first excavations of San Francisco Bay shell mounds were published (Uhle 1907; Nelson 1910; E. Gifford 1916; Schenck 1926), much emphasis in California archaeology has been placed on time/space patterns, which has resulted in the refinement of numerous cultural chronologies. Coincidental with subsequent developments in cultural anthropology (see Steward 1955; Netting 1977), more recent archaeological studies have directed increasing attention toward the process of cultural change and the ecology of varying human lifeways. Environmental change is a theoretical premise that has frequently been advanced to explain shifts in the California archaeological record and associated, hypothetical population movements.

By the 1940s, a sequence of large-scale climatic changes had been proposed and the implications of these changes for human behavior were discussed (Antevs 1948, 1952; Aschmann 1958). As archaeological and paleoenvironmental data accumulated, new models incorporating human response to large-scale environmental changes were proposed (Baumhoff and Heizer 1965). More recently, Moratto, King, and Woolfenden (1978; but see comments by Byrne [1979: 196-198]) and Breschini (1983) have dis-

cussed the implications of large-scale Holocene environmental changes for prehistoric central California populations; the former concentrating on mountainous areas, the latter on the west-central portion of the state.

Over the last two decades, California archaeologists have initiated examination of smaller-scale, regional sequences of environmental change, particularly in coastal settings. These studies have benefited a growing interest in the archaeology of coastal zones worldwide (Stark and Voorhies 1978; Quilter and Stocker 1983), as well as the development of a general theory of maritime adaptations (Yesner 1980). In the early 1960s, several authors discussed the silting in of San Diego County coastal lagoons and the resultant population movement inland (Shumway, Hubbs, and Moriarty 1961; Warren, True, and Eudey 1961; Warren and Pavesic 1963). More recently, Desgrandchamp (1976) and Bickel (1978) discussed the influence of rising sea levels on the coastal environment (i.e., the development of estuaries and associated marshes) and the consequent effects upon human groups living in that environment. Bickel (1978: 16) suggested that archaeological features such as "changing settlement patterns and shifts in diet may be illuminated by consideration of local histories of sea level rise and accompanying effects." Subsequently, Erlandson (1980) presented a discussion of paleoenvironmental change at Teco-

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lote Canyon in Santa Barbara County that incorporated the influence of sea-level rise.

In this paper we will discuss the implications of small-scale paleoenvironmental change on prehistoric human populations residing in the coastal zone of central California. The subject area is central Monterey Bay; specifically, Elkhorn Slough, an estuary situated midway between Santa Cruz and Monterey, the mouth of which now forms part of the Moss Landing Harbor (Fig. 1). Although the slough is currently classified as an estuary, it has a complex hydrographic past related partially to sea-level rise and partially to other natural events. Over 40 sites have been recorded in the Elkhorn Slough area, all of which can generally be classified as shell middens, with shellfish remains constituting the bulk of cultural deposits. Analysis of data from two of these sites reveals a changing pattern of shellfish exploitation through time which correlates with the slough's hydrographic history.

Two features of estuarine ecology render archaeological sites associated with estuaries uniquely valuable to the study of human adaptive behavior: (1) they are highly productive ecosystems (Pritchard 1967a) that embody a marked resource potential for human users, and (2) estuaries are, by their nature, transient ecological phenomena characterized by change through time (Bickel 1978: 8; Nissley, Bingham, and Cottrell 1978: 13; Ricketts and Calvin 1968: 232). Archaeological representations of economic behavioral systems that utilized estuarine resources provide a context through which the dynamic interface between human populations and environment can be examined. Elkhorn Slough is of particular interest because its natural history has involved not only the dynamic tendencies typical of estuaries in general, but has also included drastic fluctuations in constituent environmental regimes. It was originally a fresh-water drainage, changed

through thousands of years of tectonic activity into an estuary. It again became a fresh-water feature early in this century as a by-product of fault activity (Jenkins 1973). Consequently, the resource complex it encompassed throughout prehistory has not remained constant. These fluctuations are indicated by several lines of evidence, including archaeological data.

In order to examine the relationship between past environments and remnants of a human behavioral system, the investigation presented here incorporates (1) paleoenvironmental background research; (2) a palynological study aimed at defining the slough's environmental history; and (3) an analysis of archaeological data, focusing on the location of sites in relation to the hydrographic landscape, and faunal assemblages present at these sites.

ENVIRONMENTAL BACKGROUND

Elkhorn Slough is the main branch of a system of tidal channels that enters the coastal plain of northern Monterey County at Moss Landing Harbor and reaches inland for about seven miles (Fig. 1). Alternating salt-marsh and mud-flat communities line the basin formed by this channel system, which is bordered to the east and northeast by rolling hills that extend into steeper terrain at the southern end of the Santa Cruz Mountains. Adjacent drainage systems are those of the Pajaro River to the north and the Salinas River to the south.

Elkhorn Slough has had a varied environmental history during this century, and evidence indicates a similarly shifting pattern in prehistoric times. The current geomorphology of the slough dates back only to 1946 and the slough's status as a tidal creek, or estuary, only to 1908 (Fig. 2). Local drainage patterns may also be fairly recent. Prior to 1908, the Salinas River curved northward near the location of its present mouth and ran parallel

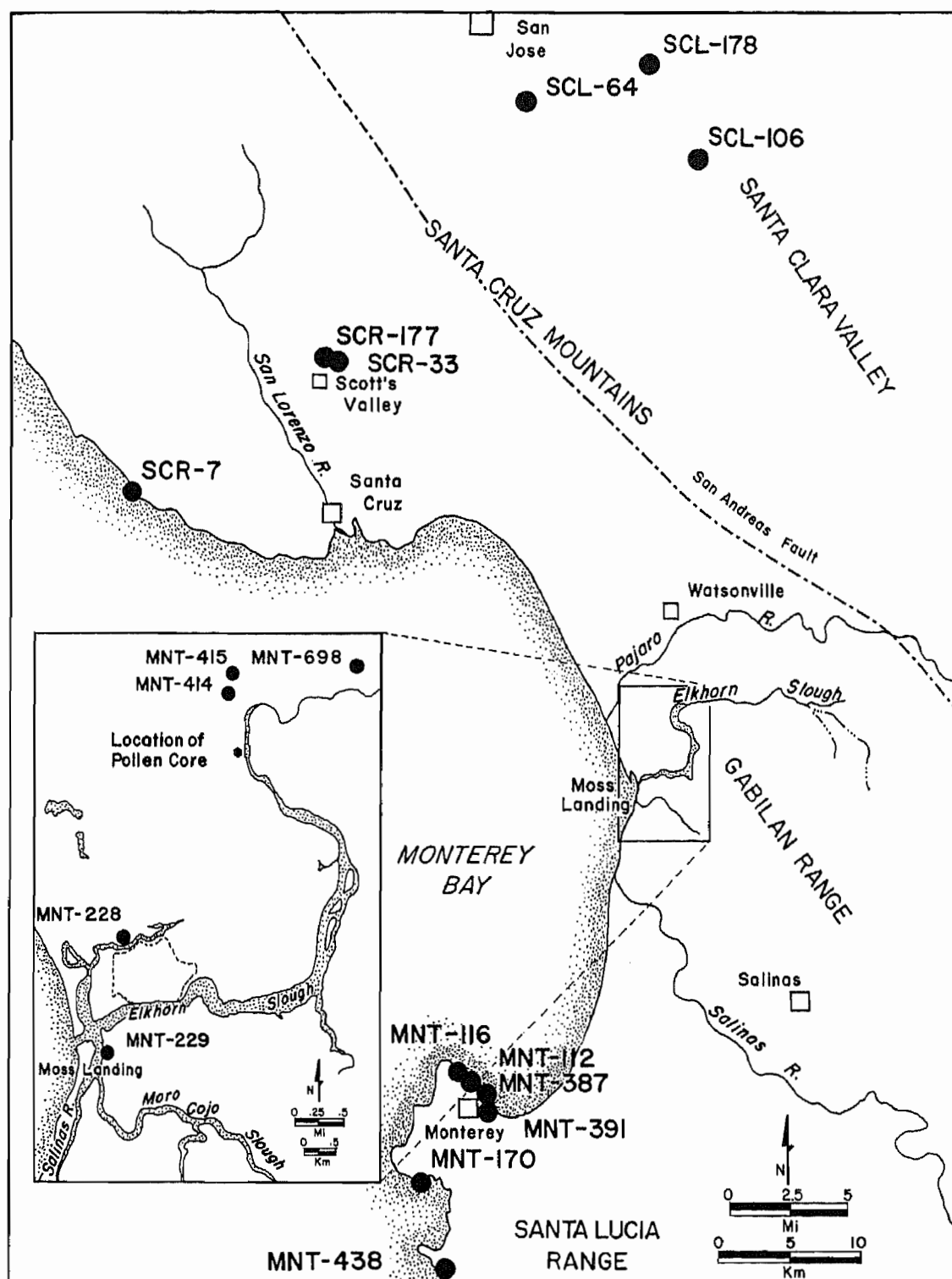


Fig. 1. Elkhorn Slough and important sites in Santa Clara, Santa Cruz and Monterey counties.

