

EARLY COASTAL SUBSISTENCE PATTERNS IN CENTRAL CHILE: A SYSTEMATIC STUDY OF THE MARINE-INVERTEBRATE FAUNA FROM THE SITE OF CURAUMILLA-1

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Curaumilla-1 presents the earliest date for Archaic coastal occupation and marine exploitation in central Chile (8,500 years B.P.). The remains of marine invertebrates from this site at Punta Curaumilla were studied. The number of present species, minimum number of individuals for 14 species, and mean sizes of two of these species were established. Recent studies have demonstrated that modern shellfish gatherers are important modifiers of rocky-intertidal communities in central Chile. Consequently, we attempt here to define the probable ecological role of past people at Punta Curaumilla as shellfish gatherers. The molluscan species present at Curaumilla-1 are much the same as those exploited at present by shellfish gatherers in central Chile. Two pulses of occupation were identified within the Archaic and Early Ceramic periods respectively. During these events it is likely that Precolumbian people may have temporarily or permanently modified sectors of the rocky intertidal at Punta Curaumilla.

El sitio de Curaumilla-1 presenta la fecha más temprana de ocupación costera durante el Período Arcaico y de explotación marina en Chile central (8500 años A.P.). Los restos de invertebrados marinos de este sitio en Punta Curaumilla fueron estudiados. Se estableció el número de especies presentes, el número mínimo de individuos en 14 especies y la talla promedio de dos de estas especies. Estudios recientes han demostrado que en el presente los mariscadores son importantes modificadores de las comunidades marinas del intermareal rocoso de Chile central. Por consiguiente, en este trabajo intentamos definir el posible papel ecológico de la población indígena precolombina como mariscadores de orilla en Punta Curaumilla. Las especies de moluscos presentes en Curaumilla-1 son casi las mismas especies explotadas en el presente por mariscadores en Chile central. Dos marcados episodios de ocupación fueron reconocidos en cada uno de los períodos Arcaico y Cerámico Temprano respectivamente. Durante estos eventos, es muy posible que grupos humanos precolombinos hayan modificado temporalmente o permanentemente sectores del intermareal rocoso en Punta Curaumilla.

In Chile, the collection of marine invertebrates for human consumption can be traced back to hunter-gatherers who inhabited the northern part of the country during the Archaic Period, ca. 9,000 years ago (Llagostera 1979a). A great number of shell-midden sites along the Chilean and Peruvian coast provide evidence of such activity. These deposits are primarily composed of the shells of mollusks in association with other remains of subsistence activities, as well as with artifacts that define each cultural episode.

There are, however, few studies of Chilean shell middens. Some of these studies characterize the archaeology and cultural sequence of different regions (Berdichewsky 1964; Niemeyer and Schiappacasse 1977; Schiappacasse and Niemeyer 1964; Seguel 1969), while others present numerical data on molluscan fauna and estimations of human population density (Niemeyer and Schiappacasse 1969), and analyses of fish-otolith assemblages as bioindicators of changes in the water regimes of the southern Pacific (Llagostera 1979b) or as evidence of dietary preferences (Bravo 1985).

Researchers working on the Peruvian coast explain the shifts in molluscan species composition in the shell middens as a consequence of geomorphological changes in the shoreline (Sandweiss et

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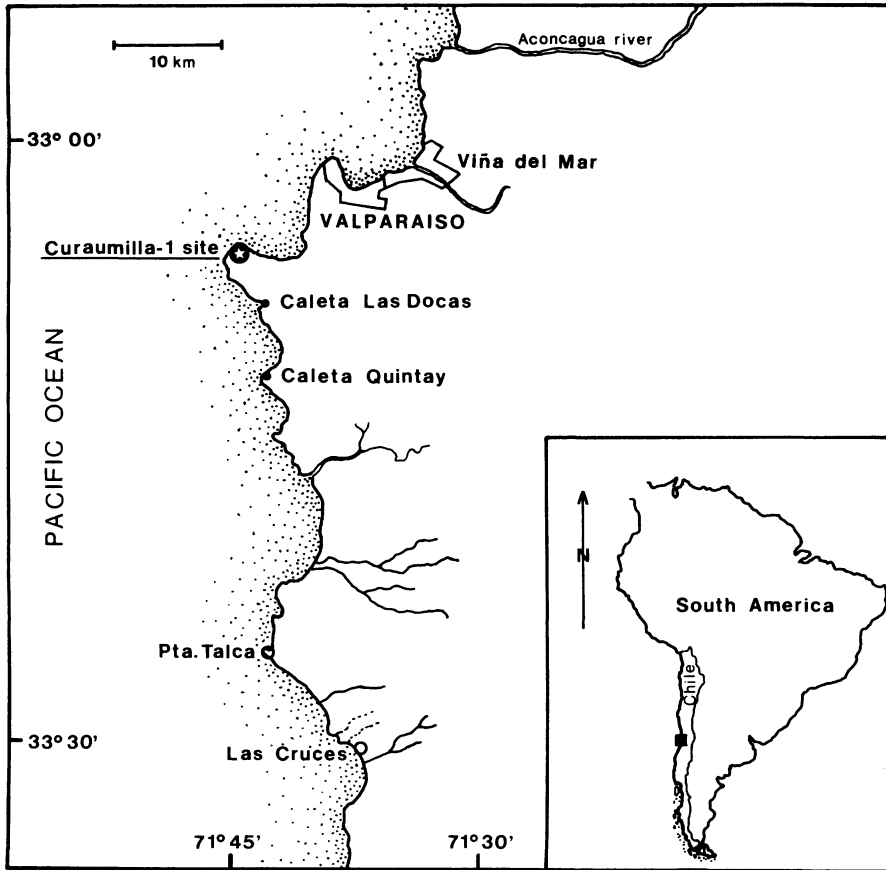


Figure 1. Geographical location of Curaumilla-1 site and nearby towns.

al. 1981, 1983). Such shell-midden studies have been complemented with geological observations that have revealed the earliest evidence (dated around 5000 B.P.) of the present oceanographic and climatic conditions of the southern Pacific area, including the El Niño phenomenon (Rollins et al. 1986). In Peru the date of 5000 B.P. marks the approximate beginning of early marine-adapted societies that find later expression in the foundations of Andean civilization (Moseley 1975; Moseley and Feldman 1988).

Recent studies of the marine ecology of littoral zones have demonstrated that humans are currently a key component in the community structure and dynamics of modern marine rocky-intertidal zones at diverse latitudes (Castilla and Bustamante 1989; Castilla and Durán 1985; Catteral and Poiner 1987; Durán et al. 1987; Hockey and Bosman 1986; Moreno et al. 1984, 1986; Oliva and Castilla 1986; Ortega 1987; Siegfried et al. 1985). Rocky-intertidal marine communities are complex systems, integrating different types of organisms. The presence or absence of a species and its local abundance is determined by physical factors such as temperature, salinity, humidity, and wave exposure; and by biotic factors such as predation, competition, and parasitism (see McQuaid et al. 1985). At present, in the case of the Chilean central coast, human shellfish gatherers prey with high efficiency and selectivity on a great variety of rocky-intertidal species, thus greatly modifying the marine communities that are present in those sites (Castilla and Bustamante 1989; Castilla and Durán 1985; Durán and Castilla 1989; Durán et al. 1987; Oliva and Castilla 1986).

