CHAPTER 13

Sampling Issues in Evaluations of Diet and Diversity:

Lessons from Diablo Canyon

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Although California can lay claim to some of the earliest studies of hunter-gatherer faunal residues in western North America (e.g., Howard 1929), problem-oriented faunal analysis is a relatively recent development that emerged coeval with and as an integral part of the "new" archaeology in the 1970s. California had a long history of involvement with shell midden archaeology prior to the processual revolution, with much thought devoted to problems of sampling and interpreting invertebrate remains (e.g., Gifford 1916, 1949; see reviews by Claassen 1998; Waselkov 1987). Studies of vertebrate remains, however, were relatively uncommon until the 1970s (although see Follett 1957). While the early faunal studies were innovative in simply completing and reporting bone identifications (e.g., Busby 1975; Follett 1975), remarkably sophisticated analyses of specific classes (for example, fish remains) were also undertaken (e.g., Casteel 1974; Casteel et al. 1977; Fitch 1972). By the 1980s, collection of all vertebrate remains was standard practice in California, and a number of studies used robust, statistically meaningful vertebrate samples to address issues of subsistence and cultural ecology (e.g., Cope 1985; Dietz and Jackson 1981; Gifford and Marshall 1984; Hildebrandt 1981; Koerper 1981; Simons 1979, 1981a, 1981b; Watts 1984).

Since the 1990s, vertebrate remains from California have been increasingly used to address questions derived from optimal foraging and other applications of human behavioral ecology. While many studies continued to focus on molluscan remains (e.g., Erlandson 1991; Jones 1991; Jones and Richman 1995; Raab 1992), issues of optimization and resource suppression have been increasingly addressed with vertebrate collections (e.g., Broughton 1994a, 1994b, 1997, 1999; Hildebrant and Jones 1992, 2002; Salls 1992; Simons 1992). Most recently, these studies have extended beyond optimal foraging to include costly signaling (e.g., Broughton and Bayham 2003; Codding and Jones 2007; Hildebrant and McGuire 2002; Jones, Porcasi, et al. 2008; McGuire and Hildebrandt 2005; McGuire et al. 2007). Inherent in many hypotheses derived from behavioral ecology are questions about diet and diversity. While methods used to reconstruct diet from faunal residues have been productively debated (Claassen 2000; Glassow 2000; Mason et al. 1998, 2000), techniques used to assess diversity have not received nearly as much attention in California as they have elsewhere (e.g., Cannon 1999, 2001; Grayson and Delpech 1998, 2003; Jones 2004; Leonard and Jones 1989; Vale and Gargett 2002; Zohar and Belmaker 2005). This is in spite of the importance of diet breadth and relative

evenness to optimization models, and the likelihood that such variables can be influenced by field and analytical sampling strategies. Kintigh (1989) was one of the first to evaluate the effect of sample size on assemblage diversity. Here we build on his work using the trans-Holocene faunal collection from CA-SLO-2 at Diablo Canyon on the coast of San Luis Obispo County in central California to discuss how certain aspects of field sampling, particularly excavation volume and screen size, influence perceptions of faunal diversity. The faunal remains from this site were recovered 40 years ago from an extensive mixed-recovery strategy that combined a large excavation volume processed with 1/4-inch (6-mm) mesh with a smaller recovery volume (a column sample) processed intensively with 1/16-inch (1-mm) mesh (Fitch 1972; Greenwood 1972). Findings from this investigation show that with respect to diversity, it might be more important to control mesh size in comparisons between spatial and temporal faunal components than to rely exclusively on one particular mesh (for example, 1/8 inch [3 mm]) for all sampling. Residues obtained from smaller mesh yield greater numbers of species and produce higher diversity values, but relative diachronic trends are exactly the same for assemblages collected with small versus large mesh. Overreliance on smaller mesh in field recovery can generate robust assemblages of microfauna, but samples of large vertebrates may be inadequate for statistically meaningful evaluation because such remains often occur in low frequencies. Thus the only way to obtain reasonable samples is to excavate sufficient volumes from deposits. Lost in all the discussions about mesh bias, however, is the fact that any mesh size provides only a relative index of the faunal component of subsistence. Relative diachronic patterns over time, regardless of mesh size, are probably more important than any one mesh class as a representation of "absolute truth."

OPTIMIZATION MODELS, DIVERSITY, AND SAMPLE SIZE

Optimization models have been employed in California for more than three decades (e.g., Beaton 1973; Broughton 1997; Erlandson 1991; Hildebrandt 1984; Jones 1991; Kennett 2005), although the earlier applications were less explicit in their use of optimization theory and/or less rigorous in their evaluation of empirical evidence. Typically archaeologists implicitly or explicitly draw on one (or more) of four models: the prey choice model (e.g., Bayham 1979), the patch choice model (e.g., Jones 1991), central place foraging models (e.g., Cannon 2003), and ideal free (or despotic) distribution models (e.g., Kennett 2005; Kennett et al. 2006). Of these, archaeologists most frequently rely on the prey choice model. Prey choice models evaluate the resources a forager should take on encounter within a homogenous patch (Stevens and Krebs 1986; Winterhalder 1981). The model predicts that foragers should preferentially select prey to maximize the rate at which resources (typically measured in kilocalories) are acquired; whether or not a resource should be taken on encounter depends on the abundance of the *highest* ranking resource. When encounter rates with the highest ranking resource decline, foragers should widen their diet breadth, in turn selecting a more diverse set of prey. Since these newly incorporated prey types are relatively low ranked, widening diet breadth is typically associated with declining foraging returns (e.g., Broughton 1997; Jones 2004).