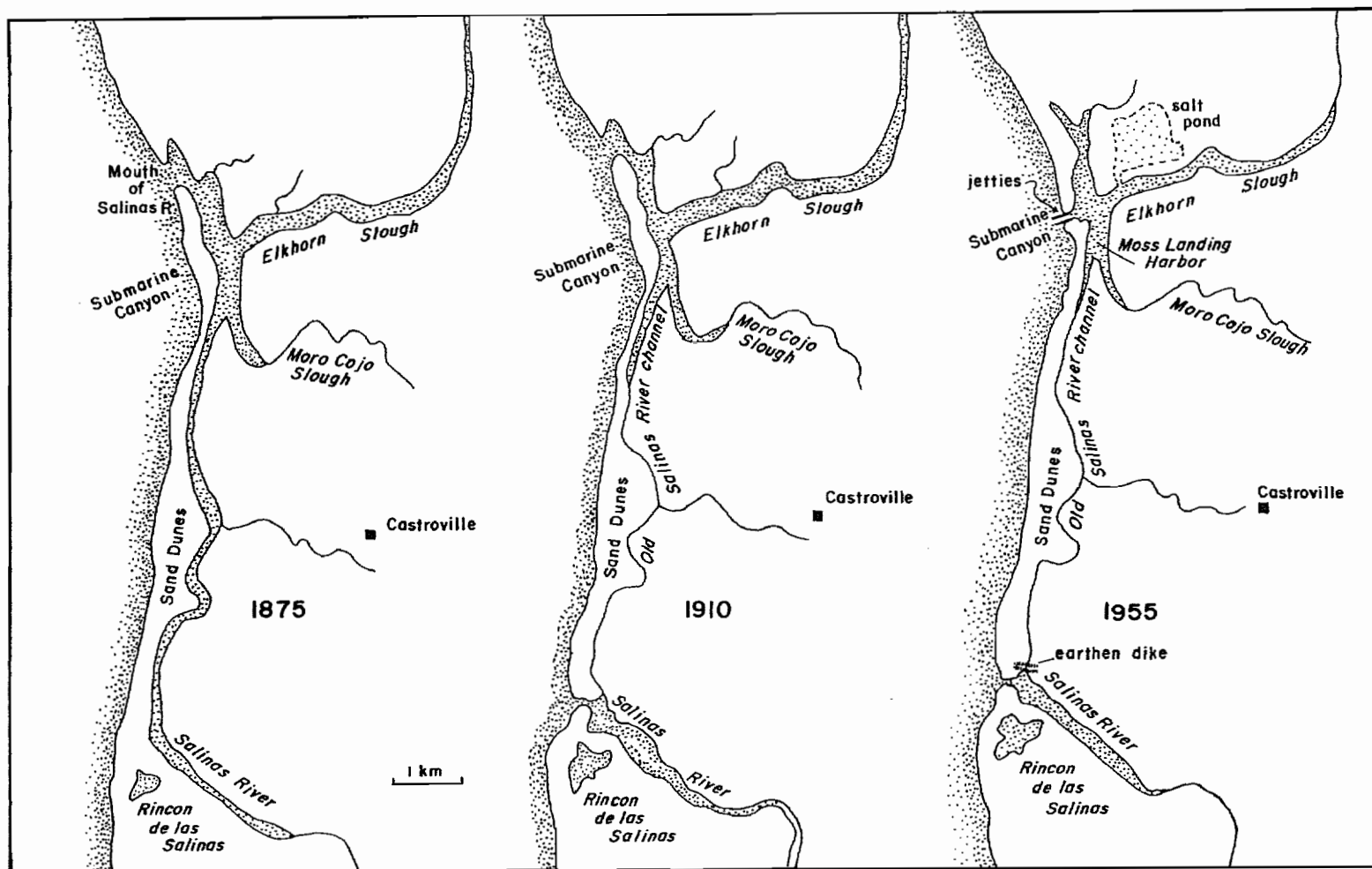


Fig. 2. Hydrographic changes in the central Monterey Bay area during the Historic Period. Adapted from Gordon (1977: 147).

to the coastline for about six miles, emptying into the ocean about one mile north of Moss Landing (Gordon 1977: 230). Elkhorn Slough opened into the river near the present site of Moss Landing Harbor. The force of the Salinas River's flow was adequate to limit tidal action and saltwater intrusion in the slough, and it was more a freshwater lagoon and tributary to the Salinas than an estuary. On a few occasions during violent winter rains, the Salinas River reportedly cut through the sand dunes near its present mouth and emptied into the ocean there (Gordon 1977: 234). The 1906 earthquake, which was caused by movements along the nearby San Andreas fault (Fig. 1), may have had latent effects on the hydrography of this area by offsetting stream courses and altering the pressure of water flow. This, in turn, created a new major opening for the river to empty into the sea (Jenkins 1973: 152). Flood-control dam construction after 1908 maintained that outlet, and the former Salinas riverbed lands were reclaimed for agricultural use (Browning et al. 1972: 18). The former mouth of the Salinas north of Moss Landing was kept open by tidal action, Elkhorn Slough filled with sea water, and the fresh-water lagoon was replaced by the estuary present today. Dredging of Moss Landing Harbor began in 1946 at the present location of the harbor mouth. Thus, the current slough entrance is now a man-made channel that opens directly into the head of the Monterey submarine canyon. The original mouth of the Salinas River north of Moss Landing gradually silted in and closed (Browning et al. 1972: 2).

Geomorphologically, Elkhorn Slough is of the "classic" estuary type: a drowned river valley. These formations are common along coastlines with a wide coastal plain (Pritchard 1967a, 1967b). The evolution of coastal-plain estuaries like Elkhorn Slough probably began with a rapid rise in sea level between 15,000 and 7,000 years ago (Atwater, Helley, and

Hedel 1977; Bloom 1971; Emery 1969; LaJoie 1972). Geological studies indicate that the Elkhorn Slough basin originated as a fresh-water river (Jenkins 1973) which, during parts of the Pleistocene, drained the area presently drained by the San Benito-Pajaro River system. Activity along the San Andreas fault throughout the last 200,000 years eventually cut the Elkhorn valley off from this original watershed, leaving it periodically devoid of fresh running water. Just when and how the Salinas River was joined to the slough, forming a fresh-water lagoon, remain in question; however, it is likely that at times the slough became infused with salt water. Oceanographic features offshore from the present position of the Salinas River mouth indicate that the mouth was maintained at that location over long periods of time, dating back to the Pleistocene (Gordon 1977: 231; Yancy 1968: 9). As noted above, the northward curve of the river to join Elkhorn Slough near Moss Landing may have been the result of seismic activity and variant drainage patterns. Also, the wave refraction patterns characteristic of Monterey Bay tend to build up high beach berms south of Moss Landing, and reports written before the river changed course suggest that the Salinas River mouth was often pushed northward (Gordon 1977: 232). Thus, past fluctuations in the location of the mouth of the Salinas River are reasonably evident, as are consequential fluctuations in the habitat of Elkhorn Slough.

The plant and animal communities seen in Elkhorn Slough today are typically estuarine, with the overall environment composed of a series of zones associated with varying degrees of tidal fill. The littoral zone, which includes mud flats and salt-marsh land with pickleweed (*Salicornia pacifica*) as the dominant vegetative indicator, contains the most important potential human food resources. Mud flats and channel banks of the littoral zone are inhabited by at least 28 species of

shellfish, and the salt marsh provides roosting and feeding grounds for a wide variety of avifauna. Outlying zones that extend from the salt marsh along borders of tributaries and fresh-water seeps include glasslands and oak woodlands. These communities also provide resting and feeding grounds for many species of the slough's avian fauna and support a wide variety of terrestrial wildlife.