We present here the first results of an interdisciplinary study of an archaeological site on the central Chilean coast. We analyze several variables for the marine-invertebrate fauna such as number

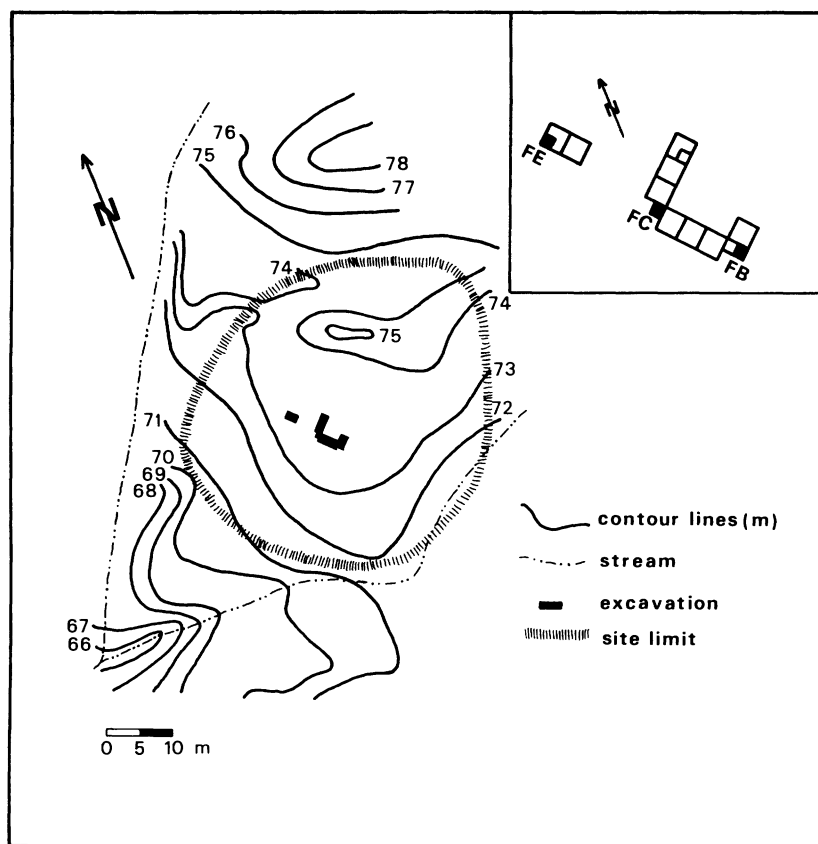


Figure 2. Punta Curaumilla shell midden: Site plan and location of faunal pits.

and abundance of species, and size structure in relation to the occupational sequence. In addition, we present a synthesis of the cultural content of the study site and a discussion from an ecological perspective of the possible role played by Precolumbian people in marine rocky-shore ecosystems.

GEOGRAPHIC LOCATION AND CHARACTERISTICS OF THE CURAUMILLA-1 SITE

The present study is based on material from excavations at the coastal archaeological site of Curaumilla-1 (33°06'S, 71°44'W), situated adjacent to the rocky littoral of central Chile. The rocky shore stretches along 9.5 km (Figure 1) with abrupt cliffs and sections of steep rocks.

The geomorphological history of the coast in central Chile indicates that ca. 8,000 years ago sea level was between 15 and 20 m below the current level (Caviedes 1972). As present interglacial conditions became established, sea level rose gradually, reaching an altimetric maximum of 5 m over the present level during the climatic optimum at 6,000–4,000 years B.P. Since then, small fluctuations in sea level have been recorded (Castilla 1988). Mollusk shells and remains of marine-vertebrate bones found at Curaumilla-1 (this paper and Ramírez et al. 1991) indicate that the site has overlooked a rocky shore since at least 9,000 years ago.

Curaumilla-1 presently lies 750 m from the shore and 70 m asl. It encompasses an area of 2,400 square meters and is bounded to the north and south by two gullies with small permanent streams (Figure 2). Remnants of the native flora are found in these small ravines and their surroundings. The vegetation, called coastal matorral, is characterized by tree species such as *Cryptocarya alba*,

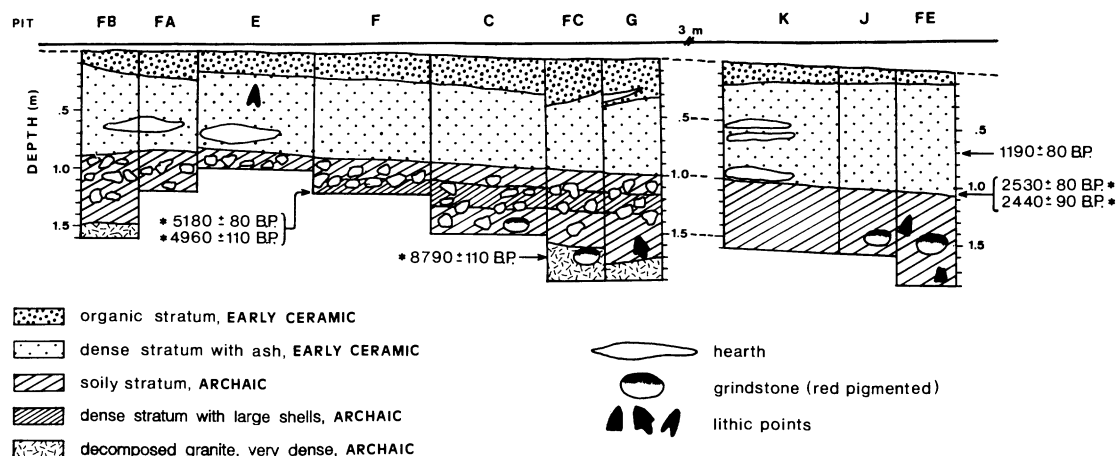


Figure 3. Stratigraphic sections of one segment of the excavation at Punta Curaumilla site (* = uncorrected radiocarbon dates for apparent age of sea water on shell samples, see text).

Peumus boldus, *Lithraea caustica*, *Pouteria splendens*, *Myrceugenia rufa*, *Citronella mucronata*, and bushes such as *Baccharis concava*, *Fuchsia lycioides*, *Chusquea cumingi*, and *Podantus ovatifolius*. However, according to local 1:10,000 aerial photographs, about 90 percent of the surface area of Punta Curaumilla area is currently covered by pine trees. There is a small island (Islote Lobos) 200 m offshore, where sea lions (*Otaria byronia*) can currently be observed year-round. On other small nearshore islands a number of sea birds, such as penguins (*Spheniscus humboldti*) and pelicans (*Pelecanus* spp.) can be found.

The rocky-intertidal area of Punta Curaumilla (Guiler 1959) is abundant in marine resources, such as macroalgae, shellfish, and coastal fishes. At present the shore of Punta Curaumilla presents difficult access to shellfishers, but nonetheless some species are exploited for human consumption and trade.

MATERIALS AND METHODS

A total of nine 1-m² quadrats was laid out in two areas in the denser part of the midden and excavated in arbitrary 10-cm levels (Figures 2 and 3). In order to carry out a more detailed study of the marine-invertebrate remains found in the shell midden, another five pits (referred to here as "faunal pits") of .5 m² extent were excavated down to bedrock, in arbitrary 10-cm levels. All material was sieved through two stacked screens of 6 mm over 3 mm. We consider in this preliminary study the marine-invertebrate remains from three of the five faunal pits (pits FB, FC, and FE).