For these reasons, diet breadth and diversity are the key components of prey choice models that researchers rely on to evaluate zooarchaeological assemblages. However, our interpretations of these models may be prejudiced by sampling bias, since some excavation techniques, particularly mesh size, can strongly influence perceptions of diet breadth and diversity (Cannon 1999, 2001; Vale and Gargett 2001). Here we suggest that three interrelated problems related to mesh size influence attempts to evaluate diet breadth archaeologically: (1) large mesh underrepresenting small taxa such as fish and rabbits; (2) large mesh misrepresenting diversity because small species are either under- or unrepresented in collections; (3) small samples that are inadequate for statistical analysis, the smallness of the sample being the result of the time involved in processing with small mesh and small excavation

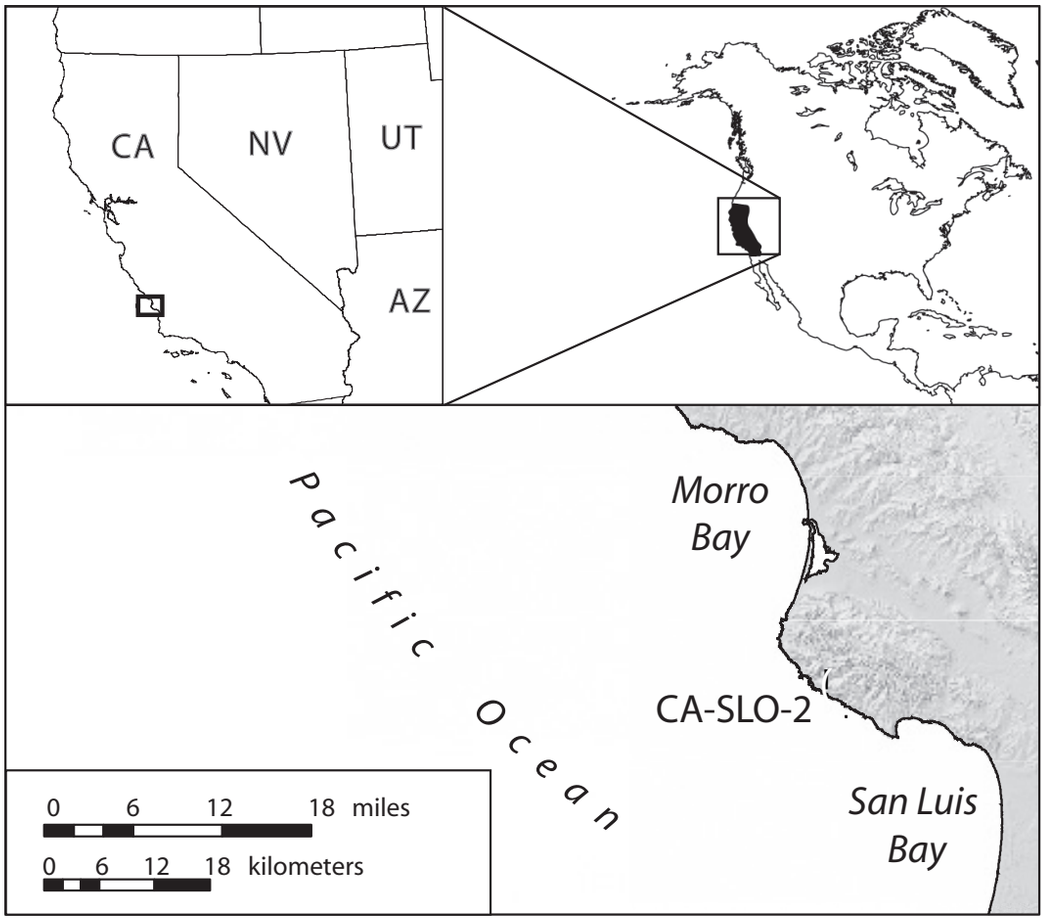

Figure 13.1. Location of CA-SLO-2.

volumes. This latter issue has been well documented by ecologists who attempt to sample and quantify biological diversity among living populations (see Magurran 1988, 2004).

Mesh Size and the Underrepresentation of Microfauna

Early thinking on the issue of screen size in faunal recovery and interpretation focused on the fact that the remains of small animals can be either wholly unrepresented in samples collected with large mesh (larger than 1/4 inch) or underrepresented (Thomas 1969). The logic underlying this issue is relatively simple in that screens with larger apertures fail to capture the remains of small animals whose skeletons are composed of small bones (as well as small artifacts such as certain types of shell beads [Erlandson 1994:54]). This issue is most apparent with fish bones (e.g., Casteel 1972; Fitch 1967, 1972), which are commonly underrepresented in samples from large mesh (e.g., Butler 1993; Gobalet 1989; and many others), but small mammals (James 1997; Stahl 1996) and mollusks (Muckle 1994) have also been shown to be underrepresented in samples collected with large mesh. Underrepresentation of certain molluscan taxa with use of larger mesh is more a problem of taphonomy than sampling, however, since fragile, thin-shelled species tend to be more underrepresented in samples from large mesh than species with durable shells. With fish and other small vertebrates, taphonomy is a contributing factor, but the size of the animal is clearly the most important variable.

The dietary importance of small but ubiquitous taxa, such as anchovies and rabbits, might be underrepresented in samples processed exclusively with

large mesh. These taxa might have been dietary mainstays in certain places at certain times, but an adaptation in which such resources were staples could be easily misinterpreted with a field program that relied exclusively on large mesh. This point has been made most frequently for fish remains, with the idea that the importance of fish in prehistoric diets can be seriously underestimated when 1/4-inch mesh is employed to investigate deposits that contain the remains of many small-bodied fish (see Gordon 1993; James 1997). The same basic case has been made for rabbits (James 1997).