Because historical and geological evidence indicates that the basin which holds Elkhorn Slough has been subjected to a long sequence of fluctuations in regional drainage patterns, distributional fluctuations in local biotic communities may also be presumed. Therefore, biotic communities occupying the slough today have not been consistently present throughout its history, although appropriate habitats may have developed when fresh-water flow was minimized enough to allow salt-water intrusion.

ARCHAEOLOGICAL BACKGROUND

The relationship between the archaeology of Santa Cruz, Santa Clara, and Monterey counties and the rest of central California has long been unclear. No data from this area were used in the formulation of the central California taxonomic system, which was based primarily on excavation data from the Sacramento/San Joaquin Delta (Lillard, Heizer, and Fenenga 1939; Heizer 1949) and the San Francisco Bay area (Beardsley 1948, 1954). With the exception of Pohorecky's (1964) site report from southern Monterey County and several preliminary studies conducted by University of California, Berkeley, graduate students (Pilling 1948, 1955), virtually no significant archaeological research was conducted on the central coast until the advent of cultural resource management in the 1960s. When study was initiated many researchers assumed the culture history of the central coast paralleled that of the Delta and, for lack of a regional sequence, employed the

central California taxonomic system to describe culture change. Although further regional synthesis is necessary (particularly in Santa Clara County), some headway has recently been made toward the establishment of a central-coast chronological sequence. The Monterey Bay area is currently better understood due to efforts made during the course of several major cultural resource management projects (Breschini and Haversat 1980; Cartier 1980a; Dietz and Jackson 1981; Breschini, Haversat, and Hampson 1983; Hildebrandt 1983). The following is a brief overview of available data regarding the central-coast sequence of human occupation.

Evidence for early human presence on the central coast comes from two controversial sites: SCR-177, the Scott's Valley site, situated 20 miles northwest of Elkhorn Slough, and SCL-178, the Metcalf site, 23 miles north in the Santa Clara Valley (Fig. 1). The Scott's Valley site has yielded four radiocarbon dates between approximately 7000 and 10,000 years B.P. (Cartier 1980a, 1984; see Table 1). Preliminary excavations at this site yielded a meager artifact assemblage in association with the radiocarbon dates. The lack of a good assemblage, combined with the fact that the dates were obtained from loose charcoal, led many researchers to question the antiquity of the site. Subsequent recovery of a large excavation sample (over 200 cubic meters of earth were removed) has provided artifactual and other support for a fairly early initial occupation of SCR-177, and several partially mixed components have been recognized in the site assemblage. Tools associated with the early dates include a preponderance of choppers, lanceolate bifaces, large unifaces, and a single Monterey chert eccentric crescent—all of which occur in assemblages dated between 10,000 and 6000 years B.P. in other parts of western North America (see Cartier [1984] for further discussion). Perhaps more importantly, obsidian hydration measurements of

flakes and biface fragments from SCR-177 support an occupation span from approximately 4000 to 8000-9000 years B.P.¹

A similar time depth has been suggested for the initial occupation of SCL-178, which yielded a series of radiocarbon dates ranging from close to 10,000 years B.P. at depths of 330-750 cm., to around 1000 B.P. at 90-100 cm. (Hildebrandt 1983: 6-3, 8-42; see Table 1). The stratigraphic context of the multi-component cultural deposit appears to be consistent with the dating.² However, neither sufficient artifactual materials nor other data (e.g., obsidian hydration measurements) that would allow for cross-checking of the radiocarbon dates were obtained from the site.³ Nonetheless, Hildebrandt (1983: 8-51) felt that the excavation data suggested initial occupation of the Metcalf site between 5000 and 10,000 years B.P. with continued regular but limited occupation through 1000 years B.P.⁴ Although neither the Metcalf nor the Scott's Valley site yielded a substantial artifact assemblage, and there are many unresolved questions about both sites, they do suggest the presence of humans in the central coast area by 8000 to 9000 B.P.

Other evidence of early human presence on the central coast has been reported from several sites with basement radiocarbon dates between 5000 and 6800 B.P.: SCL-64 and SCL-106 (Cartier 1980b) in the Santa Clara Valley and MNT-228 (Spanne 1981) in the central Monterey Bay area (Table 1, Fig. 1). While these sites suggest continued human occupation of the central coast, at present they indicate little else since the radiocarbon dates were obtained during the course of small-scale test excavations that produced no assemblages in association with the dates.

By 3500-4500 years B.P., occupation of the central coast appears to have been well-established. A number of sites, particularly in Monterey County, have yielded dates suggesting initial occupation during this time span.

These include: MNT-112, MNT-116 (Dietz and Jackson 1981), MNT-170 (Breschini and Haversat 1980), MNT-387 (Cartier n.d.), MNT-391 (Breschini and Haversat n.d.b), MNT-438 (Cartier 1983), SCR-7 (Roop 1976; Lajoie, in Edwards [1984: 2]), and SCR-33 (Cartier 1980a; see Table 1, Fig. 1). Following this widespread establishment of human occupation, a cultural break at 2000 years B.P. has been hypothesized by Breschini and Haversat (1980) and Dietz and Jackson (1981). Breschini and Haversat (1980) first suggested this break on the basis of two spatially and temporally distinct components at MNT-170. The earlier component, associated with the previously mentioned date of 4040 ± 100 B.P., was thought to represent a pre-Costanoan occupation, probably by Hokan speakers, with a generalized "forager" adaptive strategy (after Binford 1980). This strategy was represented by "middens with shell" (Breschini 1980; Breschini and Haversat 1980: 12), which are distributed both on the immediate coast and inland. The later culture, dating to approximately 2500 B.P. was thought to represent the arrival of Utian-speaking groups to the Monterey peninsula who possessed a more specialized "collector" adaptive strategy (after Binford 1980). This economic mode was represented by specialized collecting/processing sites on the coast (shell middens with extremely large, dense accumulations of shell) and inland village sites with less shell and evidence of more diverse activities (Breschini and Haversat 1980: 4-15).

While currently available data do point to a major change in settlement and subsistence, the precise nature of linguistic affiliations remains unclear and the record would perhaps be most safely interpreted as *in situ* cultural development rather than intrusion by a new linguistic group (cf. Breschini 1983). Dietz and Jackson (1981) found support for the presence of two "cultures" on the Monterey peninsula and elaborated on the settlement/