Marine invertebrates were identified to genus and species level by means of taxonomic keys (Antezana et al. 1965; Keen 1971; Mc Lean 1984; Marincovich 1973; Osorio et al. 1979). The minimum number of individuals (MNI) present at each level was determined for 14 identified species: *Concholepas concholepas* (locally named "loco"), all the species of the genus *Fissurella* (key-hole limpets), and all the species of the family Chitonidae (chitons). The following criteria were applied to determine the presence of one individual: (a) for loco, presence of umbo; (b) for limpets, shells retaining the complete apical foramen; and (c) for chitons, the first and eighth articular plates are morphologically distinct from the others and were diagnostic for each of the chiton species. The plate represented in greatest numbers determined the minimum number of individuals. In the case of the sea urchin *Loxechinus albus* and the mussel *Perumytilus purpuratus*, shells were highly fragmented, making it difficult to apply such criteria. The weight of sea-urchin tests (external skeleton) and the weight of mussel fragments were determined at each level.

All measurements on shells were done with calipers. For complete shells, total length was mea-

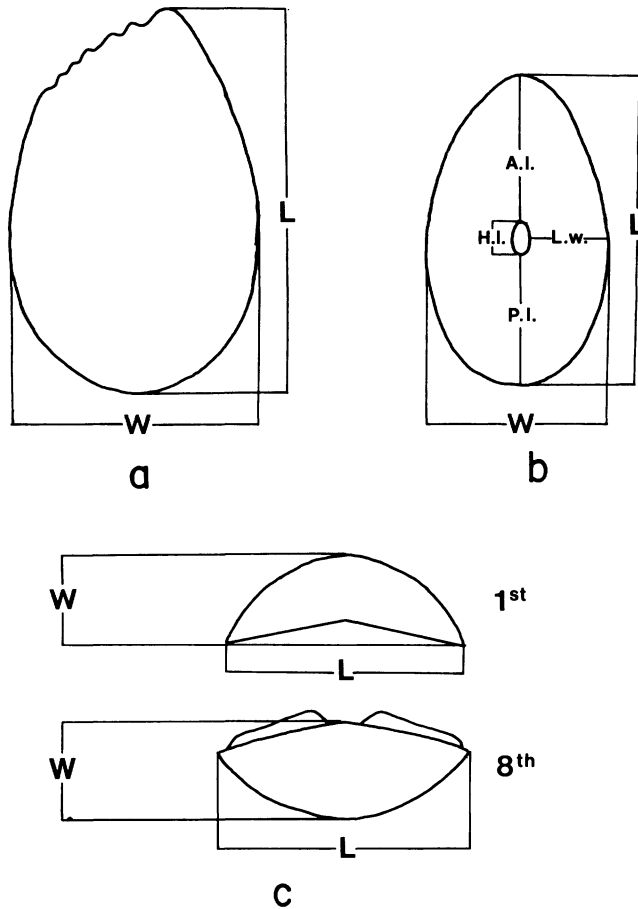


Figure 4. Morphometric measurements carried out in shells of (a) loco (ventral view); (b) key-hole limpets (dorsal view); (c) first and eighth chiton plates (dorsal view). L = length; W = width; A.I. = anterior length; P.I. = posterior length; L.w. = lateral width; H.I. = apical foramen length.

sured, while in the case of broken shells other measurements were established when possible. For loco the width (Figure 4a) was measured, for limpets the total width as well as distances from the apical foramen to the anterior and posterior ends as well as the lateral border, and length of the apical foramen (Figure 4b) were measured, and for chitons the length and width of the first and eighth plates were determined (Figure 4c).

To determine the mean sizes of loco, key-hole limpets, and chitons per level in each of the faunal pits when dealing with broken shells, we used existing regression equations for locos and limpets (Castilla and Jerez 1986; Oliva and Castilla 1992). Other equations (Table 1) were established with chitons from modern samples collected near Las Cruces (33°13'S, 71°88'W) and Punta Talca (33°25'S, 71°39'W) (Figure 1). In order to obtain accurate estimations of sizes we only employed those measurements for which the associated equation presents a coefficient of determination (r^2) equal or greater than .70.

To compare the mean sizes of shellfish species found in each level, we used a model of analysis of variance (ANOVA) that considered the mean size as a dependant variable and the levels as a source of error (Sokal and Rohlf 1981). The ANOVA were conducted with the Statistical Analysis System package (SAS INSTITUTE, INC. 1985). In the case of mean percentages, the arcsin transformation was used (Sokal and Rohlf 1981).

Table 1. Parameters of Morphometric Equations for Estimations of Size of Four Chiton Species from Measurements Conducted on Plates.

	<i>C. granosus</i>	<i>C. latus</i>	<i>A. echinata</i>	<i>Tonicia</i> spp.
1st-plate length	$a = 3.134$ $b = 1.010$ $r^2 = .917$	$a = 1.678$ $b = 1.258$ $r^2 = .765$	$a = 4.310$ $b = 1.085$ $r^2 = .753$	$a = 4.108$ $b = .985$ $r^2 = .889$
1st-plate width	$a = 7.575$ $b = .865$ $r^2 = .462$	$a = 5.586$ $b = 1.039$ $r^2 = .885$	$a = 5.882$ $b = 1.210$ $r^2 = .785$	$a = 8.018$ $b = .933$ $r^2 = .922$
8th-plate length	$a = 3.205$ $b = .957$ $r^2 = .900$	$a = 2.169$ $b = 1.049$ $r^2 = .896$	$a = 4.975$ $b = 1.025$ $r^2 = .708$	$a = 4.594$ $b = .859$ $r^2 = .932$
8th-plate width	$a = 7.092$ $b = .831$ $r^2 = .881$	$a = 8.474$ $b = .781$ $r^2 = .780$	$a = 7.407$ $b = 1.020$ $r^2 = .796$	$a = 7.560$ $b = .854$ $r^2 = .925$

Note: Standard equation $Y = (a \cdot X)^b$; size of individuals measured in cm.

STRATIGRAPHY, DATES, AND CULTURAL BACKGROUND

At Curaumilla-1 different occupational horizons were identified in a generally compact and dense shell matrix. Despite poorly represented cultural remains, three periods can be identified within this matrix, namely: an Early to Mid-Archaic (1.4–1.7 m in depth), a Late Archaic (1.0–1.4 m in depth), and an Early Ceramic (0–1.0 m in depth) (Ramírez et al. 1991).

Early to Mid-Archaic

The first occupation debris was laid on decomposing granitic bedrock. One sample of loco shell found at a depth of 1.65 m gave a date of $8,790 \pm 110$ years B.P. (Beta-22.886) (corrected for the apparent age of sea water [Taylor and Berger 1967] to 8550 B.P.) (Table 2). This is the earliest date for Archaic coastal occupation in central Chile. Dates for the Archaic from other sites are scarce. The inland site of Cuchipuy ($34^{\circ}29'S$, $71^{\circ}07'W$) is dated to 8070 ± 110 B.P. (Kaltwasser et al. 1983), while the nearby site of Tagua-Tagua has a date of 6130 ± 115 B.P., falling within the Middle Archaic period (Montané 1969). The coastal site of El Peral, adjacent to the locality of Las Cruces (Figure 1), yielded a date of $3,540 \pm 160$ years B.P. for one of the first floors of archaic occupation (Fernanda Falabella, personal communication 1989).

At Curaumilla-1 the stone-tool assemblage associated with the Archaic is characterized by stemmed projectile points and spheroidal grindstones ("handstones") (Figure 3). The stemmed points may have been used as spear tips in hunting sea lion (*Otaria byronia*), the remains of which were abundant

Table 2. Radiocarbon Dates of Curaumilla-1.

