A CASE EXAMPLE FOR MARINE INVERTEBRATE ANALYSIS:

SDi-48, POINT LOMA, CALIFORNIA

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ABSTRACT

The marine invertebrates recovered from prehistoric site CA-SDi-48 were quantified using two methods, number of identified specimen (NISP) counts and minimum number of individual (MNI) estimates. The NISP counts and MNI estimates are employed to generally reconstruct the ancient environment near the site, and the ecology and behavioral activities of the aboriginal occupants of the site. It is shown that the site was occupied by a basically sedentary group of people who refined their marine invertebrate resource procurement over time to insure a maximum return for a minimal effort.

INTRODUCTION

This presentation is a summary of the results of a detailed shellfish analysis provided for a cultural resource study at SDi-48, Point Loma, California. The focus of this study is on the use of number of identified specimen (NISP) counts and minimum number of individuals (MNI) estimates, as prescribed by Klein and Cruz-Uribe (1984), to interpret the marine invertebrate remains sample recovered from SDi-48 in an attempt to reconstruct the ecology and behavioral activities of its inhabitants. SDi-48 presented an excellent opportunity to apply NISP counts and MNI estimates to a large, stratigraphically excavated collection spanning 4,500 years. A more complete analysis is provided in Cerreto 1989.

METHODS

Sampling

The subsample used in the analysis is part of a sample that consisted of marine invertebrate remains from four units at two loci at SDi-48. Three of the units (1T, 2T, 4T) are located within the grid system at Locus A, and are all 1x1m squares varying in depth to 60, 70, and 100 centimeters respectively. Unit 14, located at Locus B is a 2x2m square, excavated to a depth of 170 centimeters. Sampling at Locus A was accomplished by collecting the remains in 10 centimeter systematic levels, while the remains at Locus B were collected in distinct soil horizons representing separate soil depositional events (numbered levels 1 through 6). With the exception of Unit 2T, all of the remains from both loci were briefly dry screened through 1/8 inch mesh to remove excessive soil, and bagged for wet screening through 1/16 inch mesh at the Westec archaeology lab. Soil from Unit 2T was shoveled directly into plastic bags and transported to a wet screening facility. The samples were given to the author after the lithic and osseous remains were removed.

The material recovered from Unit 14 was reseparated into 6.35 mm. (1/4 inch) and 3.175 mm. (1/8 inch) fractions to insure reasonably equal access for examination between the two size classes of materials. These in turn were counted separately and combined by computer for the final NISP counts and MNI estimates for the unit.

The sampling unit used in this study was the level of the excavation unit, either stratigraphic or arbitrary. Spacing of the samples was good because the larger of the loci (Locus A) was sampled systematically, with the areas suspected of yielding the highest returns being selected. The same is true for Locus B, except that because of limited space, the units were combined into a single excavation unit. Locus A contributed 3 square meters of surface area to the total sample, and Locus B contributed 4 square meters.

The Collection

Klein and Cruz-Uribe (1984:3-4) have succinctly synthesized the stages that a fossil (or archaeological) "fauna" passes through before it reaches the analyst. These are listed below in order that the materials recovered from SDi-48 can be placed in their proper perspective.

1. The Life Assemblage (the community of live animals in their "natural" proportions).
2. The Death Assemblage (the carcasses that are available for collection by people, carnivores or any other agent of bone accumulation).
3. The Deposited Assemblage (the carcasses or portion of carcasses that come to rest at a site).
4. The Fossil Assemblage (the animal parts that survive in a site until excavation or collection).
5. The Sample Assemblage (the part of the fossil assemblage that is excavated or collected).

Klein and Cruz-Uribe (1984) explain further that the fossil and sample asemblages are identical only if the entire fossil assemblage is carefully collected, in other words, the entire site is fully excavated. As this is a rare occurance indeed, the fossil assemblage must be estimated from the sample assemblage, and the larger the sample, the better. Also, they caution analysts on the importance of recovery methods. Such biases concerning marine invertebrates are postulated by Cerreto and Foertsch (1985). Other problems cited by Klein and

Cruz-Uribe (1984), in particular the attrition of ecofactual materials, are certainly not always substantiated and may even be non-existant in some instances (see Cerreto 1986).

In this study, additional care is taken because the sample assemblage was not examined. There are two means by which a sample can be analyzed, that is, either completely or partially. A complete sample is the entire excavated or collected sample (the sample assemblage above). A partial sample is also called a "subsample", and can be anything from highly reliable to highly suspect, depending upon the method by which it is selected, and whether the subsample lends itself readily to some sort of check or test for accuracy in representing the sample. Of course, the sample must be large enough to accommodate a subsampling, and the method of subsampling should produce a representative subsample. Studies in which time and other constraints prohibit the processing of the entire sample assemblage demand the inclusion of a sixth stage; the "subsample assemblage" (Cerreto 1989:22). The subsample assemblage is defined as that portion of the sample assemblage that is analyzed when a complete analysis of the sample assemblage is prohibited (Cerreto 1989:21-23).

The Subsample Assemblage

Sample size dictated that subsampling be used in this analysis, and a macroscopic rough sorting was used to obtain a representative subsample. In using the macroscopic rough sort method of subsampling, the sorters simply spread out a workable amount of material and cull all "beaks" (apices) for bivalves, apexes for gastropods, bases for barnacles, and head and tail plates for chitons along with readily identifiable fragments of all species. The size range for fragments picked out of the 1/4 inch material was not less than 2.0 cm. in diameter, and the size range for the 1/8 inch material was not less than 0.5 cm. in diameter. These remains were sorted by species as they were culled, and bagged until counted and weighed.