Table 1

CENTRAL COAST RADIOCARBON DATES MENTIONED IN TEXT

Site	Raw Radiocarbon Years B.P.	Years A.D./B.C.	MASCA Correction Years B.P. ¹	Shellfish Correction Years B.P. ²	Lab Number	Depth of Sample	Depth of Cultural Deposit ³	Material Dated	Reference
MNT-112 ⁵	4050±130	B.C. 2100	4620±210	—	RL-1360	130-140 cm.	140 cm.	<i>Haliotis</i>	Dietz and Jackson 1981:309
MNT-113	260±100	A.D. 1690	340±150	—	RL-0839	59- 63 cm.	80 cm.	charcoal	Dietz and Jackson 1981:341
"	550±100	A.D. 1400	590± 60	—	RL-0838	59- 63 cm.	80 cm.	<i>Haliotis</i>	" " " "
"	660±100	A.D. 1290	660±100	—	RL-0840	59- 63 cm.	80 cm.	<i>Mytilus</i>	" " " "
MNT-116 ⁵	3550±120	B.C. 1600	3910±190	—	RL-848	110-120 cm.	120 cm.	<i>Haliotis</i>	Dietz and Jackson 1981:442
"	3640±130	B.C. 1690	4040± 90	—	RL-849	110-120 cm.	120 cm.	<i>Haliotis</i>	" " " "
"	3650±130	B.C. 1700	4060± 90	—	RL-847	80-110 cm.	140 cm.	<i>Haliotis</i>	" " " "
MNT-170	700± 75	A.D. 1250	—	—	WSU-2389	25- 30 cm.	90 cm.	<i>Haliotis</i>	Breschini and Haversat 1980
"	4040±100	B.C. 2090	—	—	WSU-2390	67 cm.	80 cm.	<i>Haliotis</i>	" " " "
MNT-228	6880±135	B.C. 4930	—	—	UCR-1308	60- 80 cm.	74 cm.	mixed shell	Spanne 1981; Breschini, Haversat, and Erlandson 1983
MNT-387	3800±240	B.C. 1850	4228±240 ⁶	—	B-6611	base of midden	—	<i>Haliotis</i>	Cartier n.d.
MNT-391	3470± 70	B.C. 1520	—	—	WSU-2579	50- 60 cm.	100-110 cm. ⁴	<i>Haliotis</i>	Breschini and Haversat n.d.b
"	3290± 95	B.C. 1340	—	—	WSU-2580	50- 60 cm.	100-110 cm. ⁴	<i>Haliotis</i>	" " " "
"	3660±100	B.C. 1710	—	—	WSU-2578	138 cm.	140 cm.	mixed shell	" " " "
MNT-414	5200±100	B.C. 3250	—	4520±101	UCR-1075	90-100 cm.	100 cm.	<i>Protothaca</i>	Patch and Jones this article
"	5540±160	B.C. 3590	—	4860±161	UCR-0797	90-100 cm.	100 cm.	<i>Protothaca</i>	" " " "
MNT-438 ⁵	4200±120	B.C. 2250	4850±210	—	RL-1675	85 cm.	90 cm.	mixed shell	Cartier 1983
MNT-698	1760±100	A.D. 190	—	1080±101	UCR-0796	surface	?	<i>Protothaca</i>	Patch and Jones this article
SCL-64 ⁵	6590±200	B.C. 4640	—	—	UCR-0608	100-120 cm.	160 cm.	charcoal	Winter 1977a, 1977b:19
SCL-106 ⁵	5360±990	B.C. 3410	6320±570	—	RL-1055	220-250 cm.	265 cm.	charcoal	Cartier 1980b:34, 38
"	5520±480	B.C. 3410	6170±1060	—	RL-1056	250 cm.	265 cm.	charcoal	" " " "
SCL-178	8500±300	B.C. 6550	—	—	UCLA-2329B	330 cm.	610 cm.	charcoal	Hildebrandt 1983:6-3, 8-42
"	9200±1000	B.C. 7250	—	—	UCLA-2329C	350 cm.	610 cm.	charcoal	" " " "
"	9960±500	B.C. 8010	—	—	UCLA-2329D	510 cm.	610 cm.	charcoal	" " " "
"	9190±600	B.C. 7240	—	—	UCR-1294	750 cm.	880 cm.	charcoal	" " " "
"	890±290	A.D. 1060	—	—	UCLA-2354A	90 cm.	?	charcoal	" " " "
"	770±240	A.D. 1150	—	—	UCLA-2354B	90 cm.	?	charcoal	" " " "
"	960±200	A.D. 990	—	—	UCLA-2354C	110 cm.	?	charcoal	" " " "
SCR-7	3790±100	B.C. 1840	—	3110±100 ⁷	I-7828	top of midden		shell	Roop 1976; Lajoie, in Edwards 1984:2
"	5390±100	B.C. 3440	—	4710±100 ⁷	I-7827	bottom of midden		shell	" " " "
SCR-33	3280±230	B.C. 1330	3550±260	—	RL-1372	80-110 cm.	140 cm.	charcoal	Cartier 1980a
SCR-177	10,080±460	B.C. 8130	—	—	RL-1373	100-110 cm.	280 cm.	charcoal	" "
"	7180±290	B.C. 5230	8000	—	RL-1374	140-190 cm.	280 cm.	charcoal	" "
"	7050±110	B.C. 5100 ⁸	—	—	B-7714	associated with rock feature		charcoal	Cartier 1984
"	6970±150	B.C. 5020	—	—	B-7713	associated with rock feature		charcoal	" "
SLO-2 ⁵	8960±190	B.C. 7010	—	—	GAK-2044	290 cm.	330 cm.	<i>Haliotis</i>	Greenwood 1972:86
"	9320±140	B.C. 7370	—	—	UCLA-1686A	320-330 cm.	330 cm.	bone	" "
SLO-177	8430±200	B.C. 6480	—	—	UCR-0789	122-145 cm.	152.4 cm.	<i>Mytilus/Haliotis</i>	Pierce 1979:97

Table 1 (continued)

Site	Raw Radiocarbon Years B.P.	Years A.D./B.C.	MASCA Correction Years B.P. ¹	Shellfish Correction Years B.P. ²	Lab Number	Depth of Sample	Depth of Cultural Deposit ³	Material Dated	Reference
SLO-877	5150±147	B.C. 3200	--	--	WSU-2480	10- 20 cm.	?	mixed shell	Breschini and Haversat n.d.a
"	5280± 90	B.C. 3330	--	--	WSU-2481	40- 50 cm.	?	mixed shell	Breschini, Haversat, and Erlandson 1983:24
"	5420±120	B.C. 3470	--	--	WSU-2482	60- 70 cm.	?	mixed shell	" " " " "
"	6865±120	B.C. 4915	--	--	WSU-2619	40- 50 cm.	?	mixed shell	" " " " "
"	8080±100	B.C. 6130	--	--	WSU-2620	50- 60 cm.	?	mixed shell	" " " " "

1. Although MASCA corrections are usually presented in years A.D./B.C., they are here given in years B.P. for ease of comparison.
2. Using Robinson and Thompson's (1981) correction factor only on sample of *Protothaca*, the species used to develop this factor (see note 7 below).
3. In unit from which sample was taken.
4. Estimated.
5. Later dates were also obtained from upper levels of this site.
6. Actual recalibrated range for this date is 4740-3715 years B.P. with 95% reliability (see *Radiocarbon* [1982: 103-228] for discussion of recalibration ranges).
7. Lajoie recently revised these dates on the basis of Robinson and Thompson's (1981) shellfish correction factor of 680 years (Edwards 1984:2); however, it is unclear whether the correction factor should be applied to these samples. Dietz and Jackson's data from MNT-113 (see discussion in this article or Dietz and Jackson [1981:341]) clearly show that this factor is incorrect for *Haliotis* and *Mytilus*; although it is probably valid for *Protothaca* spp. and other species that reside in sheltered habitats. Robinson and Thompson (1981) used such species (*Protothaca* spp. and *Saxidomus* sp.) in developing the correction factor. There is no full report available on the excavations conducted at SCR-7 by Morejohn in the early 1970s (although a short paper has been published [Morejohn 1976]), consequently we do not know the species of the shell used for the radiocarbon determination.
8. Recalibrated range: 8295-7415 years B.P.

subsistence implications of the forager-collector dichotomy. Also following Binford (1980), they described the hypothetical foraging strategy of the early culture as including:

seasonal residential moves among a series of resource patches, gathering of foods daily on an "encounter" basis with return to a residential base near the end of each day, no use of storage, a limited foraging radius around residential bases, considerable variability in the size of foraging groups and the number of residential moves made in a year, considerable variability in the redundancy of land use from year to year, and the possible occasional occurrence of extended resource procurement trips from residential bases [Dietz and Jackson 1981: 700].

The aforementioned dates for MNT-112 and -116 are associated with components representative of this early strategy.

In contrast, the later "collector" culture was described as "characterized by storage of food during part of the year, logistically organized resource procurement parties (labor groups) and the use of residential bases (permanent and seasonal), camps, locations, stations and caches" (Dietz and Jackson 1981:701). Nineteen sites excavated by Dietz and Jackson (1981), including those with early components and a portion of MNT-170 (Breschini and Haversat 1980) contained components representing this later culture and associated dates between 250 and 2500 B.P. Numerous sites in Monterey and Santa Cruz counties and the San Francisco Bay area date to this period and, in general, human occupation can be considered to have been well established in the central-coast region by 2500 B.P.

Archaeological studies undertaken in the immediate vicinity of Elkhorn Slough have been almost exclusively limited to survey, with early work done by Golomshtok (1922), Hill (1929), Wood (1930), and Pilling (1948). With the advent of cultural resource manage-

ment a number of additional surveys have been conducted, including those of Edwards and Farley (1974), Jackson, Holson, and Morris (1977), and King (1981). These and other works resulted in the recording of approximately 40 sites along the slough and the lower courses of the Pajaro and Salinas rivers. Excavations have been conducted to the south on the Monterey peninsula and to the north along the Santa Cruz County coast. A history of these excavations has been compiled recently by Lonnberg and Morris (1981). While Elkhorn Slough is situated on a flat, sandy coastline, most previous excavations have taken place in the steep, rocky shore areas. Until 1974, when two sites on the slough were excavated (see below), no subsurface investigations had been conducted in this environmental setting.