Sample Number	Material	Depth (m)	Date (B.P.)	Corrected Age (B.P.)
Beta-22.886	shell	1.65	8790 ± 110	8550 ± 110
Beta-25.585	shell	1.25	5180 ± 80	4950 ± 80
I-15.266	shell	1.25	4950 ± 110	4720 ± 110
Beta-22.887	charcoal	1.00	2810 ± 110^a	—
Beta-25.586	shell	.90	2530 ± 80	2290 ± 80
I-15.265	shell	.90	2440 ± 90	2200 ± 90
Beta-22.888	charcoal	.70	1190 ± 80	—

^a Unreliable date (see text).

in the deposits. Some of the lithic raw materials (flint and fossilized wood) are of a better quality than locally available quartz and may have come from the interior. Heavy spheroidal handstones (10-cm diameter) are the most common lithic tool. Although they may have been used for battering and grinding plant foods, five of the six unbroken handstones were impregnated with red pigment. Similar colorants were used by Archaic hunter-gatherers in burial rituals, as has been noted at the central Chilean sites of Las Cenizas and Cuchipuy (Gajardo 1957–1958; Kaltwasser et al. 1980). No burials were found at Curaumilla-1, but ground pigments could have been prepared on site and used as body paint.

Late Archaic

This period is represented by a thick and dense layer of large loco and limpet shells, associated with angular rock fragments and the bones of sea lions. The matrix is dark brown and soily (Figure 3). Sea-lion hunting evidently continued to be important for subsistence, although there are also a few bones of camelids (*Lama guanicoe*) in this layer. The lithic artifacts include projectile points with convex bases and fine retouch. Flint and fossilized wood were still used as raw materials, although quartz dominates the overall lithic assemblage with a frequency of 91 percent. The only unbroken handstone recovered from this period is discoidal, with traces of red pigment on the surface. Nonlithic tools are represented by fragments of two punches, manufactured from sea-lion bones. Two samples of loco shell date this period between 5180 ± 80 B.P. (Beta-25.585) and 4960 ± 110 B.P. (I-15.266), corrected for sea water to 4950 B.P. and 4720 B.P. respectively (Table 2).

Early Ceramic

The ceramic occupation is characterized by a dense deposit of shells with abundant ash lenses. There is no sterile layer between this deposit and the previous one, despite a considerable hiatus of approximately 1,200 years between radiocarbon dates. From the stratigraphic section (Figure 3), different occupational episodes could be distinguished, each of them defined by thin layers of different textures and color. Notwithstanding, the cultural materials are neither sufficiently abundant nor diagnostic to recognize phases within this layer, and it is consequently presented as a single unit. In square K, in the lowermost ceramic deposits, a charcoal sample gave an unexpectedly early date of 2810 ± 110 B.P. (Beta-22.887). Two loco-shell samples collected in square H at a depth of 90 cm yielded dates of 2530 ± 80 B.P. (Beta-25.586) (corrected to 2290 B.P.) and 2440 ± 90 B.P. (I-15.265) (corrected to 2200 B.P.) (Table 2). Previous work has shown that ceramics appeared in central Chile for the first time around 2270 B.P., this marking the beginning of the Early Ceramic period (Planella and Falabella 1987). Two of the above dates obtained from the lowermost ceramic deposits of Curaumilla-1 are consistent with this date. In light of this, the date of 2810 ± 110 B.P. (Table 2) is much too early to be given serious consideration, and we judge it as unreliable.

In square K, at a depth of 70 cm, another charcoal sample was obtained from a hearth on an occupation floor, dating it to 1190 ± 80 B.P. (Beta-22.888). A copper fishhook was directly associated with this hearth, the first find of this kind on the coast of central Chile. This clearly indicates knowledge of metal working as well as fishing technology. However, fish bone and fish otoliths are very scarce or nonexistent relative to other faunal remains.

The ceramic fragments recovered ($N = 651$) are mostly nondiagnostic, but some diagnostic fragments can be linked to the traditions of the Early Ceramic period of central Chile. These types include polished black surfaces with thin walls and brown and red slips on globular wide-mouthed pots with ledges and flat strap handles. A fragment of molded peat was also found, with fine parallel imprints of plant fibers on the inner surface with a smoothed external surface. This is possibly the remains of wall material from a living shelter. In this period, animal bones were more widely used for the manufacture of artifacts: punches, shell removers, one harpoon hook of sea-lion bone, beads, and a pendant made of bird bone. The associated stone-tool assemblage includes a concave-base projectile point made of quartz, two scrapers of obsidian and quartz respectively, and two flakes of fossilized wood and quartz. Fifteen unbroken discoidal handstones were found, none of which had traces of pigment. The inhabitants' diet diversified remarkably in this phase to include a greater

Table 3. Marine Invertebrate Species Present at Curaumilla-1.

Mollusca
Polyplacophora
Chitonidae
<i>Chiton granosus</i>
<i>Chiton latus</i>
<i>Chiton cumingsii</i>
<i>Acanthopleura echinata</i>
<i>Tonicia</i> spp.
Gastropoda
Fissurellidae
<i>Fissurella limbata</i>
<i>Fissurella crassa</i>
<i>Fissurella costata</i>
<i>Fissurella maxima</i>
<i>Fissurella cumingi</i>
<i>Fissurella latimarginata</i>
<i>Fissurella pulchra</i>
<i>Fissurella bridgesii</i>
Acmaeidae
<i>Collisella zebrina</i>
<i>Collisella orbinyi</i>
<i>Scurria scurra</i>
<i>Scurria parasitica</i>
Muricidae
<i>Concholepas concholepas</i>
Thaididae
<i>Crassilabrum crassilabrum</i>
Trochidae
<i>Diloma nigerrima</i>
<i>Tegula atra</i>
<i>Tegula tridentata</i>
Turbinidae
<i>Prisogaster niger</i>
Littorinidae
<i>Littorina araucana</i>
Melampidae
<i>Marinula</i> sp.
Timusculidae
<i>Trimusculus peruvianus</i>
Bulimulidae
<i>Bulimulus</i> sp.
Pelecypoda
Mytilidae
<i>Perumytilus purpuratus</i>
Echinodermata
Echinidae
<i>Loxechinus albus</i>
Crustacea
Balanidae
<i>Austramegaballanus psittacus</i>
Xanthiidae
<i>Homalaspis plana</i>

number and abundance of species, both terrestrial and marine: sea lion, camelid, penguin (*Spheniscus humboldti*), pelican (*Pelecanus* spp.), and sea otter (*Lutra felina*); various unidentified rodents and cetaceans are also present in the faunal remains.