Importantly, James (1997) is one of the few to suggest that a solution to the mesh bias problem might be found in field programs that incorporate multiple sampling strategies (for example, partial wet-screening of deposits with 1/8-inch mesh) and proportional "correction factors" to make the samples comparable. Cannon (1999) subsequently rejected this proposal on the grounds that "correction factors" do not produce accurate results. Nonetheless, James stands as one of the few researchers to acknowledge the costs of time and money associated with exclusive use of small mesh.

Mesh Size and the Underrepresentation of Diversity

Beginning in the 1990s, problems with mesh-related recovery bias were increasingly related to issues of diversity and its two subcomponents: richness (the number of taxa present) and evenness (the relative abundance of taxa). This shift was a direct result of the increasing application of diet breadth and economic intensification models that emphasize the number of species exploited by prehistoric people and the relative importance of various taxa. The basic issue of large mesh underrepresenting small taxa, as discussed above, is the same, but the shift to an emphasis on diversity brought with it a slightly different quantitative focus.

The problems involving mesh size and diversity are well summarized by Gordon (1993), who compared faunal findings from two excavations at the Nu'alolo Kai site on Kauai Island, Hawaii: one completed in 1960 that employed "old-fashioned" methods (for example, a large excavation volume [382 m^3] screened exclusively with 1/4-inch mesh), and the second a single 1-×-2-m (3.4 m^3) unit excavated in 1990 with 1/8-inch mesh. Findings were similar to many previous studies showing that units processed with small mesh produced substantially more fish bones than those processed with 1/4-inch mesh. The overall adaptation suggested by the 1/4-inch investigation showed a heavy focus on birds, parrot fishes, rainbow fishes, wrasses, and pigs, while the 1/8-inch residues suggested an emphasis on a variety of different fishes and rats, with less use of pigs. More importantly, Gordon (1993) also showed that more fish taxa were recovered from the unit processed with 1/8-inch mesh (Table 1), indicating greater taxonomic richness for fish than was suggested by the earlier study. Furthermore, evenness was misrepresented by the findings from the ¼-inch excavation, which suggested a fairly specialized fishery dominated (65 percent) by parrot fishes, rainbow fishes, and wrasses (Table 2). Findings from the 1/8-inch excavation showed a more even distribution of taxa, with the wrasse family accounting for only 32 percent of the NISP. However, Gordon failed to acknowledge that the 1/8-inch sample of nonfish showed lower richness (fewer exploited taxa) than the 1/4-inch sample. She was also criticized for including taxa that may not have been dietary (rats and filefishes) in her analysis (Dye 1994). Nonetheless, she concluded, as have many others, that "interpretations of prehistoric human subsistence from faunal remains recovered by the larger screen sizes are questionable" (Gordon 1993:523).

Gordon's conclusions were subsequently challenged by Vale and Gargett (2002) based on findings

Table 13.1. General Findings from Two Excavations at Nu'alolo Kai, Kauai Island, Hawaii.

Mesh Size	**¼ inch**	**1/8 inch**
Excavation volume (m3)	382	3
Fish NISP	714	857
Number of fish taxa	19	21
Nonfish NISP	1,176	352
Number of nonfish taxa	8	5
Total NISP	1,890	1,209
Total number of taxa	27	26

Note: From Gordon 193:454–455.

Table 13.2. Summary of Key Fish and Nonfish Findings from Two Excavations at Nu'alolo Kai, Kauai Island, Hawaii.

	1/4- inch			1/8-insch inch		
Rank	Common name (Taxon)	NISP	%	Common name (Taxon)	NISP	%
			Fish			
1	Wrasses (Labridae)	463	65	Wrasses (Labridae)	277	32
2	Parrotfishes (Scaridae)	92	13	Filefishes (Monacanthidae)	201	24
3	Surgeonfishes and tangs (Acanthuridae)	34	5	Surgeonfishes and tangs (Acanthuridae)	86	10
			Non-Fish			
1	Bird	493	42	*Rat* *Rattus* sp.	166	47
2	Dog (*Canis familiaris*)	244	21	Bird	129	37
3	Pig (*Sus scrofa*)	220	19	Dog (*Canis familiaris*)	28	8

from an Australian shell midden (Arrawara I), where they found no additional taxa with 1/8-inch mesh than with 1/4-inch mesh, meaning no difference in richness between the two mesh sizes. Furthermore, a subsample processed with 1/16-inch mesh produced only a single additional taxon. Importantly, they recognized that most of the bony elements from that small fishes available to the Alawarra I inhabitants became unidentifiable when fragmentary; therefore the smaller mesh residues added nothing to the overall sample. They concluded that while zooarchaeologists have long said it is imperative that 1/8-inch mesh be employed at all times, the contribution of the 1/8-inch mesh depends on the nature (and size) of fishes available in local fisheries and post-depositional conditions. These conclusions were subsequently challenged by Zohar and Belmaker (2005), who questioned the small size of the 1/16-inch subsample analyzed by Vale and Gargett and suggested that if a volumetrically appropriate 1/16-inch sample was analyzed, 14 additional taxa would have been discovered. Their reanalysis of the Vale and Gargett data was strictly mathematical, however, and did not demonstrate that 14 additional small taxa were present to be found in the Australian fishery. Gobalet (2005) expressed similar concerns about the methodology employed by Vale and Gargett. Overall, these three studies offer no clear consensus on the issue of diversity (and its two subcomponents, richness and evenness) and mesh size.