Identification

Identifications were made by the author aided by five individuals. In an ideal study, an analyst should expect or attempt to examine and identify all of the material retrieved from a sample assemblage. Often, this is not possible due to time and/or other constraints.

All of the elements included in this subsample assemblage were identified with the aid of Cerreto and Foertsch (1985) and Keen and Coan (1974) for identifications to the generic (genus) level, and supplemented by Abbott (1954), Allen (1969), Fitch (1953), McClean (1969), McConnaughey and McConaughey (1986), Morris (1966), and Ricketts et al. (1985) when help with specific (species) identification was needed. Although specific identification is not always necessary for behavioral inferences, it is often quite useful in ecological reconstruction. In certain cases, only the class level (taxonomically speaking) was determined. For example, in this study the barnacles and crabs were not more specifically identified because of their small numbers, while the chitons cannot be accurately identified without their fleshy girdles present (Keen and Coan 1974:117).

DATA ANALYSIS

Weights

Although weight was recorded for future researchers, it is invalid for the purposes of this analysis, and is not discussed in this presentation. An Ohaus triple beam balance (700 series) with a 2,610 gram capacity and accuracy to 0.1 gram was used to weigh the remains, and the weights were recorded on raw data sheets and entered into a data file for future use.

Counts

Two counts were employed in this analysis: 1) the number of identifiable specimens (NISP) counts and, 2) the minimum number of individuals (MNI) estimates. Both techniques have their advantages and disadvantages as discussed in detail in Klein and Cruz-Uribe (1984). Fortunately, each of these indexes compliments the other's weaknesses, and some of the problems cited by Klein and Cruz-Uribe do not exist when applied to marine invertebrate analysis (Cerreto 1989:16-17).

MNI estimates for SDi-48 shell remains were accomplished by separating the left and right apexes (the beaks or hinges) of the valves in bivalves (pelecypods), and the head and tail plates for the chitons (polyplacaphora). All of the gastropod apexes, and complete or partial barnacle (cirripedia) bases were counted as one. More specifically, all bivalves, with the exception of *Argopecten*, *Donax*, *Hinnites*, and *Tagelus* were separated into left and right valves for quantification. *Argopecten* and *Hinnites* were not separated because breakage of these shells more directly affects the identification of the left and right elements. *Donax* and *Tagelus* were not separated through an oversight on the part of the author. The MNI for all four of the above mentioned species was the total apical or hinge count divided by two, which is not an accurate MNI estimate, while for the other bivalves the MNI estimate was the largest of the left or right counts. Of the above named species, only *Argopecten* is present in large enough numbers to affect interpretations.

MNI estimates for gastropods are made by using the presence of a complete apex, even if the rest of the shell is available, unless there is clear evidence that the apical end has been crushed. Exceptions to this are *Cypraea*, *Diodora*, *Fissurella*, Megathura, and Serpulorbis. Cypraea was counted if the inner or outer lips are present. The next three species are counted if their apical openings are complete or nearly complete. Serpulorbis are counted as colonies when a communal base is present.

Decapods are counted if the complete upper or lower claw, or at least the proximal hinged end of the claw is present. Crabs were not speciated below the class level because of their small numbers. Sea urchin (Strongylocentrotus spp.) MNIs are counted only if their mouth parts (Aristotle's lantern) are present, and this is problematic as recovery may be biased (Cerreto and Foertsch 1985).

Disturbance

Other than the grading fill and a cap of asphalt pavement, there is no known historic disturbance to the site (Gallegos 1988). The degree of mixing due to bioturbation between the soil horizons at Locus B and within the soil horizon at Locus A is unknown. However, earlier work on this site suggests that little disturbance occurred within these loci (see Gallegos and Cheever 1987).

Taphonomic

Weathering in all stages of progression is evident on some of the remains. That is, the state of the remains were anywhere from pristine (no signs of weathering) to extremely weathered (calcareous lumps with no identifiable landmarks). Burned marine invertebrate remains were recovered from SDi-48. While the burned remains were not formally quantified, there was an apparent randomness noted at least in regard to species.

Finally, all shell that was determined to be part of the death assemblage (dead prior to collection) was removed from the analysis. Evidence of death prior to collection was based upon the presence of sessile organisms within the internal portion of any shell, the presence of sessile organisms on the exterior of any shell not normally exposed for attachment, and evidence of successful predation by carnivorous gastropods.

Analytic

Due to the scope of this work, analysis was narrowed to specifically concentrate on answering questions concerning the general environmental setting and possible changes in the environment over time, subsistence catchment and possible changes over time, diet, and intrasite variability.

To accomplish this, certain procedures extraneous to simply weighing and counting the remains were employed. Such procedures included the use of an arbitrary limit to "significant" species. Called the trace level in this study, this arbitrary limit is set at 1% of the unit sample total, with all species below this level excluded from most of the analyses. Also, the use of "species blocks", or comparative columns of species by MNI frequencies, instead of simply choosing two prominent species, afforded a much clearer view of subsistence patterns. Most importantly, the remains are examined in a more ecologically based manner in hopes of providing an in-depth study of scheduling and procurement methods used by the site's inhabitants. Although some ecologically based studies have been performed in other analyses, the ratio of epifaunal to infaunal collected has not been reported. Epifauna are described as those organisms that remain exposed on (do not sink, burrow, or bore into) any substrate they might inhabit. Infauna are described as those organisms which burrow or otherwise reside within any substrate they might inhabit (Ricketts et al. 1986:450). Either presents a different set of circumstances for procurement related activities. For instance, epifauna are more readily available for collecting while infauna are often more likely to require some thought and effort. Also not previously reported, diagnostic species are used to further define environmental particulars. Diagnostic species are defined as species that exist only in a specific habitat, tidal zone, or substrate (Cerreto 1989:28).