Radiocarbon dates show that the lowest 50 cm of deposit in the site accumulated over approximately 4,500 years during the Archaic period, while during the Ceramic period, 30 cm of dense

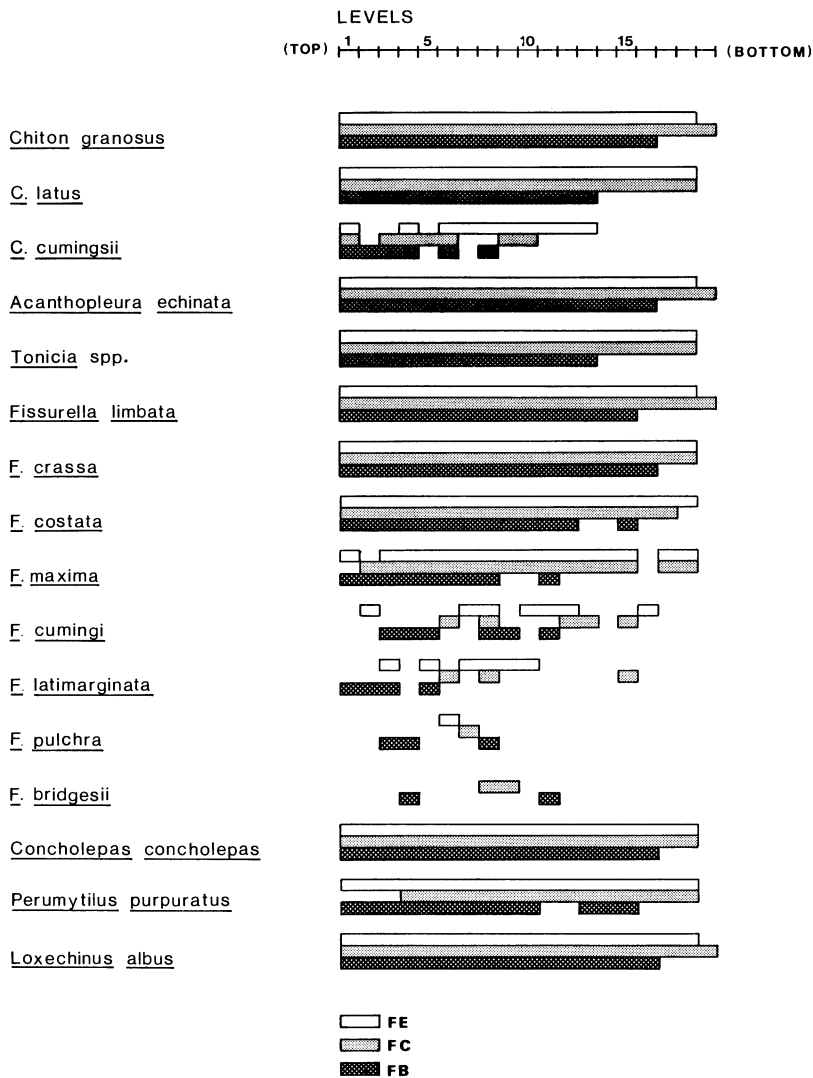


Figure 5. Occurrence (presence/absence) of 16 species of invertebrates per level in the three pits analyzed.

shell deposits built up over approximately 1,600 years. From the stratigraphic section (Figure 3), it is apparent that there were no obvious changes in the focus of deposition during the Archaic compared to the Ceramic period.

RESULTS FROM THE MARINE-INVERTEBRATE ANALYSES

Number of Species

Table 3 lists invertebrate species found at the study site. Apart from *Bulimulus* sp., a terrestrial species, all species occur on the cold-water rocky shores of central Chile. Twenty-seven species were identified while specimens from three other genera could not be identified to species level. Twenty-eight species (90.3 percent) are mollusks, two species (6.5 percent) are crustaceans, and only one species (3.2 percent) is echinoderm. Of the 31 species, 26 are herbivores, 3 are carnivores, and 2 are filter feeders.

Table 4. Abundance (MNI) of Loco, Key-Hole Limpet and Chiton per Level in Three Faunal Pits.

Levels	Loco	Limpets	Chitons
Faunal pit FE			
1	32	106	116
2	31	195	176
3	50	172	280
4	32	186	144
5	43	268	156
6	42	275	220
7	42	268	224
8	44	376	320
9	57	296	320
10	85	395	436
11	89	320	536
12	104	202	252
13	26	81	112
14	55	84	156
15	39	83	108
16	76	147	100
17	23	42	48
18	6	36	21
Faunal pit FC			
1	4	21	104
2	1	42	112
3	1	31	120
4	3	49	204
5	7	73	284
6	65	144	200
7	53	213	320
8	37	199	248
9	21	131	148
10	16	102	180
11	43	41	56
12	71	55	104
13	68	45	100
14	40	47	80
15	34	53	68
16	25	25	28
17	16	34	52
18	4	13	20
19	0	2	8
Faunal pit FB			
1	26	141	148
2	27	135	176
3	52	234	216
4	55	191	196
5	46	176	280
6	62	152	224
7	48	135	176
8	82	164	184
9	49	69	160
10	39	43	100
11	26	44	92
12	21	31	76
13	13	25	40
14	15	29	28
15	17	39	44
16	4	7	16

Note: Horizontal lines in body of table represent the stratigraphic border between Archaic and Ceramic levels.

Figure 5 shows the presence or absence of the more abundant of the species throughout all the levels and in the three faunal pits. Apart from *Chiton cumingsii*, *Fissurella latimarginata*, *F. pulchra*, and *F. bridgesii*, the rest of the species are present in most of the levels in all three faunal pits. Ceramic levels 1–6 show 18–20 percent more species compared with the Archaic levels.

Species Habitat

C. granosus is very abundant in the mid-intertidal zone, and is predominantly found on steep rock surfaces. *Acantopleura echinata* is restricted to mid- and low intertidal zones in exposed areas of heavy surf within and below the kelp band of *Lessonia nigrescens*. *Tonicia* spp. and *C. latus* generally occur in the mid-to-low intertidal, the former on shallow sloping rock walls and steep surfaces, the latter on the undersides of boulders and on vertical walls (Marincovich 1973; Otaíza and Santelices 1985). *F. crassa* has high mean densities at the mid-intertidal on both exposed and sheltered platforms. The density of *F. limbata* at the mid-intertidal is higher on exposed as opposed to sheltered platforms, and it increases in both mesohabitats at the low intertidal levels (Oliva and Castilla 1986) where *F. costata* also becomes very common (Marincovich 1973). The last author regards the mussel *Perumytilus purpuratus* as a species that forms densely packed beds throughout the upper-middle intertidal zone. *L. albus* is a sea urchin commonly found on the bottom of intertidal pools, and subtidal areas (Osorio et al. 1979). *C. concholepas* (loco) is a carnivorous snail. Small specimens (≤ 8 cm) tend to occur in the intertidal, while larger individuals actively migrate toward the subtidal (Rivas and Castilla 1987). However, in central Chile, this bathimetric distribution is obscured by the shoreward migration of subtidal populations of large loco during autumn and winter to form reproductive aggregations (Du Bois et al. 1980).

Abundance of Species

Table 4 shows the MNI of locos, key-hole limpets, and chitons per level in the three faunal pits. In all three pits, the patterns are similar. It can be observed that, in general, chitons are more abundant than limpets and limpets more abundant than locos. Pits FE, FC, and FB, levels 8–11, 5–8, and 3–6 respectively, show values of MNI for key-hole limpets and chitons that are 2.5–3 times higher than the earliest levels. These high abundances subsequently decrease in the latest levels. Loco shells per level show a similar pattern in all three faunal pits, with abundances in Ceramic period levels almost double those of the Archaic.

Figures 6 and 7 show the abundance of sea urchins and mussels, expressed as total weight of the test remains and total weight of valve fragments per level, in each of the three faunal pits. Sea urchins tests are 6–16 times more abundant in the ceramic levels than in the earlier ones. A great variability in mussel abundances can be observed among the three pits (Figure 7). Despite this variability, mussel valves are 5–10 times more abundant in the first six Ceramic period levels than in the previous Archaic levels and later Ceramic levels.