Diversity and Sample Size

Underlying the issue of screen size are more basic issues related to the measurement and statistical evaluation of diversity, addressed most thoroughly by ecologists (see Magurran 1988, 2004). In many archaeological applications of the prey choice model, a key variable is dietary diversity (e.g., Grayson et al. 2001; see also Jones 2004). In attempts to measure biological diversity, it has long been recognized that number of taxa identified is clearly correlated with sample size. As sample size increases, the number of taxa identified increases, until a point at which further sampling would be redundant; however, this point is rarely, if ever, reached by archaeological research programs (Orton 2005). This situation is directly relevant to archaeological sampling strategies, as larger excavation volumes inevitably produce evidence of a greater number of taxa. Such results can be seen in the Gordon study, where more taxa were recovered from the 1/4-inch sample because excavation volume was considerably larger than with the 1/8-inch sample (Table 1). Fish remains showed greater richness in the 1/8-inch sample, but nonfish remains did not. Mathematical calculations (for example, Margalef's Index) have been developed

to compensate for the effect of sample size, but it is important to realize that even these cannot deal effectively with small samples. A basic premise underlying diversity sampling is that a reasonable attempt must be made to try to identify the range and relative representativeness of taxa within the sampling universe. For archaeological sites, this generally means that a substantial excavation volume must be investigated. Because it is more time-consuming to process deposits with small mesh, it is common for investigations relying exclusively on small mesh and targeting microfauna to be limited to relatively small recovery volumes. In California, the remains of larger animals are usually highly fragmentary and cannot be readily identified to species. To recover robust collections of identifiable specimens, it is usually necessary to excavate large excavation volumes. While there is no consensus on what constitutes an adequate sample for this purpose, findings from CA-SLO-2 at Diablo Canyon on the central California coast provide some insights into this issue and questions concerning evaluations of diversity and mesh size.

THE DIABLO CANYON FAUNA

CA-SLO-2 was one of six sites investigated in 1968 in anticipation of the construction of the Diablo Canyon Power Plant. The site is an unusually large (approximately 400-×-320-m) and deep (3.4-m) midden, situated on a narrow coastal terrace on the north bank of Diablo Creek in San Luis Obispo County. Its formal artifacts and a sample of faunal remains were reported in 1972 by Roberta Greenwood. More recently the remainder of the faunal collection was analyzed, and a suite of new radiocarbon dates shows that the site was occupied intermittently from ca. 8300 cal B.C. through historic contact (A.D. 1769) (Jones, Porcasi, et al. 2008). Four temporal components have been identified within this overall span of occupation: component I (280–340 cm), dating to 8300–6500 cal B.C.; component II (200–280 cm), dating to 5000–3000 cal B.C.; component III (70–200 cm), dating to 1600 cal B.C.–cal A.D. 1000; and component IV (0–70 cm), dating to cal A.D. 1500–1769. The faunal collection associated with these occupations included more than 35,000 bird, mammal, reptile, and fish remains with more than 12,000 identified to a meaningful taxonomic level (genus for mammals and birds; family for fish). The collection is curated by the San Luis Obispo County Archaeological Society Collection Repository on the Cuesta College campus in San Luis Obispo.

Sampling Strategy

From the standpoint of sampling methodology, the Diablo faunal collection was generated through a mixed recovery strategy that was designed to sample artifacts, microfaunal remains, and macrofaunal remains as efficiently as possible. Three different field sampling methods were employed, each with a different objective. Thirty 1-×-2-m units, distributed randomly through the direct impact area, were processed with 1/4-inch mesh and were intended to provide large samples of artifacts and remains of large animals; a 25-×-25 cm column (0.8 m^3) was water-processed with 1/16-inch mesh to recover fish bones; and a 1-×-1-m unit was processed with nested 1/4-inch and 1/8-inch mesh to recover shell remains. A total of 109 m^3 of deposit was excavated from the 1-×-2-m units, although only 98.9 m^3 could be accounted for in the most recent faunal analysis due to attrition to the collection while it was in storage for 30 years. Findings from the fish and shell columns were reported in detail in the 1972 monograph (Fitch 1972; Greenwood 1972), while the complete vertebrate findings from the 1-×-2-m units were reported more recently (Jones, Porcasi, et al. 2008). Fitch's analysis of the fish bone column is particularly important because it represents one of the most intensive analyses of fish bone ever completed in California. Fitch used a microscope to sort and identify fish bones from the column and took approximately 900 hours to complete the identifications (Fitch 1972:102). It is highly unlikely that anyone will ever repeat such an intensive analysis. Given the constraints of time and money on archaeological excavations, both the macro and micro samples from Diablo Canyon must be considered adequate representations for the site as a whole. The Diablo collection

also provides an opportunity to evaluate relative diachronic trends based on variation across four temporal components. Such diachronic variability was not considered in either the Gordon (1993) or Vale and Gargett (2002) studies.

The faunal collection from CA-SLO-2 is similar to that from the Gordon (1993) study from Hawaii in that it includes remains recovered from a relatively large recovery volume (98.9 m^3) excavated with 1/4-inch mesh and a control sample recovered from a smaller volume (0.8 m^3) and processed more intensely, in this case with 1/16-inch mesh. Details of the analytical procedures employed in the analyses of these remains are found in Fitch (1972) and Jones, Porcasi, et al. (2008). A total of 13,517 bird, mammal, and reptile remains, including specimens from of a variety of small burrowing animals (for example, Botta's pocket gopher [*Thomomys bottae*] and California ground squirrel [*Spermophilus beecheyi*]), were identified from the 1/4-inch mesh sample. Because it is highly likely that these elements were intrusive, they were removed from further consideration. Dye (1994) noted that Gordon (1993) did not take this step in her analysis of finds from the Hawaiian middens, which flawed the study. For interpretive purposes, the Diablo collection was further compressed by eliminating specimens that could not be identified to the genus level for birds and mammals or to the family level for fish. The resulting sample for birds and mammals includes 2,789 NISP (Table 3) representing 29 species of birds, 15 terrestrial mammals, seven marine mammals, and one reptile (the western pond turtle [*Clemmys marmorata*]). A total of 9,646 fish bones was identified from the 1/4-inch sample; 6,070 to the family level or better.