Habitats

For this study the habitats are defined as 1) exposed non-rocky shorelines consisting of cobblestones, sand, mud, shell, shell fragments, and mixtures of any and/or all of these, but having no large rocky outcroppings; 2) exposed rocky shorelines consisting of the above substrates but having large rocky outcroppings; 3) bays, either enclosed or protracted, and composed of any combination(s) of the preceding habitats; and 4) marine dominated estuaries. Marine dominated estuaries feature extensive sand and mud flats that are exposed at low tides. Bays and estuaries exhibit very similar characteristics, often attracting the same organisms and so tempting their combination as a single habitat. However, there are certain organisms that are specific to either bays or estuaries, and therefore the separation of the two can deliver important information on paleoenvironment.

Tidal Range

Tidal ranges are commonly divided into five zones, the uppermost horizon, the upper intertidal, the middle intertidal, the lower intertidal, and the subtidal (Ricketts et al. 1986:7-9). These zones are not fixed at a particular height, and will vary according to wave action and habitat. The uppermost horizon (also called the splash, spray or supralittoral) is defined as the zone at the highest reach of storm waves' spray to the mean of all high tides. The upper intertidal is defined as the zone at the mean high tide line to the mean flood line (the higher of two daily low tides). The middle intertidal is defined as the zone at the mean higher low water line (mean flood line) to mean lower low water line (the area typically uncovered twice a day). The lower intertidal is defined as the zone exposed only at minus tides (from the mean lower low water line to the lowest low water line). The subtidal zone is defined as the zone that is never exposed by tidal actions. In this study the upper, middle, and lower tidal zones are compared to one another. The supralittoral is not considered because it is represented by only one species (*Melampus*), and the subtidal is combined with the lower tidal zone because almost all of the organisms in the subtidal are also found in the lower zone (exceptions are *Megasurcula* and *Trachycardium*).

Substrates

For this study the substrates presented in the tables are grouped into three broader categories. These categories are the hard, soft, and biotic substrates. Hard substrates consist of large rock outcrops, cliffs, boulders, cobbles, gravels, and shell beds. Soft substrates consist of sands, muds and any degree of mixture of the two. Biotic substrates are defined as when living plants or animals are used as a living surface for any organism (see Cerreto 1989:31 for a more detailed discussion of biotic substrates). Biotic substrates are not discussed in this presentation because they are only represented by a single species (*Notoacmaea insessa*).

SOURCES OF ERROR

Qualitative error is possible through inter- and intraobserver error in identification of the material due to particle size, or the ease with which any one particular species might be identified. This in turn will directly affect the NISP and MNI (quantitative error). Quantitative error can be introduced through omission, accidental inclusion, or through errors in measurement (mistakes in counting or weighing). These sources of error are discussed below.

Identification and Particle Size Error

The author rechecked a sample of the work of each of the speciators (the author included), and liberally estimated the amount of interobserver error for identification of the remains to be less than 5%.

Counts

Omission presented a more serious problem because the "rough sort" sampling method used for this analysis might introduce error into the NISP counts. Because counting every identifiable fragment in the sample assemblage is precluded by time constraints in this study, the actual NISP for the subsample assemblage may be artificially suppressed. Concern about the differential collection of shell fragments during sorting is foremost, because inferences made from the NISP counts may be in error if there is any bias, and in turn can bias inferences drawn from the MNI. Therefore, if a subsample assemblage is to approximate a sample assemblage, it must create the same proportions between the NISP and MNI counts for the subsample assemblage as those of the sample assemblage. At this point sampling related problems may occur, because the proportions generated between the NISP and MNI counts for the subsample may not represent the proportions for the sample. Fortunately, the proportions columnwise per level between the NISP and MNI counts ranged only from 1.12% to 8.89%, with a mean of 3.62%. Therefore, the "rough sort" method used for the remains from Unit 14 created a representative subsample. A liberal estimate of less than 5% is noted for interobserver error for both miscounts and accidental inclusion.

Weights

Although the remains were washed during the wet screening process, not all of the soil was removed. The inclusion of soil is noted particularly, but not exclusively, for the coiled gastropods, and error caused by this inconsistency is present to an unknown degree.

RESULTS

The summary results of this analysis are presented in this section. Unit 14 is used as the "Rosetta Stone" for the three other units (1T, 2T, 4T) because it is the largest of the sampling units, and because six distinctive soil horizons were detected at Locus B (Unit 14). Locus A is apparently a singular depositional event, speaking strictly in terms of soil horizon, not shell deposition.

The Units Overall

Over 300,000 grams of marine invertebrate remains were recovered from four units at SDi-48. A total count of the subsample yielded 234,992 pieces of marine invertebrate remains representing 44,297 individuals. The percentage of MNI to NISP for the collection is 18.85% (a ratio of 5:1). The remains of 64 genera and classes (hereafter referred to as species for the sake of convenience, although several species may actually be present within any genus) were retrieved, and these represent the variety of species for the entire collection from SDi-48. A list of all species recovered from SDi-48 is presented in Table 1. Common names are not used because many organisms will have numerous local names, some of which will be the same name for entirely different organisms.