INVESTIGATION RESULTS

Palynology

Given the environmental history of Elkhorn Slough, we hypothesized that past vegetative communities (e.g., fresh-water river, fresh-water marsh, and salt-water marsh) would be readily detectable in a pollen profile from the slough. A soil column of 340 cm. was collected from the bank of the slough's upper reach and eight pollen samples were taken from the column. Pollen grains were extracted and analyzed by Pollen Research Associates, San Mateo, California. Stratigraphy and pollen from the column clearly reflected the most recent (1908) shift from a fresh-water to a salt-water marsh. The top 10 cm. consisted of brown clay that yielded 93% Cheno-Am pollen—the grouping which includes *Salicornia*. Below 10 cm. there was a distinct shift to a black, silty clay, which continued to a depth of 340 cm. This stratum exhibited a lack of Cheno-Am grains and a preponderance of fresh-water marsh species, including willow (*Salix* sp.) and several species of the Cyperaceae family. A *Eucalyptus* grain

was found at a depth of 340 cm. indicating that the time span represented by the column was no greater than 120 years, and that sediment accumulation during the fresh-water period was markedly greater than during the salt-water period. Although the results of the pollen analysis do not encompass a sufficient time depth with which to address prehistoric issues, they do show how a pollen profile can reflect hydrographic shifts, and provide a framework for future studies of deeper columns.

Archaeology

Our archaeological investigations were guided by the premise that molluscan assemblages in the sites at Elkhorn Slough represent the process of shifting human subsistence strategies necessitated by a changing environment. Fundamental factors influencing the natural distribution of molluscs are: (1) degree of wave shock; (2) type of available substrate—rock, sand, mud, or some combination of these; and (3) amount of tidal exposure (Ricketts and Calvin 1968). Temperature, salinity, and the chemical and nutritional nature of the medium further influence distribution. Thus each species is endowed with a "natural habitat of clearly defined nature" (Meighan 1971: 419). Because molluscs are generally confined to these very specific ecological conditions, their appearance in archaeological sites serves as a paleoecological indicator. That is, the overall assemblage of molluscan species in a site can indicate the nature of the environments from which they were collected (e.g., from the open coast, or from a protected estuarine environment). Differences in the nature of the assemblage throughout a site (e.g., between levels) or among sites in a given region may indicate fluctuations in local ecosystems through time and in corresponding shellfish consumption patterns.

The archaeological research began with a review of site survey records that aided in evaluating trends in cultural remains (particularly molluscan dietary debris), size and general nature of sites, and the location of sites in relation to hydrographic features. Excavation data were available for MNT-414 and MNT-415, two shell middens situated within 100 m. of each other on the west bank of the eastern branch of the slough (Fig. 1). Eleven 1 x 1-m. units with depths varying between 10 and 100 cm. at MNT-414, and two units 60 and 20 cm. deep at MNT-415 were excavated in 1974 by Rob Edwards and the Santa Cruz Archaeological Society. The results of these excavations were later reported by D. Gifford (1977) and Patch (1979). Shellfish data consisted primarily of percentages (by weight) of different molluscan species, which quantified the variable occurrences of those species within each site and between sites. The only typeable artifacts from the two sites were two Desert Side-notched projectile points of Monterey chert; one from the 10-20 cm. level of unit 47/32 at MNT-414 and the other from the surface of MNT-415.

For this study, radiocarbon dates (uncorrected for secular variation) of 5540 B.P. ± 160 , or 3590 B.C. (UCR-747), and 5200 B.P. ± 100 , or 3250 B.C. (UCR-1075), were obtained for two specimens of clam shell (*Protothaca* sp.) from the bottom level (90-100 cm.) of unit 52/62 at MNT-414. Because atmospheric mixing with water and the mixing between water masses is slow compared to more uniform ^{14}C activity in the atmosphere (from which dating standards are derived), radiocarbon calibrations from marine shell typically produce excessively old apparent ages (see Gillespie and Temple [1977] for a discussion of the "reservoir effect"). Compensation for this requires calculating ^{14}C activity of surface ocean water bicarbonates in the growth region of the site being dated, then comparison of the resultant

value to modern, terrestrial standard ^{14}C activity. The latter values are generally low along the central coast of California, but may be more significant for specimens from contexts like Elkhorn Slough, as restricted circulation and admixture of fresh water tend to impart a lowered ^{14}C content (Berger, Taylor, and Libby 1966).

Robinson and Thompson (1981) proposed a "reservoir" correction factor for radiocarbon dates on marine shell from the southern Pacific northwest coast. Using samples of *Saxidomus* spp. and *Protothaca* spp. (one of which was acquired from Monterey Bay), they derived a correction figure of -680 ± 15 years to be applied to central California marine shell dates. Although this correction factor was apparently intended for application to dates obtained from any species of marine shellfish, it appears to be valid only for species that resided in sheltered habitats (such as *Protothaca* spp. and *Saxidomus* spp., used in formulating the correction factor).

Data obtained by Dietz and Jackson (1981) from MNT-113 clearly show that a correction factor of -680 years is excessive when applied to specimens derived from exposed habitats. They obtained radiocarbon dates from a *Haliotis rufescens* shell filled with charcoal, the charcoal it contained, and from a *Mytilus californianus* shell (also found within the *Haliotis* shell)—all of which fell within 400 radiocarbon years of each other (Dietz and Jackson 1981: 702).⁵ Since the MNT-414 dates were obtained from one of the sheltered habitat species used by Robinson and Thompson (1981) to develop the correction factor, we have employed it as follows: 5540 B.P. ± 160 (UCR-747) is corrected to 4860 B.P. ± 160 ; and 5200 B.P. ± 100 (UCR-1075) is corrected to 4250 B.P. ± 100 .⁶

To augment previously gathered data, systematic surface collections of molluscan remains were made at another site situated on

the slough, MNT-698, in order to determine whether differences in shell assemblages existed among sites. Twenty-two surface collection units from this shell midden located on the eastern bank of the northeastern end of the slough (Fig. 1) indicated an assemblage similar to that reflected in excavation data from MNT-414 and -415. This surface assemblage was radiocarbon dated at 1760 B.P. ± 110 or A.D. 190 (UCR-796), from a sample of *Protothaca* sp. ("reservoir" corrected to 1080 ± 110 B.P.).

Most molluscs represented at sites MNT-414, -415, and -698 were estuarine forms that are found in the slough today. The four most well represented species were little-neck clam (*Protothaca* sp.), gaper clam (*Tresus nuttallii*), Nuttall's cockle (*Clinocardium nuttallii*), and bay mussel (*Mytilus edulis*). Table 2 shows the fluctuations in frequency (by weight) of these species from the surface to the lowest levels in the deeper units excavated at MNT-414 and -415. Most of the shell at MNT-414 was found between 10 and 30 cm. depth, while units excavated below 30 cm. at MNT-414 and -415 (one unit, 29/100, at the latter site) yielded more shell from the 30-60 cm. levels than from deeper levels (Tables 2-4). As shown in Tables 3 and 4, a general increase in the amount of shell (of all major species except *Tresus nuttallii*) occurred between 30-50 cm. in the deepest units of each site. At the 70-80 cm. level in unit 52/62 (MNT-414) and at the 30-40 cm. level in unit 29/100 (MNT-415), the amount of *Protothaca* sp. and *Clinocardium nuttallii* declined, while the amount of *Mytilus edulis* showed a sharp increase. Greengo's (1951) data from a single subsurface testing unit at MNT-229, situated near the mouth of Elkhorn Slough, showed similar trends although no time frame can be assigned to that assemblage.