Analytical Methods

Analysis focused on two measures: bone counts, and diversity measures derived from those counts. To assess trends in the variation of bone counts, an χ^2 test was performed. Because χ^2 tests run on contingency tables with small marginal totals should be regarded with suspicion (Shennan 1997), we ran a Monte Carlo simulation with 2,000 iterations based on the structure of the data; χ^2 and alpha (*p*) value were then calculated by comparing the actual data to the simulated data (R Development Core Team 2008). To further examine how the bone counts of particular species varied between the 1/4-inch and 1/16-inch mesh samples, the adjusted residuals (calculated as the observed count minus the expected count over the square root of the expected count) were examined for the five highest ranking taxa in each sample, and alpha (*p*) values were calculated utilizing a function in R that draws on the binomial probability theorem to generate probabilities based on observed and expected cell counts (see Everett 1977).[1]

Further analysis utilized four diversity measures. The first two (ΣTAXA [or *S*] and Margalef's index) are a measure of species richness, while the second two (Berger-Parker's index and Simpson's evenness) examine species evenness (see Magurran 1988, 2004). While the number of taxa in a sample (ΣTAXA) is the typical measure of species richness, Margalef's index attempts to control for sample size by normalizing the sum of all taxa by the sum of individual specimens. Species evenness (and the inverse, dominance) are best thought of as a measure of the relative abundance of each taxa represented in the sample. Berger-Parker's index measures evenness by the number of specimens in the highest ranking taxa over the sum of all individual specimens. It is usually expressed as its reciprocal to ensure that an increase in the index value corresponds to an increase in diversity; thus a decrease in the index value corresponds to increasing dominance (or specialization). Simpson's evenness is one of the more robust and easily interpretable evenness measures (Magurran 2004). To help control for bias introduced by sample size, Simpson's is typically expressed as its inverse over the sum number of taxa represented in the sample. In this form, its value ranges between 0 and 1 and is typically interpreted as the probability that two specimens come from two different taxa if randomly drawn from the sample. Equations and worked-out examples are found in Magurran (2004).

To evaluate the relative trends in diversity between assemblages through time, a generalized linear model (GLM) with specified family (or error structure) and link function was run on the

diversity values for each assemblage per component. Poisson-log, gamma-inverse, and binomial-logit family and link functions were used for count data, nonnormally distributed data, and data bound between 0 and 1, respectively (see Faraway 2005, 2006). All analysis was performed in R 2.6.2 (R Development Core Team 2008).

Sample Comparisons

An χ^2 test comparing the overall 1/4-inch sample with the 1/16-inch sample shows that the two differ from one another significantly (χ^2 = 4,638.71, p = .0004; see Table 3). An examination of the adjusted residuals shows that four of the top five taxa are overrepresented in the 1/4-inch sample when compared to the 1/16-inch sample. These are lingcod (*Ophiodon elongates*), cabezon (*Scorpaenichthys marmoratus*), rockfishes (*Sebastes* spp.), and pricklebacks (*Stichaeidae*); all differ significantly than what might be expected by chance alone (see Table 3). Likewise, four of the top five represented in the 1/16-inch sample are overrepresented when compared to the 1/4-inch sample. These are wolf-eel (*Anarrhichthys ocellatus*), surfperch (*Embiotocides*), northern anchovy (*Engraulis mordax*), and night smelt (*Spirinchus starki*). The former four are all relatively large, line- or spear-caught taxa, while the latter four are all relatively small, typically net-caught taxa (Love 1996; Salls 1988).

Overall, the 1/4-inch mesh sample suggests that larger species—rockfish and cabezon—were the most commonly exploited fish (Table 3). Surfperches, on the other hand, are not represented among the top five taxa in the 1/4-inch sample, but they dominate the 1/16-inch sample. Northern anchovies, a very small fish, are also represented in considerably higher frequencies by the 1/16-inch mesh sample. This pattern is very similar to that identified in the Gordon study, in which a small taxon, filefish, was more heavily represented in the small-mesh samples. As with the Hawaiian study, there are unresolved questions about the dietary significance of the small fish, since Fitch (1973:108) realized that the anchovy bones in the CA-SLO-2 midden probably arrived via the stomach contents of larger fish and marine mammals and do not necessarily reflect human subsistence. Thus, while smaller fish are underrepresented by the larger mesh size, the implications of this difference for issues of diet and prey diversity are less clear.

Comparisons of ratios derived from the two samples demonstrate more clearly the differences in interpretation caused by mesh size. For the site as a whole, a ratio of fish bone (n = 6,007) to deer bone (n = 1,201) based on the 1/4-inch sample is approximately 5:1, while in the 1/16-inch sample, the ratio of fish to nonfish is only 2.1:1. Fitch (1979) did not provide a detailed report of nonfish remains in the 1/16-inch column. However, if the 1/16-inch

Table 13.3. Summary of Macro- and Microfaunal Samples from CA-SLO-2.