Unit 14

There is a total NISP of 162,009 and a total MNI of 36,612 representing 68.94% and 82.65% of the entire collection respectively. The percentage of MNI to NISP for this unit is 22.60% (a ratio of 4:1). Table 2 shows the MNI estimates for Unit 14. The remains of 64 species were retrieved from

TABLE 1

COMPLETE SPECIES LIST FOR SDi-48

PELECYPODA	GASTROPODA
Anomia	Acanthina
Argopecten	Alia
Chione	Astraea
Donax	Bulla
Glans	Cerithidea
Hinnites	Collisella asmi
Laevicardium	C. instabilis
Macoma	Conus
Mactra	Crepidula
Modiolus	Crepipatella
Mytilus	Crucibulum
Nuttallia	Cypraea
Ostrea	Diodora
Pododesmus	Fissurella
Protothaca	Haliotis (intertidal)
Pseudochama/Chama	Haliotis (subtidal)
Saxidomus	Homalopoma
Semele	Limpets
Septifer/Hormomya	Littorina
Spisula	Lottia
Tagelus	Lucapinella
Tivela	Megasurcula
Trachycardium	Megathura
Tresus	Melampus
	Nassarius
MISCELLANEOUS	Neverita
	Norrisia
Barnacles	Notoacmaea insessa
Pollicipes	Olivella
Chiton	Polinices
Crab	Serpulorbis
Scaphapoda	Tegula
Sea Urchin	Volvarina
Non-marine Gastropod	Gastropod

Unit 14. Of these, only 16 occur in proportions above the trace level (in this analysis less than one percent is considered to be trace). These 16 species are listed in order from their highest to their lowest counts by level in Table 3. In general, the MNI estimates decrease from level 6 to level 2. However, in level 1 the MNI percentage, while still lower than previous percentages, increases again by 50% when compared to level 2. More specifically, the MNI counts and percentages decrease by half from level 6 to level 5. Although the counts and percentages decrease by about a quarter overall, the counts for level 3, 4, and 5 vary by less than one fifth and less than 4% between themselves. Also, the counts in these levels show a distinct difference in their quantities for species below the highest two species (at least twice and as much as three times as many individuals). The counts and percentage for level 2 decrease by three fourths from level 3. For level 1 the MNI counts and percentage increase by half compared to level 2. Three distinct groupings of the levels in Unit 14 are apparent: levels 1 and 2, levels 3, 4, and 5, and level 6. The ranking in the species blocks in levels 1 and 2 are almost identical. Levels 3, 4, and 5 consist of fairly similar rankings, with level 3 showing more variability between the three.

Table 4 shows the total counts and the ratios between the habitats, tidal ranges, and faunal types discussed above. Overall, there is a 2:1 ratio of Rocky Shore species over Sand and Mud Flat species, a 1:1 ratio between the full and lower tidal ranges, and a 3:1 ratio of epifauna to infauna. More specifically, the ratio of Rocky Shore to Sand and Mud Flats is 1:1 for level 6, and 4:1 for levels 4 and 5. In level 3 this ratio decreases to 3:1, but returns to a 4:1 ratio in level 2, and increases to a 6:1 ratio in level 1. The ratios between the full and lower tidal ranges are 2:1 in level 6 in favor of the lower tidal range, 1:1 in levels 3, 4, and 5, and 2:1 in favor of the full tidal range in levels 1 and 2. The faunal types shows a 2:1 ratio of epifauna to infauna in level 6, and this increases to a 5:1 ratio in level 5 and 7:1 in level 4. In level 3 the ratio of epifauna to infauna decreases to 6:1, and to a 5:1 ratio in level 2, increasing to a 6:1 ratio in level 1.

<u>Unit 1T</u>

There is a total NISP of 5,129 and a total MNI of 895 representing 2.18% and 2.02% of the entire collection respectively. The percentage of MNI to NISP for this unit is 17.45% (a ratio of 6:1). The remains of a total of 34 species were retrieved from Unit 1T, 10 of which occur above the trace level. These 10 species are listed in order from their highest to their lowest counts for all levels combined in Table 5. Table 5 also shows the species total MNI counts and ratios for habitats, tidal range, and faunal types for

TABLE 2

MNI ESTIMATES FOR UNIT 14

SPECIES	MNI	SPECIES	MNI	SPECIES	MNI
Anomia	3	Acanthina	5	Barnacles	19
Argopecten	1841	Alia	138	Pollicipes	0
Chione	3194	Astraea	320	Chitons	3631
Donax	85	Bulla	1	Crabs	22
Glans	4	Cerithidea	41	Scaphopoda	1
Hinnites	86	Collisella a.	69	Sea Urchin	0
Laevicardium	0	C. instab.	0		
Macoma	2	Conus	1		
Mactra	1	Crepidula	559		
Modiolus	347	Crepipatella	345		
Mytilus	1178	Crucibulum	6533		
Nuttallia	3	Cypraea	1		
Ostrea	6016	Diodora	0		
Pododesmus	19	Fissurella	21		
Protothaca	3586	Haliotis	40		
Pseudo/C.	926	Homalopoma	10		
Saxidomus	841	Limpets	557		
Semele	75	Littorina	124		
Sept/Horm.	249	Lottia	78		
Spisula	3	Lucapinella	2		
Tagelus	49	Megasurcula	10		
Tivela	20	Megathura	3		
Trachycard.	1	Melampus	14		
Tresus	217	Nassarius	1		
		Neverita	1		
		Norrisia	6		
		Noto. ins.	4		
		Olivella	164		
		Polinices	6		
		Serpulorbis	1		
		Tegula	3256		
		Volvarina	5		