Most of the molluscan species represented at MNT-414 and -415 are adapted to an estuarine habitat, and many can presently be

Table 2
UNIT-LEVEL QUANTITIES OF SHELL¹ (WEIGHT IN GRAMS)
RECOVERED FROM CA-MNT-414 AND -415²

	29/100	37/18	46/92	47/32	47/72	49/22	52/42	52/62	67/36	82/47	92/60	Total
0- 9 cm. ³	115.4	164.2	16.2	207.7	216.9	116.4	194.1	356.1	308.1	456.8	60.7	2212.6
10-19 cm.	175.2	547.6	21.5	229.6	544.0	*	188.9	636.0	473.0	361.5	*	3177.3
20-29 cm.	182.3	460.4	17.4	489.4	410.3	*	398.3	622.4	485.3	228.0	*	3293.8
30-39 cm.	239.1	601.9	*	*	703.8	*	*	1100.8	*	*	*	2645.6
40-49 cm.	215.1	588.4	*	*	635.2	*	*	1353.2	*	*	*	2791.9
50-59 cm.	57.0	855.5	*	*	*	*	*	1189.1	*	*	*	2101.6
60-69 cm.	*	377.4	*	*	*	*	*	1107.5	*	*	*	1484.9
70-79 cm.	*	*	*	*	*	*	*	1034.0	*	*	*	1034.0
80-89 cm.	*	*	*	*	*	*	*	651.6	*	*	*	651.6
90-99 cm.	*	*	*	*	*	*	*	330.2	*	*	*	330.2

1. Species includes *Protothaca* spp., *Clinocardium nuttallii*, *Mytilus edulis*, *Macoma nasuta*, *Tresus nuttallii*, *Tresus* and *Macoma*, *Ostrea lurida*, *Balanus* sp., and species unidentified.

2. Compiled from D. Gifford (1977), and Patch (1979). Table does not include shell weights for unit 70/94, the integrity of deposits in this unit was notably disrupted by gopher activity. Unit 29/100 is the only unit listed from MNT-415. Shell weights from unit 60/80, MNT-415, are not included because the unit-levels were incompletely excavated. The pedestal excavated around a rock cluster (labeled Feature 1) between 20 and 50 cm. in unit 29/100 at MNT-415 contained 46.7 gm. of shell. The shell tallies for levels 20-29 cm., 30-39 cm., and 40-49 cm. do not include shell weights from this pedestal.

3. Includes surface.

* Not excavated.

found in nearby mudflats. *Mytilus*, however, does not currently occur in the immediate vicinity of these sites. It is found along the rocky banks of the slough's lower reaches. Substrates more suitable to *Mytilus*' habitation probably existed in the slough near the sites during an earlier period in its development. As noted above, *Mytilus* appeared in greater quantities in the lower levels of the sites (at least in the units examined). If we postulate that the lowest levels of MNT-414 and -415 represent human occupation of the area during the early stages of Elkhorn Slough's development as an estuary, rocky basins scoured by the fresh-water stream that had previously filled the channel may have been more common here than mud flats. Thus, a more suitable habitat for mussels probably existed in the immediate vicinity, and this resource could have been conveniently collected by the site's inhabitants. As the estuary expanded, fill produced extensive mud flats better suited to forms like *Protothaca*, *Clinocardium*, and *Tresus*.

DISCUSSION

Environmental History

By combining the site shellfish data with geological history and palynology, the following historical/environmental sequence for Elkhorn Slough is evident:

1. Elkhorn Slough was originally a fresh-water river, cut by drainage of inland lakes during the Pleistocene;

2. At some point between the Pleistocene and the historic period, the channel was filled with salt water long enough for a well-developed estuarine ecosystem to be established, as evidenced by midden remains. All species of molluscs represented in the archaeological sites sampled were salt-water species, mostly of estuarine habitat. According to the dates on shell from MNT-414, -415, and -698, the estuarine community existed as early as ca. 4860 B.P. and as recently as ca. 1080 B.P. It may have remained intact until an even later date, given the occurrence of the two Desert Side-notched projectile points in

Table 3
CA-MNT-414: SHELL TOTALS (WEIGHT IN GRAMS)
BY SPECIES AND LEVEL¹

	<i>Protothaca</i> spp.	<i>Clinocardium</i> <i>nuttallii</i>	<i>Mytilus</i> <i>edulis</i>	<i>Macoma</i> <i>nasuta</i>	<i>Tresus</i> <i>nuttallii</i>	<i>Tresus and</i> <i>Macoma</i> ²	<i>Ostrea</i> <i>lurida</i>	<i>Balanus</i> sp.	Unidentified
0- 9 cm.	1159.1	289.1	59.5	27.4	208.6	98.1	18.9	2.0	234.5
10-19 cm.	1517.0	524.2	185.3	35.6	431.2	124.3	27.9	5.3	151.3
20-29 cm. ³	1346.2	482.1	174.0	35.9	244.2	199.0	22.7	5.2	112.8
30-39 cm.	1089.2	480.1	255.1	16.7	120.8	216.4	0	0	228.2
40-49 cm.	1094.5	529.7	414.3	0	88.2	245.9	0	0	204.2
50-59 cm.	1105.1	258.4	385.7	0	6.5	142.3	0	0	146.6
60-69 cm.	498.9	255.0	365.7	3.6	0.5	95.1	0	0	266.1
70-79 cm.	361.5	185.0	361.6	0	0	81.7	0	0	114.2
80-89 cm.	196.0	141.5	199.4	42.5	0	0	0	0	72.2
90-99 cm.	112.3	35.0	91.0	0	58.3	0	0	0	33.6

1. Compiled from D. Gifford (1977). Table does not include shell weights for unit 70/94 (see note 2, Table 2).

2. This category was established during analysis to accommodate shell specimens that could not be clearly distinguished as one or the other form—*Tresus nuttallii*, or *Macoma nasuta*. Non-beak fragments of these two species are very similar.

3. Shell from the 20-29 cm. level of unit 47/32 was not sorted. Species tallies for this level do not include materials from that provenience.

Table 4
CA-MNT-415: SHELL TOTALS (WEIGHT IN GRAMS)
BY SPECIES AND LEVEL¹

	<i>Protothaca</i> spp.	<i>Clinocardium</i> <i>nuttallii</i>	<i>Mytilus</i> <i>edulis</i>	<i>Macoma</i> <i>nasuta</i>	<i>Tresus</i> <i>nuttallii</i>	<i>Tresus and</i> <i>Macoma</i> ²	<i>Ostrea</i> <i>lurida</i>	<i>Balanus</i> sp.	Unidentified
0- 9 cm.	55.7	36.7	6.5	1.1	4.9	10.0	0	0.2	0.5
10-19 cm.	70.2	45.8	17.0	0.8	29.5	11.3	0	0	0.6
20-29 cm.	71.9	31.8	24.8	8.0	32.5	10.8	0	0.3	2.2
30-39 cm.	50.3	42.2	87.3	0	20.1	38.1	0	0.4	0.7
40-49 cm.	58.4	40.6	76.5	4.8	26.3	7.8	0	0.2	0.5
50-59 cm.	22.1	14.2	12.7	0	5.2	2.7	0	0.1	0

1. Compiled from Patch (1979). Shell totals for unit 60/80 not included (see note 2, Table 2).

2. See note 2, Table 3.

the upper levels of MNT-414 and -415 that date to between A.D. 1300 and A.D. 1700 in other parts of the state (Baumhoff and Byrne 1959);

3. At a later time, the slough became a fresh-water lagoon, connected to the Salinas River, as described by early historic documents and indicated in the pollen profile;

4. Between 1908 and 1910, the slough was again filled with salt water and established as an estuary when the Salinas River shifted course, as historically documented and indicated in the pollen profile. In addition to these fluctuations, it is highly probable that

movements along the San Andreas fault, and/or meanders of the Pajaro and Salinas Rivers, imposed additional changes. Short-term periods of fresh-water infusion probably occurred at various intervals during the course of slough development.

Human History

What, then, were the effects of paleoenvironmental shifts at Elkhorn Slough on local prehistoric human populations, and how can they be recognized archaeologically? We proposed the following chronology of cultural events.

Available data suggest that humans may have entered the central coast region as early as 8,000 to 9,000 years ago when the slough was still primarily a fresh-water drainage. Many other California sites that date to this period (e.g., Borax Lake, Tulare Lake, and Buena Vista Lake sites) indicate a lacustrine adaptation with a probable emphasis on hunting (Fredrickson 1974; Fredrickson and Grosman 1977). People infiltrating the coastal areas, including the central coast region around Elkhorn Slough, would presumably have continued such an adaptive strategy. Sites occupied during this era would have been most efficiently located inland rather than on the immediate coast, in order to accommodate a subsistence strategy in which terrestrial resources were emphasized. The SCR-177 and SCL-178 sites may represent such a lifeway. Shellfish were probably included in the diets of people who occupied these sites to a minor degree, as suggested by the relatively low frequency of shellfish remains in the lowest component of SCL-178 (Hildebrandt 1983: 8-111). No shellfish remains were recovered from SCR-177, the Scott's Valley site (Cartier 1984). It should be noted, however, that preservation was extremely poor at the latter site and recovery of all types of faunal material was very limited.