Figure 8 shows the mean abundance in percentages with standard deviation of key-hole limpet species in each pit. In general, *F. limbata* predominates throughout all the levels with an overall abundance ranging from 47 to 54 percent, followed by *F. crassa*, (14–22 percent) and *F. maxima* (3–5 percent). *F. cumingi*, *F. latimarginata*, *F. bridgesii*, and *F. pulchra* are present only in some of the levels (Figure 5) and in low abundance, never over 6.5 percent.

Figure 9 shows the mean abundance in percentages with standard deviation of the chiton species in each pit. In general, *C. granosus* predominates throughout all levels in the three faunal pits with an overall abundance ranging from 35 to 37 percent, followed by *Tonicia* spp. (24–25 percent) and *A. echinata* (17–21 percent). *C. latus* always comprises less than 17 percent of the total. *C. cumingsii* is found in a discontinuous distribution through the sequence (Figure 5) with an abundance of less than 3 percent.

Size Distribution

Figure 10 shows the mean and standard error of the sizes of loco and *F. limbata* shells throughout the different levels in each faunal pit. Excepting *F. limbata* in pit FE, it appears that the mean sizes

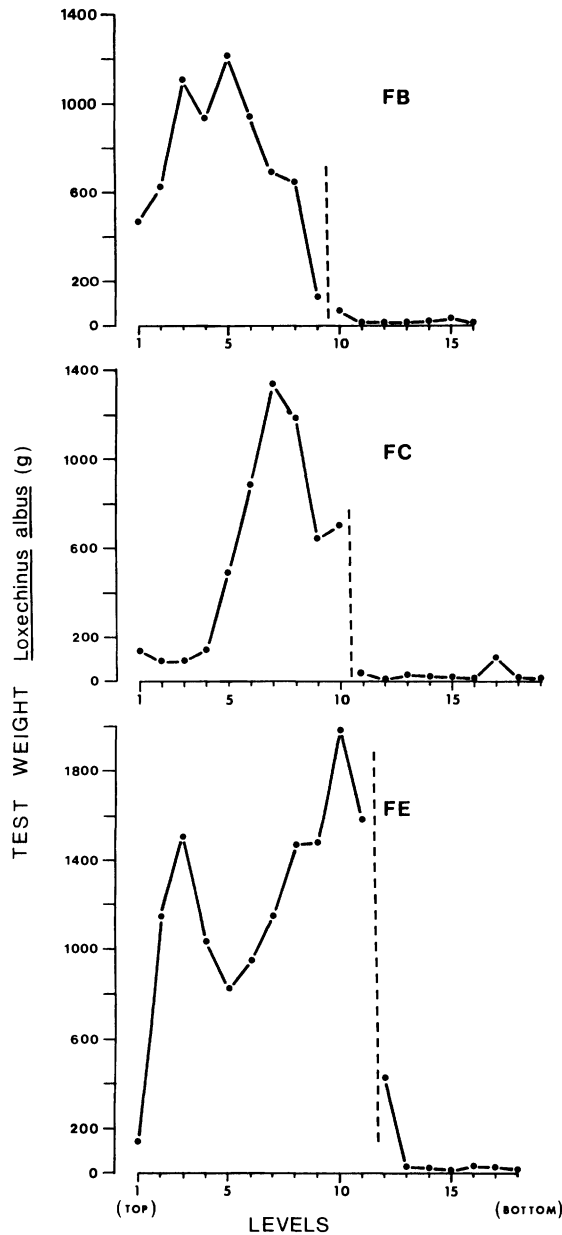


Figure 6. Weight of *Loxechinus albus* tests per level in the three faunal pits. Dashed lines represent the stratigraphic border between the Archaic and Ceramic periods.

of both species are larger in the Archaic levels than in the Ceramic period levels; this is particularly true of loco. It is also apparent that pronounced changes in the mean sizes of one species often coincide with similar trends of the other species at certain points within the sequences (pit FB levels 5–8, 12–13; pit FC levels 9–10, 11–12; pit FE levels 4–8). Using ANOVA, it was determined that in the three faunal pits (excepting *F. limbata* in FE) the mean sizes of both species in the Archaic are significantly greater than in the Ceramic levels (both species, in each pit, $p < .001$). In a second

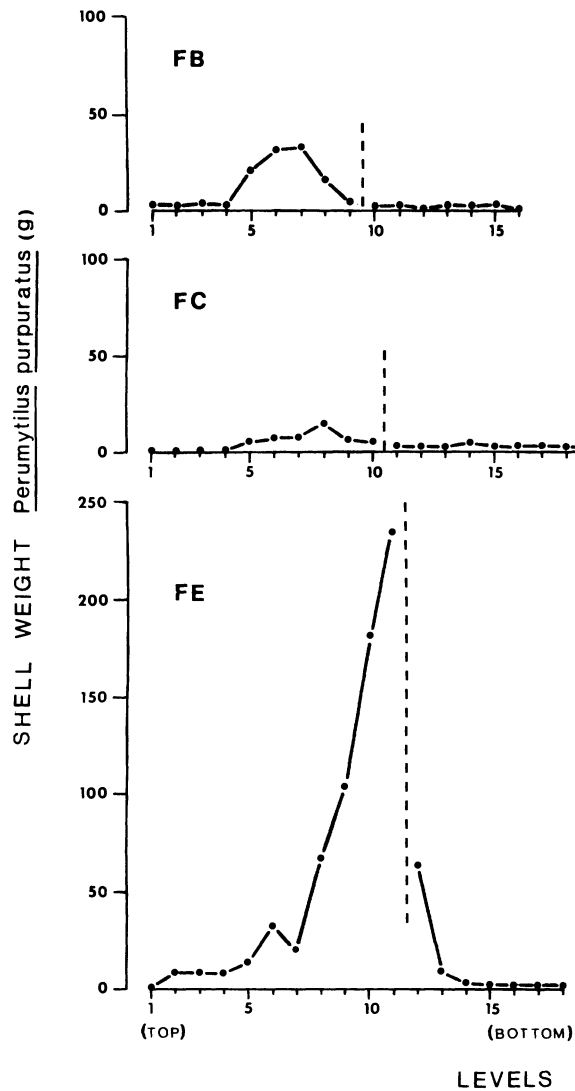


Figure 7. Weight of the valves of *Perumytilus purpuratus* per level in the three faunal pits analyzed. Dashed lines represent the stratigraphic border between the Archaic and Ceramic periods.

ANOVA, the mean sizes within each cultural period were compared. It was determined that in each faunal pit, loco mean size decreased significantly twice during the Archaic, and twice again during the Ceramic period (Figure 10). In the case of *F. limbata*, a similar pattern was established, with mean size decreasing significantly at least once in each cultural period. Other ANOVAs were conducted with *F. crassa* and *F. costata* size data. For each of these species, the mean sizes in the Archaic period are significantly greater than those of the Ceramic levels. The small numbers of measurable shells per level for both species prevented any further statistical analysis. Mean sizes of chiton species in one cultural period do not differ significantly from those in the other period ($p > .05$). In addition, no significant differences were found when mean sizes within each cultural period were compared ($p > .05$).