TABLE 3

SPECIES IN ORDER OF ABUNDANCE PER LEVEL FOR UNIT 14

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5	LEVEL 6
Tegu n=594	Cruc n=347	Ostr n=1144	Cruc n=1786	Cruc n=2000	Prot n=2109
Cruc n=403	Tegu n=241	Cruc n=890	Ostr n=1642	Ostr n=1548	Chit n=1659
Ostr n=266	Ostr n=191	Tegu n=462	Argo n=567	Chit n=831	Chio n=1528
Chit n=250	Chit n=141	Prot n=456	Chio n=432	Chio n=549	Ostr n=1225
Chio n=165	Prot n=115	Argo n=444	Chit n=407	Tegu n=541	Tegu n=1146
Prot n=121	Chio n=113	Chio n=407	Prot n=291	Prot n=494	Cruc n=1107
Ps/C n=99	Ps/C n=51	Chit n=343	Tegu n=272	Argo n=333	Myti n=667
Limp n=36	Limp n=35	Ps/C n=318	Myti n=168	Myti n=208	Saxi n=638
Crep n=28	Crep n=33	Myti n=112	Crep n=140	Ps/C n=116	Argo n=459
	Argo n=27	Limp n=93	Ps/C n=122	Gast n=102	AstO n=357
	Gast n=17	Crep n=73	Limp n=90	Limp n=87	Modi n=300
	Myti n=16	Gast n=72		Saxi n=85	Gast n=249
					AstA n=227
					Ps/C n=220
					Limp n=216
					Crep n=213
					Tres n=194

Argo = Argopecten AstA = Astraea apex AstO = Astraea operculum Chio = Chione
Chit = Chiton Crep = Crepidula Cruc = Crucibulum Gast = Gastropods Limp = Limpet
Modi = Modiolus Myti = Mytilus Oliv = Olivella Ostr = Ostrea Prot = Protothaca
Ps/C = Pseudochama/Chama Saxi = Saxidomus Se/H = Septifer/Hormomya Tegu = Tegula

Note: Two types of count are used for Astraea; the operculi count and the apical count. If these counts are not equal, they are averaged into subsequent calculations. In this case, the count for Astraea (Level 6) is n=292.

MNI estimates do not include counts from Features 1A, 3A, and 6A.

TABLE 4

UNIT 14 TOTAL COUNTS AND RATIOS FOR HABITAT, TIDAL RANGE, AND FAUNAL TYPE

	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5	LEVEL 6	TOTALS	PERCENTS
Habitat								
Rocky Shores	1,676	1,072	3,507	4,627	5,433	6,994	23,309	70.34
Sand/Mud Flats	286	255	1,307	1,290	1,461	5,228	9,827	29.66
Ratios	6:1	4:1	3:1	4:1	4:1	1:1	2:1	
Tidal Range								
Full Range	1,311	908	2,489	3,430	3,271	4,057	15,466	46.67
Lower Range	651	419	2,325	2,487	3,623	8,165	17,670	53.33
Ratios	2:1	2:1	1:1	1:1	1:1	1:2	1:1	
Faunal Types								
Epifauna	1,676	1,099	3,951	5,194	5,766	7,453	25,139	75.86
Infauna	286	228	863	723	1,128	4,769	7,997	24.14
Ratios	6:1	5:1	6:1	7:1	5:1	2:1	3:1	

Notes: Ratios are rounded off to the nearest whole number.
Habitats have been collapsed into Rocky Shores or Sand/Mud Flats.
The mean middle to lower and lower to subtidal zones are considered to be lower tidal range.
Percents are for the totals shown in this Table.

MNI estimates do not include counts from Features 1A, 3A, 6A.

all levels combined. The ratios are 2:1 for Rocky Shores to Sand and Mud Flats, 4:1 for Lower to Full Tidal Range, and 2:1 for Epifauna to Infauna.

Unit 2T

There is a total NISP of 14,895 and a total MNI of 1,891 representing 6.34% and 4.27% of the entire collection respectively. The percentage of MNI to NISP for this unit is 12.70% (a ratio of 8:1). The remains of 40 species were retrieved from Unit 2T, 13 of which occur above the trace level. These 13 species are listed in order from their highest to their lowest counts for all levels combined in Table 6. Table 6 also shows the species total MNI counts and ratios for the habitats, tidal range, and faunal types for all levels combined. The ratios are 4:1 for Rocky Shores to Sand and Mud Flats, 1:1 between tidal ranges, and 3:1 for Epifauna to Infauna.

Unit 4T

There is a total NISP of 47,931 and a total MNI of 3,469 representing 20.40% and 7.83% of the entire collection respectively. The percentage of MNI to NISP for this unit is 7.23% (a ratio of 14:1). The remains of 40 species were retrieved from Unit 2T, 13 of which occur above the trace level. These 13 species are listed in order from their highest to their lowest percentage for all levels combined in Table 7. Table 7 also shows the species total MNI counts and ratios for the habitats, tidal range, and faunal types for all levels combined. The ratios are 2:1 for Rocky Shores to Sand and Mud Flats, 2:1 for Full to Lower Tidal range, and 3:1 for Epifauna to Infauna.