		6-mm (1/4-Inch) Mesh Sample					1-mm (1/16-Inch) Mesh Sample				
Taxon	**Common Name**	**Count**	**Rank**	**Percent**	**Residuals**	***p***	**Count**	**Rank**	**Percent**	**Residuals**	***p***
Anarrhichthys ocellatus	Wolf-eel	0	-	.00	-9.75	< .0001	116	3	8.72	20.83	< .0001
Embiotocides	Surfperch	225	4	3.71	-14.52	< .0001	473	1	35.54	31.01	< .0001
Engraulis mordax	Northern anchovy	0	-	.00	-12.01	< .0001	176	4	13.22	25.66	< .0001
Ophiodon elongatus	Lingcod	200	5	3.29	2.60	.0058	3	-	0.23	-5.55	< .0001
Scorpaenichthys marmoratus	Cabezon	2,176	2	35.85	9.07	< .0001	9	-	0.68	-19.37	< .0001
Sebastes spp.	Rockfishes	2,788	1	45.93	6.44	< .0001	221	2	16.60	-13.76	< .0001
Spirinchus starki	Night smelt	0	-	.00	-8.83	< .0001	95	5	7.14	18.85	< .0001
Stichaeidae	Pricklebacks	357	3	5.88	3.75	.0001	0	-	0.00	-8.01	< .0001
Other		324	-	5.34	-	-	238	-	17.88	-	-
	Total (*n*)	6,070					1,331				

Notes: From Jones et al. 2008; Fitch 1972. An χ^2 test was run on all identifiable taxa (χ^2 = 4,638.71, p = .0004); only a subset of the top five for each sample are shown here.

mesh sample is extrapolated volumetrically to make it comparable to the 1/4-inch sample, the fish-to-deer bone ratio is 137:1. While ratios derived from the 1/4-inch mesh suggest a modest emphasis on fishing by the Diablo inhabitants, the 1/16-inch sample suggests an intensely maritime adaptation. This is the same relative trend identified in many other comparisons between mesh sizes, but in this instance the results are slightly exaggerated by the strong differences between 1/4-inch and 1/16-inch mesh rather than between 1/4-inch and 1/8 inch mesh. Many studies suggest that the true nature of subsistence adaptations can be revealed only with findings from 1/8-inch mesh. Do findings from 1/16-inch mesh provide an even more accurate characterization?

Comparing the two samples also reveals variation in diversity related to mesh size. Comparison of indices for richness (ΣTAXA and Margalef's index) and evenness (Berger-Parker's index and Simpson's evenness) derived from the two samples shows greater richness and evenness in the 1/16-inch sample (Table 4). This is consistent with the species abundance rank distributions from the Gordon (1993) study, but it conflicts with Vale and Gargett's (2002) findings from Australia. However, it does not necessarily indicate that those findings were inaccurate, since the Australian fishery may be different from those of Hawaii and central California in terms of the range of the availability of tiny fishes.

Overall, these findings imply, not surprisingly, that the microsample processed with 1/16-inch mesh reported by Fitch (1972) shows a greater representation of smaller taxa (Table 3) and dramatically higher volumetric concentrations of fish bone. While the majority of the bones recovered from the 1/16-inch sample were unidentifiable (10,834 out of 12,165), the identifiable portion of the samples still produced a wider range of taxa (40 compared to 29 taxonomic classes) and higher overall diversity (Table 4).

Table 13.4. Diversity Indices Comparing Fish Bone from the Two Samples from CA-SLO-2.

	6-mm (1/4-inch) Mesh Sample	1-mm (1/16-inch) Mesh Sample
Fish NISP (*n*)	6,070	1,331
Excavation volume (m^3)	98.9	0.8
ΣTAXA (*S*)	29	40
Margalef's richness	3.21	5.42
Berger-Parker's index	2.18	2.81
Simpson's evenness	0.05	0.14

Intercomponent Comparison

When the Diablo findings are classified into more meaningful temporal components, they show clear if not important patterns. The 1/4-inch sample is dominated throughout by rockfish (*Sebastes* sp.), while the 1/16-inch sample emphasizes the importance of surfperch (*Embiotocidae*) (Table 5). The 1/16-inch fish bone samples also show consistently higher richness (Figure 2) and evenness (Figure 3) than the 1/4-inch samples over time (Table 5). However, the relative diachronic trends within each sample are nearly the same for three of the indices. A comparison of the diachronic trends between the differing mesh samples shows that the trends are highly correlated for the number of taxa (poisson-log GLM, $z = 52.46$, $p < 0.0001$), Margalef's index (gamma-inverse GLM, $t = -5.0$, $p = 0.0377$), and Simpson's evenness (binomial-logit GLM, $z = 7.484$, $p < 0.0001$). This implies that while there might be quantitative differences in these diversity measures, the relative trends through time are nearly indistinguishable. This was not the case for Berger-Parker's index (gamma-inverse GLM, $t = -0.76$, $p = 0.524$), however. This is largely due to discrepancies in the diachronic change from the Middle- to Late-period components: while the 1/4-inch sample is marked by a decrease in evenness, the 1/16-inch sample shows an increase (see Figure 3). Magurran (2004) notes that Berger-Parker's index may be biased by sample size when the number of taxa in a given sample are fewer than 100, and this may be the cause of the discrepancy here. If anything, this confirms Magurran's (2004) suggestion that Simpson's evenness measure should be used when the number of taxa in a sample equals less than 100. Despite this statistical difference, the overall trends between the 1/4-inch and 1/16-inch samples are remarkably similar, with only a minor deviation in the transition between the last two temporal components (Figure 3).

Table 13.5. Summary of Key Findings from the CA-SLO-2 Faunal Remains by Temporal Component.