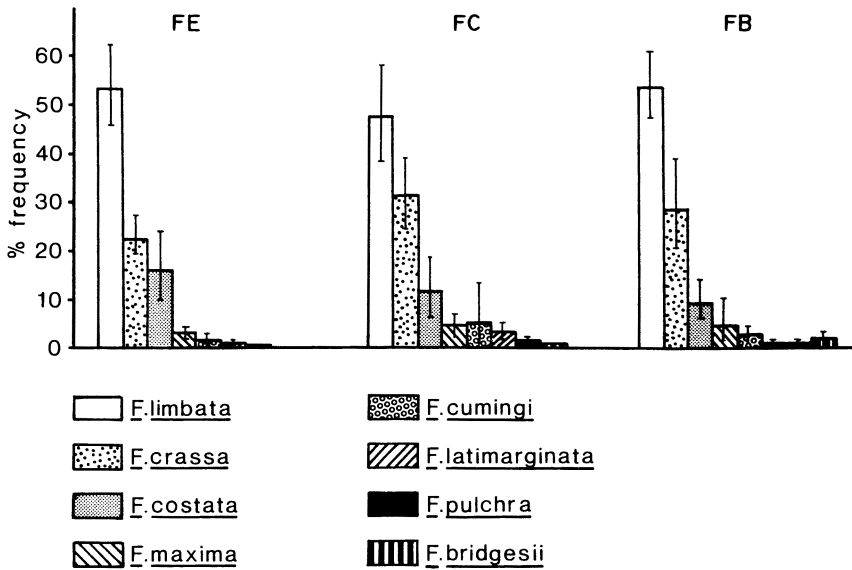


Figure 8. Mean abundance, expressed as percentage, and standard deviation of the key-hole limpet species present in the three faunal pits.

DISCUSSION AND CONCLUSIONS

Quantitative analysis carried out on the marine-invertebrate remains of Curaumilla-1 clearly show a great deal of variability between the three faunal pits (Table 4, Figures 6–7, and 10). Some of this variability has to do with the absolute numbers of individuals or weight of invertebrate remains per level and not with the general trends within each cultural period. Thus, some common patterns in terms of MNI and weight are apparent throughout the sequence in each of the faunal pits. Other observations indicate rather more important variability between pits. Mean-size data of

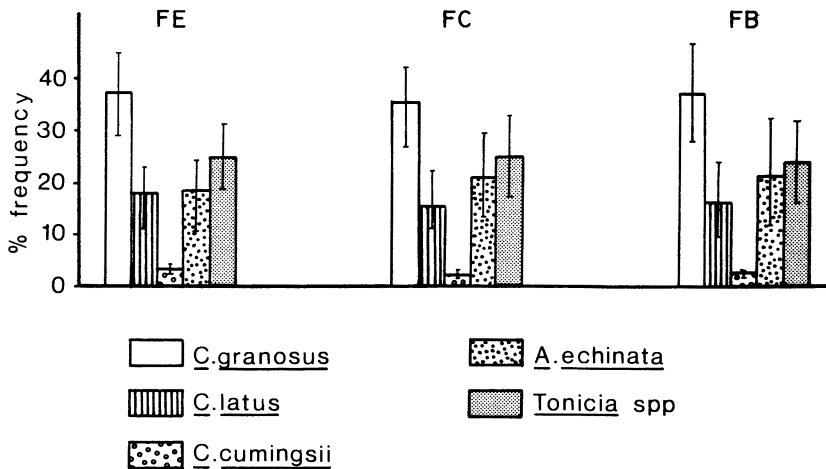


Figure 9. Mean abundance, expressed as percentage, and standard deviation of the chiton species present in the three faunal pits analyzed.

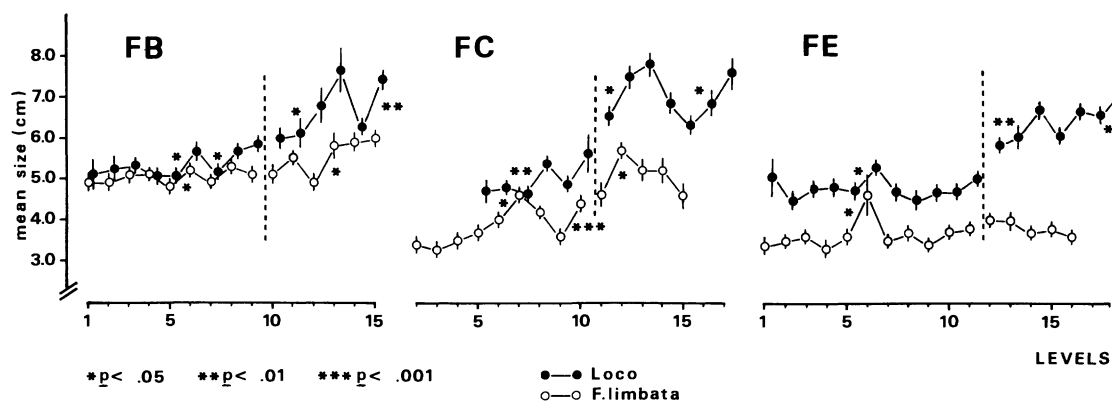


Figure 10. Mean size and standard error of loco and key-hole limpet shells per level in the three faunal pits analyzed. Levels at the top and/or bottom of some of the pits with small samples of measurable shells are not reflected here. Dashed lines represent the stratigraphic border between the Archaic and Ceramic periods.

F. limbata in pit FE do not follow closely the trends for this species evident in the other two pits. In our opinion, this observation has important implications for shellfish analysis in general. One should be cautious in considering a priori separate sample pits as identical replicates, and should avoid major conclusions obtained on the basis of one such column sample. An equally important consideration is that of sample size. In the present analyses ANOVAS were not possible on *F. crassa* and *F. costata* due to the low number of measurable shells. In assessing the ecological implications of shellfish gathering in the past, as wide a range of species as possible needs to be studied. In determining the overall size of the samples to be taken one thus needs to be particularly mindful of the nature of preservation and abundance of ecologically important species.

It is clear that excavation by natural stratification, where possible, is by far preferable to that by arbitrary levels. At Curaumilla-1 patterns potentially common to each of the sample pits have probably been partly obscured by the mixing of different depositional events within arbitrary levels. However not all masking of patterns can be attributed to excavation strategy, as other aspects such as variation in activity areas, and depositional factors such as compaction, slumping, and erosion are also likely to have been important.

We turn now to the results of the analyses. The general dominance of chitons over key-hole limpets and loco (Table 4) throughout the sequence needs brief comment. Both of these last species can easily be shelled on the beach, whereas chitons require more processing such as cooking to extract the flesh. It is thus possible that we may be underestimating the relative proportion of limpets and loco compared with chitons in real dietary terms.

At Punta Curaumilla, three stages of marine-invertebrate exploitation, mostly from the mid- and low intertidal, can be established. The first stage is represented by the Archaic deposits, dating to between 8500 and 4000 B.P. The Archaic has a smaller range of species than later stages, with loco relatively more common and fewer key-hole limpets, chitons, mussels, and sea urchins. The depth of deposit per unit time as well as its soil-like nature suggest fewer visits and/or a rather less intense exploitation of marine organisms than was the case later.

The second stage of exploitation is represented by the first of two Ceramic period occupations, dating to between ca. 2500 and 1300 B.P. The depth of deposit per unit time and a denser matrix of shell suggest a higher rate of mollusk-shell accumulation compared to the Archaic. This may be the result of changes in the frequency and duration of visits to the site and/or an increase in population. More species are represented than was the case in the Archaic. There are more key-hole limpets, chitons, mussels, and sea urchins compared to loco.