INTERPRETATIONS

Unit 14, Locus B

Species from rocky habitats occur most frequently in the collection. This suggests that a predominantly rocky shore habitat was being exploited. However, this rocky shore environment included a bay/estuary habitat. This is evidenced by the MNI ratios between these three habitats. Some error might exist for these ratios because the *Ostrea*, which is included in the rocky habitats, may have been attached to rocks in the bay or to shell beds on the sand or mud flats. In fact, when the *Ostrea* and other bay/estuary species are separated into bay species as opposed to open coast rocky and open coast sandy a different picture emerges showing a 1:1 ratio throughout levels 3, 4, 5, and 6 and a 2:1 ratio for levels 1 and 2.

A closer look at the diagnostic species for these habitats reveals a rocky shores species (*Chiton*, *Crepidula*, *Crucibulum*, *Limpets*, *Mytilus*, *Ostrea*, *Pseudochama*, *Tegula*), and 3 sand/mud flat species (*Argopecten*, *Chione*, *Tresus*) occurring above the trace level. However, further breakdown of these species indicates only two (*Mytilus* and *Pseudochama*) are specifically open coast rocky shores species, while *Argopecten*, *Chione*,

TABLE 5

SPECIES IN ORDER OF ABUNDANCE AND SHOWING HABITAT, TIDAL RANGE, AND FAUNAL TYPE FOR UNIT 1T

SPECIES	HABITAT	TIDAL RANGE	FAUNAL TYPE	MNI COUNT
Ostrea	Rocky	Lower Range	Epifauna	n=284
Chione	S/M Flat	L/S Range	Infauna	n=234
Chiton	Rocky	Full Range	Epifauna	n=90
Protothaca	S/M Flat	M/L Range	Infauna	n=62
Pseudo/Chama	Rocky	L/S Range	Epifauna	n=62
Crucibulum	Rocky	Full Range	Epifauna	n=30
Tegula	Rocky	Full Range	Epifauna	n=28
Saxidomus	S/M Flat	L/S Range	Infauna	n=19
Mytilus	Rocky	Full Range	Epifauna	n=14
Sept/Horm	Rocky	M/L Range	Epifauna	n=10
Cerithidea	S/M Flat	Lower Range	Epifauna	n=9
Totals and Ratios	Rocky 518 S/M Flat 324 2:1	Full 162 Lower 680 1:4	Epifauna 527 Infauna 315 2:1	

TABLE 6

SPECIES IN ORDER OF ABUNDANCE AND SHOWING HABITAT, TIDAL RANGE, AND FAUNAL TYPE FOR UNIT 2T

SPECIES	HABITAT	TIDAL RANGE	FAUNAL TYPE	MNI COUNT
Ostrea	Rocky	Lower Range	Epifauna	n=341
Chiton	Rocky	Full Range	Epifauna	n=319
Chione	Rocky	L/S Range	Infauna	n=165
Protothaca	S/M Flat	M/L Range	Infauna	n=128
Crucibulum	Rocky	Full Range	Epifauna	n=117
Argopecten	S/M Flat	Full Range	Epifauna	n=115
Tegula	Rocky	Full Range	Epifauna	n=108
Pseudo/Chama	Rocky	L/S Range	Epifauna	n=83
Mytilus	Rocky	M/L Range	Epifauna	n=61
Astraea O	Rocky	Lower Range	Epifauna	n=40
Saxidomus	S/M Flat	L/S Range	Infauna	n=37
Astraea A	Rocky	Lower Range	Epifauna	n=21
Tresus	S/M Flat	Lower Range	Infauna	n=19
Totals	Rocky 1245	Full 659	Epifauna 1195	
and	S/M Flat 299	Lower 885	Infauna 349	
Ratios	4:1	1:1	3:1	

TABLE 7

SPECIES IN ORDER OF ABUNDANCE AND SHOWING HABITAT, TIDAL RANGE, AND FAUNAL TYPE FOR UNIT 4T

SPECIES	HABITAT	TIDAL RANGE	FAUNAL TYPE	MNI COUNT
Ostrea	Rocky	Lower Range	Epifauna	n=789
Protothaca	S/M Flat	M/L Range	Infauna	n=515
Chiton	Rocky	Full Range	Epifauna	n=315
Pseudo/Chama	Rocky	L/S Range	Epifauna	n=247
Mytilus	Rocky	Full Range	Epifauna	n=230
Tegula	Rocky	Full Range	Epifauna	n=206
Chione	S/M Flat	L/S Range	Infauna	n=169
Crucibulum	Rocky	Full Range	Epifauna	n=142
Modiolus	S/M FLat	Lower Range	Infauna	n=86
Argopecten	S/M Flat	Full Range	Epifauna	n=51
Saxidomus	S/M Flat	L/S Range	Infauna	n=47
Sept/Horm	Rocky	M/L Range	Epifauna	n=37
Astraea	Rocky	Lower Range	Epifauna	n=36
Gastropod	Rocky	Full Range	Epifauna	n=36
Totals	Rocky 2038	Full 980	Epifauna 2089	
and	S/M Flat 868	Lower 1926	Infauna 817	
Ratios	2:1	2:1	3:1	

Crucibulum, Ostrea, and Tresus are specifically bay/estuary species. Chitons, Crepidula, Limpets, and Tegula might occur either in bays or along open rocky coasts. No diagnostic species above the trace level are present for open sandy shore habitats. The low incidence of open sandy shore species suggests that an open sandy beach was present, but that it was either farther away or not often frequented because of collection economics. Through time, Mytilus and Pseudochama are collected in lesser numbers while Chione, Crucibulum, and Ostrea remain relatively high in numbers. This suggests that in the time of the later occupations the rocky foreshores may have been lost, or replaced by the cobblestone beach presently at this locale. Therefore, it is most likely that a rocky bay/estuary habitat was dominant.