The rapid rise in sea level, which was completed by 7000 B.P., inundated the mouth of Elkhorn Slough with salt water. As salt-water infusion continued, and changes in local drainage patterns decreased the flow of fresh water into the channel, a suitable environment for estuarine species developed. In the early stages of the estuary, shellfish species such as *Mytilus edulis* and *Ostrea lurida* which prefer denser clay or rock substrates, would probably have predominated until sufficient sediments accumulated to suit burrowing species like *Tresus nuttallii*, *Protothaca staminea*, and *Clinocardium nuttallii*. Thus the region's earlier human inhabi-

tants would have had different shellfish species available to them, depending on the time of their entry.

Simple availability of shellfish would not necessarily have dictated their exploitation. Other processes must have operated to encourage adoption of a general marine resource utilization strategy in the Monterey Bay area. Although he was referring to an open coast situation, Osborn (1977) argued that marine food resources are, in general, inferior to terrestrial resources in terms of caloric yield versus human labor investment. Earlier, Gould (1964) made similar observations about estuarine resources. According to this viewpoint, aquatic resources would only be exploited when the terrestrial resource base was depleted as a result of intermittent environmental stress or when over-exploitation occurred as a result of human population growth. Yesner (1980) proposed an alternative view. He noted that although the overall biomass of oceans is lower than the terrestrial environment, coastal zones are highly productive; particularly estuaries and upwelling zones. Further, while marine foods are generally low in caloric yield, they supply an adequate protein complement and are high in important nutrients, especially calcium. Also, shellfishing is a highly efficient strategy because costs are low. It requires no specialized or elaborate technology, food sources are highly concentrated, and it allows a low dependency ratio because all members of the group can participate (Yesner 1980). Yesner (1980: 734) suggested that maritime procurement strategies became fully operative throughout the world during the Holocene as a consequence of the "push and pull" of changing environments. Holocene climatic changes imposed pressure on inland resources and forced human groups to orient food-getting activities closer to the coast. Sea-mammal hunting may have pre-dated intensive shellfishing and introduced humans to a maritime lifeway. As

coastlines stabilized geologically, the resource base expanded and shellfishing became a viable economic pursuit. With subsequent population growth, this strategy was intensified and groups were ultimately locked into a maritime lifeway.

The overall reduction in land area following the Holocene sea-level rise undoubtedly imposed on central California groups a type of stress akin to that outlined by Yesner (1980). Settlement locations and territorial boundaries would have been required to shift almost generationally as an increasing expanse of terra firma was lost to the encroaching sea (Bickel 1978: 8). Radiocarbon dates on shellfish remains from MNT-414 indicate that slough resources were being utilized by 4860 B.P., and that an at least partially sandy-bottomed estuary must have been developed there by that time. The success of an earlier, terrestrial-based adaptive strategy may have brought the region's population close to the carrying capacity (cf. Glassow 1978) of that resource sphere, or rendered maintenance of that lifeway too costly. In-migration of new groups may have added further stress. The cost-effective strategy of shellfish collection provided a useful supplement to the subsistence base. A developing salt marsh at Elkhorn Slough would have provided a substantial habitat for bird life, giving the area still greater potential for food sources.

The molluscan assemblage at MNT-414 may reflect the maturation of Elkhorn Slough as an estuary, as well as related changes in patterns of resource utilization. Similar changes are reflected in shell middens in the San Francisco Bay area (Greengo 1951; Gerow with Force 1968; Bickel 1978), although Elkhorn Slough differs from the Bay area in that it has probably been subjected to more drastic fluctuations in environmental regimes.

As population growth continued in the central coast region, demographic stress would have warranted still more intensive

exploitation of shellfish, necessitating increased sophistication of procurement strategies (e.g., the later "culture" defined by Breschini and Haversat [1980] and Dietz and Jackson [1981]). An influx of new peoples at this time (as suggested by Breschini 1980, 1983) would have compounded the effects of local population growth, and may indeed have been a catalyst for accelerated change. The new strategy may have included establishment of shellfish processing stations on the immediate coast around the mouth of Elkhorn Slough, on the Monterey peninsula, and on the northern Santa Cruz County coast. The increase in overall shellfish remains between 30 and 60 cm. depth in unit 29/100 at MNT-414 may represent such increased exploitation, while the shift in dominant species indicates development of the mud-flat habitat (Fig. 3).

Estuarine shellfish exploitation continued in the Elkhorn Slough vicinity through 1080 B.P., as indicated by the radiocarbon date on shellfish remains from MNT-698, and probably as late as A.D. 1300-1700, based on the time-span of Desert Side-notched projectile points (Baumhoff and Byrne 1959: 60).

In 1769, Fr. Juan Crespi of the Portolá expedition described Elkhorn Slough in his diary as a branch of the Salinas River (Bolton 1927: 201). Thus at some point between A.D. 1300 and 1769, a shift in hydrography occurred, returning Elkhorn Slough from an estuary to its original fresh-water environment—an incident that may have taken place at other times since initial development of the estuary. Estuarine shellfish exploitation sites such as MNT-414 and -415 were probably abandoned when the estuarine regime was altered by the shift in the river's course, as indicated in unit 29/100 at MNT-414 by the marked decrease in shell above 30 cm. depth (Fig. 3). While the loss of shellfish resources undoubtedly forced changes in food procurement strategies and quite probably in the

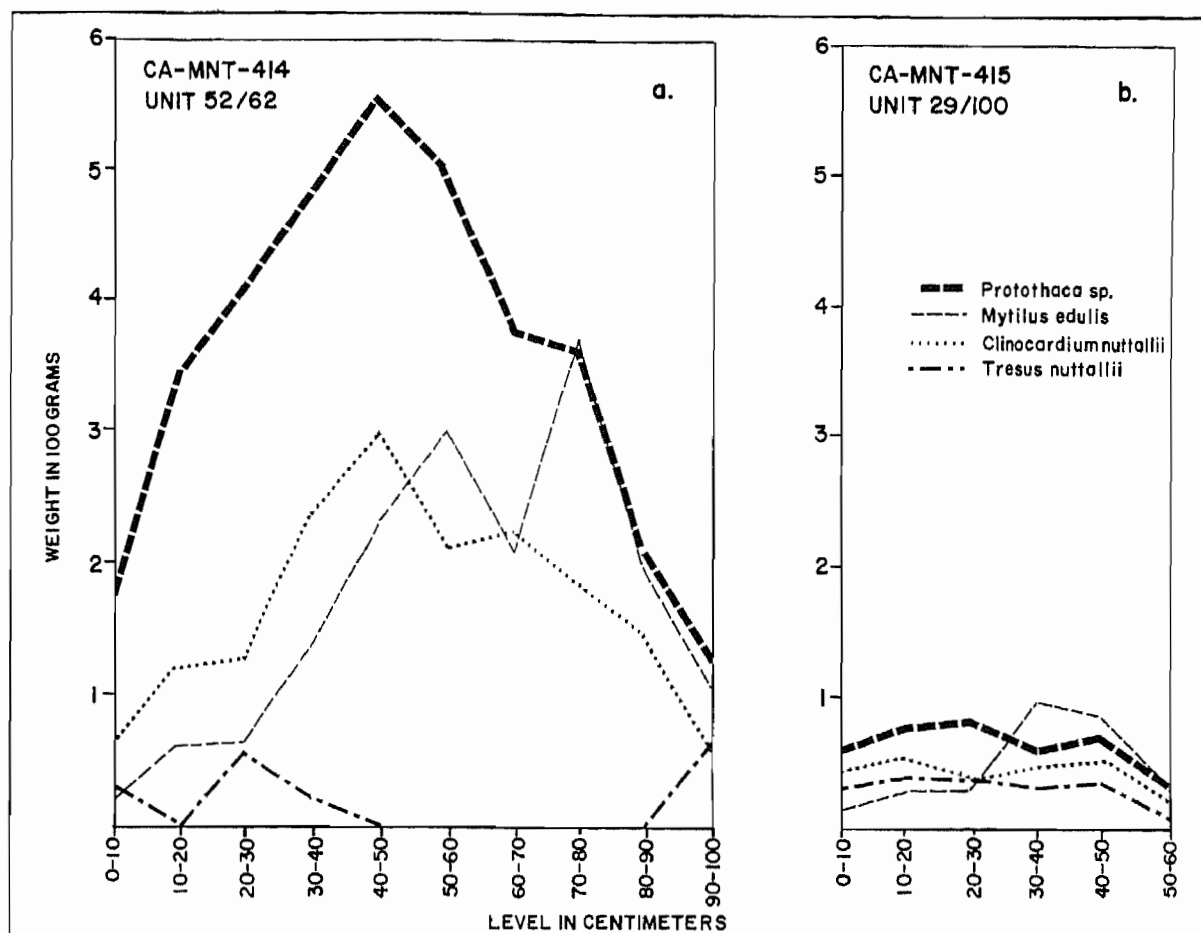


Fig. 3. Shellfish remains recovered from two representative units at MNT-414 and -415.

distribution of local populations, it apparently did not result in crisis. Fr. Crespi noted that Costanoans were present in the immediate slough vicinity at the time of the Spanish expedition, from which we can infer that local, non-estuarine resources were exploited during fresh-water phases.