		6-mm (1/4-Inch) Mesh Sample								1-mm (1/16-Inch) Mesh Sample							
		IV		III		II		I		IV		III		II		I	
Taxon	**Common Name**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**
Anarrhichthys ocellatus	Wolf-eel	0	.0	0	.0	0	.0	0	.0	5	1.6	57	8.1	45	16.6	9	20.9
Embiotocides	Surfperch	41	2.3	166	4.3	16	4.3	2	5.6	106	33.8	240	34.1	113	41.7	14	32.6
Engraulis mordax	Northern anchovy	0	.0	0	.0	0	.0	0	.0	44	14.0	104	14.8	27	10.0	1	2.3
Ophiodon elongatus	Lingcod	47	2.6	128	3.3	19	5.2	6	16.7	1	.3	0	.0	1	.4	1	2.3
Scorpaenichthys marmoratus	Cabezon	587	32.4	1,372	35.6	199	54.1	18	50.0	3	1.0	4	.6	2	.7	0	.0
Sebastes spp.	Rockfishes	961	53.1	1,733	45.0	88	23.9	6	16.7	101	32.2	90	12.8	25	9.2	5	11.6
Spirinchus starki	Night smelt	0	.0	0	.0	0	.0	0	.0	18	5.7	68	9.7	9	3.3	0	.0
Stichaeidae	Pricklebacks	96	5.3	244	6.3	16	4.3	1	2.8	0	.0	0	.0	0	.0	0	.0
	Total (*n*)	1,811		3,855		368		36		314		703		271		43	
	ΣTAXA (S)	15		26		15		8		20		35		21		12	
	Margalef's	1.87		3.06		2.39		1.99		3.30		5.19		3.57		2.92	
	Berger-Parker's	1.88		2.04		1.8		2.13		2.96		2.93		2.40		3.07	
	Simpson's	.17		.11		.19		.43		.21		.16		.21		.51	

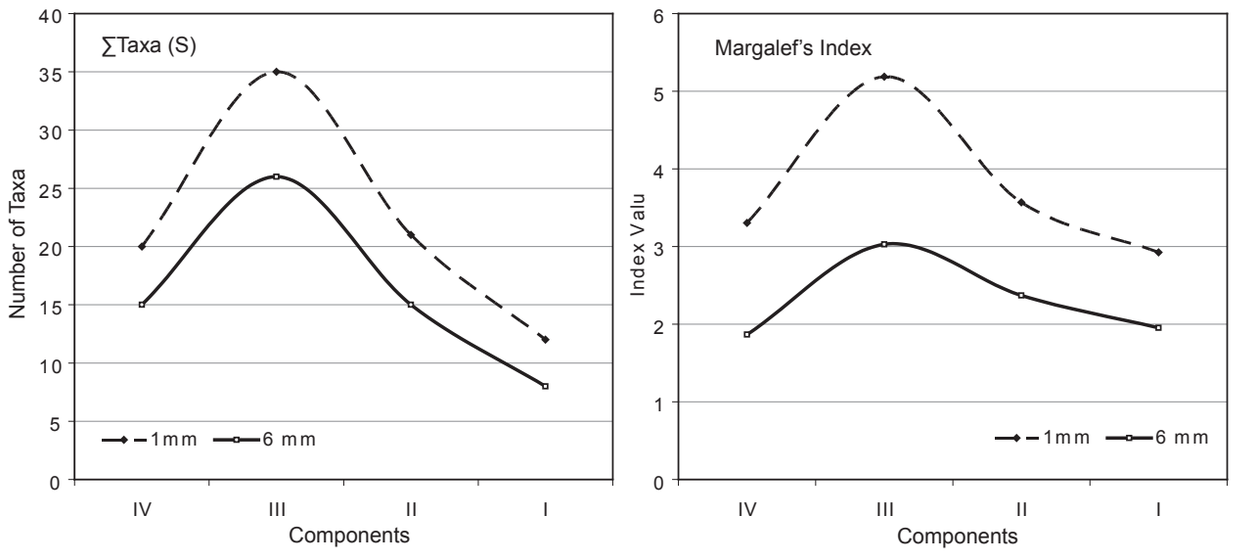

Figure 13.2. Richness (ΣTAXA and Margalef's index) values from CA-SLO-2 fish remains by temporal component and mesh size.

On the whole, these data suggest that smaller mesh can indeed produce more species, indicating greater richness and a more even distribution of those taxa. However, the relative diachronic trends in diversity are, for the most part, statistically the same, regardless of mesh size. In the case of the Diablo fauna, this provides strong justification for relying on the evenness and richness values from the combined fish, bird, and mammal remains from the 1/4-inch mesh samples (Figure 4) for interpreting subsistence because the samples are robust and were recovered with the same technique. In terms of absolute dietary preferences, large mesh suggests that the Diablo inhabitants were more interested in terrestrial foods, whereas 1/16-inch mesh suggests they were intensive fisherpeople. However, issues of absolute sample size still confound this difference, since a larger sample screened through 1/16-inch mesh would surely produce a greater quantity of larger fauna. Had a 1/8-inch mesh sample been