The third and final stage is represented by the second Ceramic period occupation of the site, starting ca. 1200 B.P. and ending with the abandonment of the site some time before Spanish

colonization. The overall number of species, as well as the MNIs of previously heavily exploited invertebrates diminishes. This is probably due to fewer visits, changes in the pattern of subsistence and/or settlement. The presence of a copper fishhook, the first and only artifact indicating fishing, suggests diversification of diet. Fish remains, however, are very scarce, and further sampling is required to assess properly the importance of fishing.

With respect to the ecological implications of Curaumilla-1, it is important to emphasize the presence—throughout the deposits and in substantial numbers—of an important high-trophic-level predator like loco, of herbivores like key-hole limpets, chitons, and sea urchins, and of a dominant competitor for primary space (rock) like the mussel (Figure 5). The existing ecological literature defines loco as a key species in the organization of marine communities in the rocky intertidal of central Chile (Castilla 1981; Castilla and Durán 1985; Castilla and Paine 1987; Paine 1969). Loco actively preys on the mussel *P. purpuratus*, the predominant competitor for primary space in the rocky middle intertidal. In nonharvested rocky shores with high densities of loco, the overall number of species increases initially due to the liberation of primary space by the activities of this predator (Castilla and Durán 1985). This “free” space, a limiting resource in the rocky intertidal, may be occupied by new species, in either a transient or permanent way (Durán and Castilla 1989). With regard to herbivores, it is relevant to note that recent experimental studies conducted in central Chile on *F. crassa*, clearly point to the limiting effect of grazing by this species on algal cover (D. Oliva, personal communication 1991).

The species of marine invertebrates currently exploited by shellfish gatherers in the rocky intertidal of central Chile are more or less the same species present in Curaumilla-1 (Durán et al. 1987; Oliva and Castilla 1986). These modern shellfishers, collecting from the rocky intertidal and shallow subtidal for subsistence purposes today, apply a very simple technology. They collect the mollusks with their bare hands or by means of piece of iron (*chope*) or knife. Along 1.5 km of rocky-intertidal shore line at Las Cruces (Figure 1), these gatherers collected approximately 4.5 tons of key-hole limpets and 3.6 tons of loco (wet biomass) in a one-year period (Durán et al. 1987). These studies and those conducted on the southern coast of Chile (Moreno et al. 1984) as well as in South Africa (Branch 1975; Hockey and Bosman 1986) have conclusively shown that efficient, persistent, and selective human predation on species of different trophic levels greatly modifies rocky-intertidal communities.

Before considering the possibility that Precolumbian people brought about similar modification to paleo-intertidal communities, we need to discuss the kinds of archaeological evidence that would be a reflection of such effects. Some of the more obvious consequences of overexploitation on present-day marine organisms are a decrease in mean size and abundance accompanied by an increase in growth rate (Branch 1981; Castilla and Bustamante 1989; Hockey and Bosman 1986; Ortega 1987). Thus, in archaeological terms, a decrease in mean size and a change in the size distribution of a species should be detectable through the site sequence, or portions thereof if overexploitation took place. With respect to abundance, the potential archaeological signature is more difficult to assess. A decrease in abundance of any species in an archaeological deposit could be related to behavior having nothing to do with predation intensity: for instance the shelling of mollusks on the beach before return to the site, or changing cultural preferences. Alternatively, one may hypothesize that if larger individuals of heavily exploited species became scarcer on the shoreline, people may have collected more smaller specimens or switched some of their attention to other species in order to achieve the required amount of protein (Claassen 1986). Growth-rate observations are possible by thin sectioning portions of the organism's shell; this technique, however, fell beyond the practical possibilities of our analysis. Clearly, whereas off-site shelling or changing cultural preferences are difficult to establish archaeologically, the last two options can be addressed with archaeological data by interactively examining parameters of abundance, size, and number of species.

Although it is clear that some of the consequences of human exploitation of intertidal communities are potentially detectable in archaeological residues, we need also to remember that changes in size and abundance of a species can also be due to environmental factors (Claassen 1986; Swadling 1976). In central Chile, dramatic modifications in marine ecosystems have been attributed to abrupt coastal uplift and episodic El Niño events (Castilla 1988; Castilla and Oliva 1990; Soto 1985;

Tomicic 1985). The reported effects included observations on biomass, abundances, and relative frequencies of species. Unfortunately, no observations were made on possible changes in the mean size of the affected species. However, environmental fluctuations affect the various shellfish species differently (Claassen 1986). It thus seems unlikely that simultaneous decreases in mean size of ecologically different species could be easily attributable to changes in the environment.

Turning once again to Curaumilla-1 we note the statistically significant and simultaneous episodic decreases in the mean sizes of loco and *F. limbata* that occurred through the deposits. Ecological observations and considerations of the excavation strategy outlined above lead us to believe that these episodes of size reduction can be interpreted as a sequence of events of intense accumulation of residues from these two species over time. As human occupation of any one site or area is unlikely to have been unbroken, particularly among hunter-gatherers, such trends toward smaller sizes need not be continuous. During human absences from the area molluscan populations will recover, size structure will be reestablished, and mean sizes will increase. When occupants return to an area, this should, with appropriate stratigraphic resolution, be reflected by an increase in the mean size of persistently exploited species relative to those in immediately deeper deposits. Such an increase in mean size is shown particularly well by the loco mean-size sequence (Figure 10). We suggest that the observation in Figure 10 indicates two major pulses of occupation in the Archaic and Ceramic periods respectively, during which loco as well as *F. limbata* were heavily collected, causing decreases in mean sizes. The first event has an Early to Mid-Archaic date, and the second is associated with the Late Archaic.

Artificial excavation levels do not necessarily represent discrete stratigraphic events. Such a level could actually contain the remains of two or more different events or even only part of one. The former case, we think, is responsible for intermediate mean sizes of loco or *F. limbata* between levels of higher and lower mean size, particularly in pit FC. Such stratigraphic cross mixing could also explain why peaks in mean size of both species are slightly out of phase with one another (i.e., Figure 10; pit FC levels 7–8, 13–14).

In considering the recovery of the mean sizes of shellfish following a hiatus, it is notable that the mean sizes of loco and *F. limbata* are practically the same between the last archaic level and the first of the Ceramic, a period represented by a 1,200-year hiatus. Here, an argument invoking distortions due to the particular method of excavation does not seem appropriate. In this instance, an environmental explanation may be more relevant, although it is possible that deposits representing this return event are not located within our excavation, or for that matter, may not be represented at this site. Geological observations on the coast of central Chile have determined that the Flandrian Transgression resulted in a high stand of the sea of +5 m around 6000–4000 B.P. (Caviedes 1972), which falls within the Archaic occupation. We are, however, uncertain about the consequences of this and other concomitant global changes on marine-invertebrate communities. Thus, an environmental explanation for the absence of change in the mean size of loco and *F. limbata* before and after the Archaic–Ceramic hiatus is possible but still difficult to demonstrate conclusively with the evidence at hand.

In subsequent seasons our aim will be to excavate the site by natural stratigraphy when possible, hoping to isolate discrete occupation events. In addition, further studies have to be undertaken to supplement those already completed: a complete faunal analysis across the spectrum of remains represented, a geomorphological study of Curaumilla's coast lines, a reconstruction of oscillations in sea-water temperature by oxygen-isotope analysis on marine shells present in the archaeological deposits, as well as further radiocarbon dates to test the contemporaneity of the proposed pulses of occupation in the three faunal pits, and in the more distant future, a comparative study of similar sites in the same area.

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