Species from the lower, and perhaps the middle, tidal zones occur more frequently in the collection than species from the upper zones. This suggests that overall scheduling for this marine resource was in favor of the lower tidal range. The diagnostic species occurring above trace levels are Astraea, Chione, Modiolus, Ostrea, Pseudochama, and Saxidomus, and all of these are located in the lowest tidal range. Only half of these species (Chione, Ostrea, and Pseudochama) are still being collected in the upper levels of occupation. This supports the suggestion that scheduling favored times during low tides, but that eventually species from the entire range were collected.

Substrate types should more realistically reflect the ratios of rocky to non-rocky species because, while an organism may survive in a particular habitat and habitats can vary by constituent make-up, an organism's choice of substrates is almost always specific to its survival. Still, some substrates can cloud interpretations if they appear in habitats in which they would not normally occur. The combined ratio suggests an equal amount of organisms from rock and sand/mud substrates were being collected regardless of habitat. The diagnostic species occurring above the trace levels for rock substrates (Astraea, Chitons, Limpets, Mytilus, Pseudochama, Tegula), and sand/mud substrates (Argopecten, Chione, Protothaca, Saxidomus, Tresus) suggest a 1:1 ratio for species removed from hard and soft substrates. Of these species, only Chitons, Limpets, and Tegula for rock substrates and Chione and Protothaca for sand/mud substrates (still suggesting a 1:1 ratio). A look at the order of species abundance also suggests that rock and sand/mud substrates yielded roughly equal amounts of resources.

Epifauna occur more frequently in the collection than infauna. The higher occurrence of epifauna suggests that either the occupants at this locus sought the more easily procured organisms, and/or that those organisms representing the epifauna were more numerous. Epifauna are usually the most obvious and easily captured shellfish, sometimes requiring little more than quickly plucking the animal off of the rocks. At worst, the use of some sort of pry bar might be necessary, or perhaps the animals attached portion might be smashed (using any object handy at the time) to facilitate easier removal. Infauna require at least some additional effort to collect, because they must be dug from their substrate. However, some organisms are more easily removed (e.g., Chione and Protothaca) because they do not dig as quickly or as deep as other organisms.

Units 1T, 2T, and 4T, Locus A

The units at locus A show some variation between themselves but are basically comparable to Unit 14. It is possible that unit depths may have affected ratios by varying their volumes (Units 1T, 2T, and 4T are 60, 70, and 100 centimeters respectively). The species present in Units 1T and 2T most closely approximate levels 4 and 5 in Unit 14, while 4T is similar to the species in level 6. In fact, Unit 4T is generally similar to level 6 for Unit 14 in all regards (habitat, tidal range, and faunal types). Unit 2T is also generally similar to level 5 for Unit 14 in regard to habitat, tidal range, and faunal types, while Unit 1T varies somewhat and more closely approximates level 6. It is likely that the remains retrieved from Units 1T, 2T, and 4T represent a time period somewhere from the middle to the earlier occupational levels of Locus B. In other words, the remains from Units 1T, 2T, and 4T fit within levels 4, 5, and 6 in a chronological sense. If this is so, then species blocks showing the order of abundance may be a useful tool for correlating horizons or levels within a site or between loci of the same site.

DISCUSSION

The interpretations above may indicate 1) shifts in subsistence requiring less exploitation of shellfish due to an increasing dependence upon other food resources, 2) shifts in procurement methods and scheduling that consolidated collection efforts allowing more return for less effort, 3) an overall decrease of all procurement activities at this locus due to population decreases, assimilation impacts, or change to a more seasonally based usage for the locus, 4) shifts in environmental conditions limiting the availability of all or certain species of shellfish, 5) the shellfish were being "overfished" by the aboriginal population.

The first argument is reasonable only if corresponding shifts in the opposite direction are evident in the other faunal sample assemblages. An examination of the terrestrial faunal totals by level show that there is a general decrease through time, with a slight increase in level 1 (number counts for levels 1 through 6 are 32, 29, 87, 115, 154, and 327 respectively). In addition, the marine vertebrate remains shows that the numbers for the California sheephead (Semicossyphus pulcher), which was the most collected marine vertebrate species, follow the same pattern as the marine invertebrate remains (the number counts for levels 1 through 6 are 617, 355, 1,559, 1,667, 2,459, and 1,524 respectively). The numbers for the sheephead in levels 5 and 6 appear reversed in comparison to the numbers for the shellfish. This may indicate an increased effort at obtaining these organisms (see Gallegos 1988).

An increased dependence upon plant materials may have produced or compensated for the fluctuation in the shellfish collecting. Although plant materials may not survive in the fossil record, the tools used to process the materials will remain and quantities should reflect any changes in subsistence. An examination of the cultural material by level indicates a similar pattern of decreasing quantities of flakes, flake tools, debitage, and groundstone differing only with the apparent absence of flake tools and ground stone in levels 1 and 2. This may indicate a lesser dependence on non-marine fauna and/or a seasonal factor at work (see Gallegos 1988).