SUMMARY AND CONCLUSIONS

The archaeological sites at Elkhorn Slough do not reflect intense exploitation of shellfish over the last 6,000 years. Harvest of slough shellfish was probably first necessitated by population increase, as one of many resources exploited through a broad-based, non-

specialized adaptive strategy, similar to the "foraging" strategy described by Breschini and Haversat (1980) and Dietz and Jackson (1981) for the Monterey peninsula. MNT-414, which probably first functioned as a "location or low bulk procurement site" (Binford 1980: 9; Dietz and Jackson 1981: 669) visited by small groups of foragers for short periods of time (as indicated by the low density of artifacts and shell in the lower, older portion of the site), may be representative of this strategy. As Elkhorn Slough's hydrography changed and habitats were altered, people were forced to adjust the amounts of different species being exploited. This adjustment is

reflected in intrasite vertical/temporal fluctuations in shellfish species percentages.

Perhaps due to additional population pressures, exploitation of the resource increased, although it was probably never used as a staple or truly "marketed" item. Rather, shellfish supplemented a varied diet when hydrographic conditions rendered them available. The amount of shellfish remains at MNT-414 did increase through time, however, indicating that exploitation of the resource was intensified. Whether this means that the site became more of a specialized collecting and processing station as part of an adaptive strategy similar to that of the later "collector" culture on the Monterey peninsula (Breschini and Haversat 1980; Dietz and Jackson 1981) remains unclear. Shell density in the Elkhorn Slough middens never reached the magnitude of later occupations on the Monterey peninsula or in the San Francisco Bay area. Hydrographic changes, which periodically altered slough habitats and shellfish populations, would have provoked greater use of non-aquatic resources. A more fluid overall subsistence strategy probably existed at Elkhorn Slough throughout prehistory as a product of a fluctuating environment, allowing some targeting on specific resources, but preventing over-reliance on any one item.

FUTURE WORK

Because Elkhorn Slough has clearly had a varied hydrographic history we have invoked environmental change to explain horizontal and vertical differences in molluscan assemblages in archaeological sites. Changes in the relative frequencies of certain species through time may also reflect fluctuating exploitation patterns, including changing preferences for certain species and over-use or exhaustion of one species with consequent replacement in the ecosystem and subsistence strategy with another. Human over-use could have accentuated the natural population de-

cline of various species (cf. Botkin 1980). In order to more precisely define the relationship between past Elkhorn Slough environments, its resources, and their utilization by aboriginal populations, future work should include: (1) deeper, temporally controlled pollen columns defining the slough's environmental history; (2) determination of the seasonality of collecting activities to assess variations in intensity of exploitation through time (Weide 1969; Shackleton 1973; Drover 1974; Killingley 1981; but see comments by Koerp-er [1980], Baily et al. [1983], and Killingley [1983] for problems with the methods used in making seasonality determinations); (3) chemical analyses of soil samples to determine the extent of shell disintegration and to compensate for taphonomic bias in shell tallies (Koloseike 1968, 1969); (4) examination of changes in intensity of exploitation through differences in shell size averages (Strauss et al. 1980); (5) examination of differential deposition of certain parts of the endo- and exo-skeletons of intertidal organisms that may be indicative of processing for storage and/or trade as suggested by Layton (1982); (6) attempts to obtain better temporal control of midden assemblages through establishment of a central coast estuarine shell radiocarbon correction factor, dating of non-shell midden constituents, and use of other dating methods (e.g., obsidian hydration when obsidian is present); and (7) quantification of energy expenditure versus food yield values for various shellfish species, to determine the role of such factors in selection of exploited species.

Multiple group migrations into the central coast region may have played a role in population growth, consequent initiation of shellfish harvesting, and eventual increases in shellfish exploitation. Expansion of the resident population may also have resulted from internal growth promoted by the initial addition of shellfish to the subsistence system. In

order to substantiate hypothetical central coast linguistic group movements, so that the distinction between *in situ* population growth and migration-induced growth can be recognized, future research must also focus on the local cultural historical sequence. Such work should focus on artifact styles, archaeological manifestations of ethnolinguistic boundaries and trade networks, as well as a number of other subjects. Finally, shifts in the nature of subsistence strategies (e.g., from "forager" to "collector") cannot be substantiated until further data are available regarding duration of residence in the sites discussed and settlement patterns for the region as a whole. Ultimately, synthesis of these various lines of inquiry should lead to a regional model of Monterey Bay area prehistory that incorporates human response to changing environments, and which is applicable to other areas with similar environmental settings.

NOTES

1. Twenty-eight obsidian samples were sourced for geologic origin and measured for hydration band thickness. Of these, twenty-one were derived from the Napa Glass Mountain source. Two of the Napa specimens exhibited diffuse hydration, leaving nineteen with readable bands. Band thickness ranged from 4.3 to 8.0 microns. Average band thickness for the Napa specimens was 5.7 microns and the mean was 6.2 microns (Origer 1984: 11). Origer (1982) proposed a hydration rate for Napa obsidian recovered in Marin and Sonoma counties that converts microns into years. According to his formula, the Scott's Valley site obsidian hydration data suggest human occupation from 2836 to 9817 years B.P. This conversion is given only for the purpose of comparison, since ultimately a regional obsidian hydration rate must be established. However, climatic differences between Scott's Valley and Sonoma County are not so great that an occupation span between 4000 and 8000-9000 years B.P. would be unreasonable for SCR-177.

2. Four cultural components were defined at SCL-178: I—10,000 to 5000 B.P.; II—5000 to 3000 B.P.; III—3000 to 1000 B.P.; IV—post-1000 B.P. The lower components correspond fairly well with the

buried "A" soil horizons, which suggests stratigraphic integrity. However, there are problems with horizontal relationships between components (Hildebrandt 1983: 8-50).

3. Eighteen pieces of obsidian were recovered from this site during the course of testing (Dietz 1977) and final excavation. Twelve were sourced for geologic origin, and three were subjected to obsidian hydration measurement. Of the latter three specimens, one (from the deepest portion of the site) showed no hydration. The remaining two (both of Napa obsidian, found above 90 cm. depth) had rim values of 1.54 and 1.93 microns.

4. Although unrecognized by the authors, one artifact recovered from the lower depths of the site (300 cm.) supports the radiocarbon dating. Specimen No. 4307, a wide, side-notched projectile point of Franciscan chert, is a type that has been recovered from all sites with dates in excess of 8000 years B.P. in San Luis Obispo County (cf. SLO-2, Greenwood [1972]; SLO-877, Breschini and Haversat n.d.a; SLO-177, Pierce [1979]; see Table 1).

5. These radiocarbon dates, which were obtained from MNT-113, were as follows: *Haliotis rufescens*, 550 B.P. ± 100 (RL-838); *Mytilus californianus*, 660 B.P. ± 100 (RL-840); and charcoal, 260 B.P. ± 100 (RL-839) (Dietz and Jackson 1981: 341)

6. No other radiocarbon dates from Monterey or Santa Cruz county sites have been derived from the appropriate species, therefore we have made no further corrections. One attempt has been made to correct two dates from SCR-7, but it is unclear whether or not the factor should be applied to those samples (see Table 1, Note 7).

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