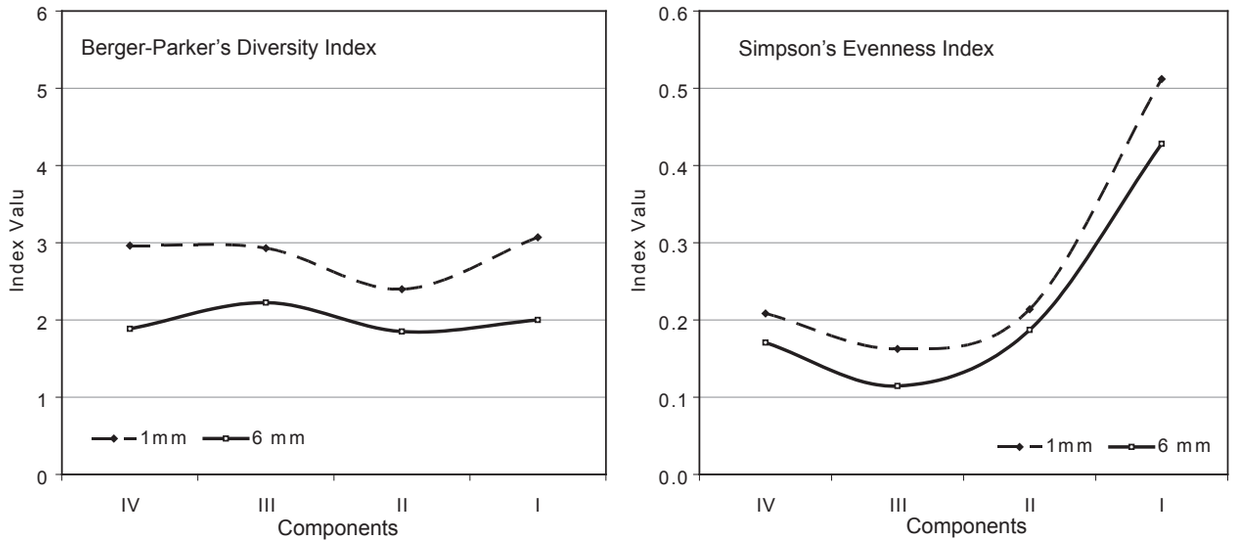

Figure 13.3. Evenness values (1/Berger-Parker's index and Simpson's evenness) from CA-SLO-2 fish remains by temporal component and mesh size.

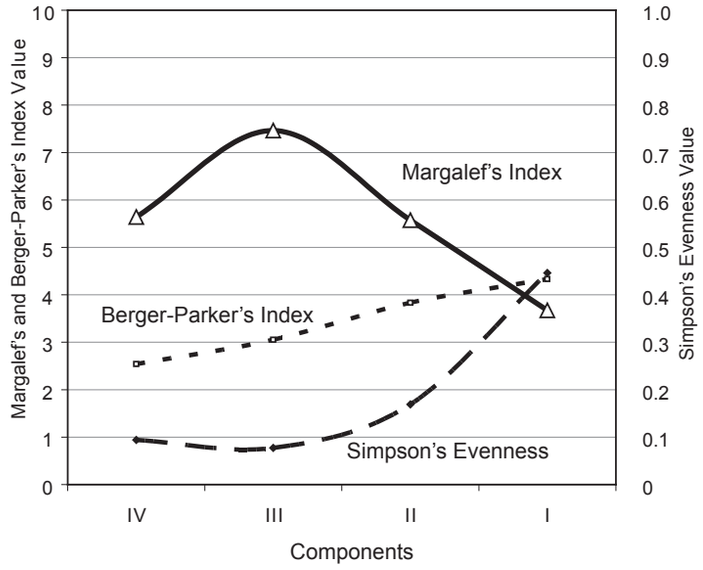

Figure 13.4. Richness and evenness over time for combined bird, mammal, and fish bones from 6-mm mesh samples from CA-SLO-2.

obtained from Diablo Canyon, it almost certainly would have provided values between the 1/4-inch and 1/16-inch samples. Given these findings, there is no justification for deciding which of these characterizations is "more accurate." Rather, it should be recognized that 1/4-inch, 1/8-inch, and 1/16-inch samples all provide relative indices.

DISCUSSION AND CONCLUSION

Issues of diet, diversity, and mesh size have been heavily debated over the last several decades with no emergent consensus. The Diablo Canyon fish remains recovered from an intensive analysis of residues from 1/16-inch processing confirm findings from Gordon's (1993) study, which showed

Table 13.6. Diversity Values by Temporal Component from CA-SLO-2.

	Component				Total
	IV	III	II	I	
Bird and Mammal (nonfish)					
ΣTAXA (*S*)	30	39	23	9	50
Simpson's evenness	.10	.09	.16	.45	.07
Berger-Parker's index	1.95	2.13	2.11	2.33	2.08
Margalef's index	4.50	5.23	3.68	2.14	6.26
Combined (fish and nonfish)					
ΣTAXA (*S*)	45	65	38	17	79
Simpson's evenness	.09	.08	.17	.45	.06
Berger-Parker's index	2.54	3.05	3.83	4.33	2.95
Margalef's index	5.64	7.46	5.57	3.67	8.61

that smaller mesh yields a broader (richer) fish assemblage than larger (1/4-inch) mesh. More importantly, the Diablo findings highlight the fact that any mesh size only provides a relative index of subsistence. Diachronic trends in richness and evenness, when based on robust samples, are the same regardless of mesh size. Thus it may be more important to produce robust, statistically meaningful samples and to hold mesh size constant across temporal and spatial components. In other words, no single mesh size provides the absolute truth on subsistence. Findings from CA-SLO-2 also highlight the value of large excavation volumes for producing statistically meaningful assemblages of remains of larger animals. While diversity statistics from small volumes processed with small mesh can be considered meaningful for microfauna (for example, fish) because robust samples can be generated, larger excavation volumes are often needed in California to produce meaningful measures of diversity for large animals and for the combined vertebrate component of diets. Because excavation with small mesh is generally time-consuming and it may be difficult to excavate large volumes, the Diablo project shows the value of mixed recovery strategies for developing robust samples of all types of constituents.

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NOTE

1. This function was written in R by Ian G. Robertson based on a function in Keith Kintigh's commercially available package Tools for Quantifying Archaeology (see http://tfqa.com/).