The second argument is reasonable if it can be shown that there is a change in the patterns of resource collection. There does appear to be change in procurement and scheduling through time for this collection. As already noted, it seems evident that marine invertebrates from a bay/estuary habitat were most often collected, and this remained unchanged through time. It is also evident that collecting occurred more often during lower tides in the earlier occupational level, which shifted toward ambiguity during the middle levels of occupation until, in the later occupational levels, the full tidal range was being exploited. However, the collecting probably took place during the time of a low tide. This signifies a change from a more rigid collecting schedule to one more flexible. Epifauna were always selected over infauna, although the selection increases with time. However, it appears as if certain species were being collected because they were easier to obtain and not because they had more body mass.

The third argument is also reasonable provided that the other data sets indicate that a) there was a population decrease which in turn affected the amount of shellfish (and other fauna) collected (whether directly or indirectly), b) the artifact assemblage shows similar changes, and/or c) there is no seasonal pattern evident within the temporal framework. The other data sets (lithics, faunal) do show a pattern similar or identical to that of the marine invertebrates, that is, a decreasing amount of material remains through time. However, unlike the lithics, all faunal materials increase in numbers again in level 1. If the animal remains (except for marine invertebrates) suggest fairly consistent amounts through time, it should be safe to assume that the population remained fairly consistent and that dependence shifted from one food resource to another. However, if the shellfish are the major resource constituent, then fluctuations within the temporal framework may indicate fluctuations in the population at this locus provided that there is little or no seasonal factor at work, and especially if the other resources mirror these fluctuations. In this case, it appears that all of the other resources follow the same basic pattern as the shellfish, and that lithic quantities also decrease or disappear completely.

The fourth argument is reasonable only if it can be shown that decreasing amounts of species or changes in species collected has been directly affected by changes in the environment (e.g. to the substrate or the habitat), and that these changes were drastic enough to cause the changes in species amount and variety. A drastic change in the environment is not likely considering the rate projected for sea level rise during the periods of site occupation (10 centimeters per century, or one millimeter per year). In fact, the similarity of the make-up of the species blocks suggests that nothing more drastic than simple biosuccession fluctuations through time is occurring. While it is apparent that species variety was decreasing from the earlier to the later occupational levels (level 1 has one-half the number of species of level 6), this may indicate a shift in the environment, that certain species were being "fished out" (see the fifth argument below), or that the site inhabitants were selecting certain species over others and reducing or deleting these other species from their collecting efforts as a matter of economics. It is apparent that, in this collection, it is more likely certain species were being selected for through time. However, more subtle changes in the environment are apparent by the loss of certain minor species.

The fifth argument is reasonable if it can be shown that certain species were being "fished out". This might be seen in the collection as certain species appearing in smaller sizes through time. The consistency of the most frequently collected species and the variety of their size classes in all levels does not support the overexploitation of resources to explain the decreasing species variety, or their decrease in quantity, through time.

SUMMARY

From 1500 to 6000 years B.P., the inhabitants of SDi-48 collected marine invertebrates from the nearby rocky bay/estuary habitats. The most noticeable change during this timeframe is the decrease in the amount and variety of the shellfish collected from level 6 to level 1. The analysis suggests that a shift in procurement methods and scheduling and, to a lesser degree, a changing environment serve to explain the changes in species abundance and variety, and a preference of certain species over others through time. Such shifts from early to later occupation included selection of easily procured organisms, inclusion of species from all tidal zones, and a loss of open coast species. The continuity of species present and the quantity of shell points toward a single group of somewhat sedentary people who were refining their resource procurement to ensure a maximum return for minimal effort.

CONCLUSIONS

This study was successful in showing the usefulness of NISP and MNI in the analysis and interpretation of marine invertebrate remains recovered from archaeological sites. Using these techniques, a reconstruction of the general environment, and the ecology and behavioral activities of the site occupants was possible. It was determined that:

1) A decrease in the quantity and diversity of marine invertebrate resources occurred over time until the latest level of occupation when a 50% increase in quantity was apparent.

2) The majority of species came from a rocky bay/estuary environment, and minor environmental changes may have been responsible for the loss of open coast species, and further embayment through time.

3) Collecting occurred most often during low tides, but changed over time, from an earlier preference for times of lowest tides and lower tidal zone species, to an inclusion of more species representing the full tidal range.

4) An equal amount of species from hard and soft substrates were collected.

5) More epifauna were selected, or more epifauna were present for collection by the site inhabitants.

6) Those organisms that were easiest to collect were selected over other species available.

7) It is possible that species blocks may be used to correlate horizons or levels within a site, and between loci of a site.

NOTES

The author thanks the following assistants and students whose hard work greatly aided and accelerated this analysis. They are: Vicki Mason, Marv Malkson, Anita Creer, Florine Carson, Jackie Hanson, Larry Carbone, Arthur Kuhner, Jeanne Tealer, Suzanne Bennett, Amy Schroth, Patty Singer, John Goodman, Mike Foertsch, Richard Shube, Allyson Asher, Bill Wilson, Ted Schickler, Challys Estabrook, Ronnie Pavone, Gino Calvino, and Theresa Cerreto. Chris Drover was also helpful during this project. The author also specifically thanks Mark Peterson, Wayne Bonner, and Karen Cerreto, whose invaluable time was generously shared, Adella Schroth and Ivan Strudwick who read and criticized the earlier version of this report, and the attendants of the Westec consultants meeting wherein

much information and numerous ideas were shared.

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