SIZE VARIATION AMONG MOLLUSCS FROM SITES NEAR THE LOWER SANTA YNEZ RIVER

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ABSTRACT

The abundance of very small mussels (Mytilus californianus) at sites in northern Santa Barbara County has been attributed to human overexploitation. However, other explanations are possible. Small valve size can be caused not only by overharvesting by humans, but also by environmental conditions adverse to mussel growth or survival; by intensive predation by sea otters, starfish, or other animals; or conceivably by intentional or unintentional size selection by aboriginal shellfish collectors.

INTRODUCTION

There is a common assumption among archaeologists that if a faunal assemblage contains the remains of unusually small members of a species, it is because of intensive exploitation. Typically, we assume that hunter-gatherers prefer larger individuals as a source of food so that the presence of many small individuals at a site reflects the scarcity of larger animals of the same species (cf. Claassen 1986).

For example, Serena (1984) notes that valves of the California mussel, or Mytilus californianus, collected from prehistoric sites on Vandenberg Air Force Base are generally smaller than mussels seen along the central coast today or on historic sites in the area. He suggests that "...the extraordinary size of these animals [on an historic site] bespeaks the pattern of large size selection practiced by the Euroamerican occupants of the site, and may indicate as well the recovery of local mussel beds from the extensive exploitation practiced by the aborigines (Serena 1984:121)." In their recent article in American Antiquity concerning coastal adaptations near Point Conception, Glassow and Wilcoxon (1988) calculate meat yield per mussel using Greengo's (1952) estimate of 4.26 g of meat per animal rather than Tartaglia's (1976) estimate of 9.06 g because the lower number "...may partially compensate for the pressure that collection exerts on shellfish colonies " (Glassow and Wilcoxon 1988:42).

It is certainly not unreasonable to assume that human exploitation may reduce the average size of surviving shellfish, but data from the Union Oil Pipeline Archaeological Project in Santa Barbara County (Woodman and Rudolph 1988) suggest that other explanations are possible. Small valve size can be caused not only by overharvesting by humans, but also by environmental conditions adverse to mussel growth or survival; by intensive predation by sea otters, starfish, or other animals; or conceivably by intentional or unintentional size selection by aboriginal shellfish collectors.

PROJECT DESCRIPTION

Several large, dense shell middens dot the coast north and south of the Santa Ynez River (Glassow et al. 1981; Glassow and Wilcoxon 1988), but shells were found to be uncommon on most sites investigated for the Union Project. None of the sites investigated, not even those close to the shore, produced more shell than a few people with baskets could have carried from the nearest collecting location. Even at SBa-689, the site with the most shell, the density was much lower than on middens to the south, where densities as high as 680 kg per m^3 have been observed (Glassow et al. 1981; Glassow and Wilcoxon 1988).

Today near Vandenberg, there are several intertidal habitats that support invertebrates. These include estuaries, sandy beaches, and rocky outcrops.

Estuarine habitats are uncommon in the Vandenberg area. Only the mouth of the Santa Ynez River supports true salt marsh and mud flats, and they cover only 160 ha (Mahrdt et al. 1976). This estuary supports a low diversity of invertebrates and recent collections have produced no bivalves or barnacles (Mahrdt et al. 1976).

Sandy beaches are common near the mouth of the Santa Ynez River and extend continuously 1 km northward to Canada Tortuga and nearly 7 km southward to Honda Canyon. Another long stretch of beach is found 8 km to the north. These beaches support an impoverished intertidal fauna of crabs, beach hoppers, Pismo clams, razor clams, olive shells, and sand dollars (Henningson, Durham, and Richardson Sciences 1984; Ricketts et al. 1968; Rodriguez et al. 1975). Despite the frequency of this habitat on Vandenberg, few edible invertebrate species are found there, and only the Pismo clam can provide a substantial quantity of meat.

Rocky intertidal habitats can be found at many locations north and south of the Santa Ynez River. These outcrops generally support communities dominated by California mussels. Less stable rocky substrates, such as boulder beaches, may have populations dominated by turban snails and other grazers (Seapy and Littler 1978).

SAIC recovered over 13 kg of shell during the 1986 investigations and I analyzed over 6 kg. Fauna known to favor rocky intertidal zones contributed over 99 percent of the invertebrate remains from the Union Project. California mussels, platform mussels, red abalone, black turban snails, limpets, chitons, and goose barnacles dominate the assemblages. The California mussel is by far the most abundant mollusc on prehistoric sites throughout the Vandenberg region. The contents of the Union sites and of other sites demonstrate that shellfish collectors preferred rocky intertidal habitats throughout 9,000 years of occupation (Glassow at al. 1976; Serena 1984; Spanne 1974). This preference was undoubtedly due to the higher density, higher diversity, more predictable locations, and relative ease of collection of shellfish in rocky intertidal habitats than of shellfish in beaches and estuaries.

There is no evidence from the Union Project for temporal change in prehistoric shellfish exploitation. The assemblages at SBa-689 and at SBa-931, 4 km to the west and across the Santa Ynez valley, are surprisingly similar given the 6 to 7,000 years separating their occupations. However, changes in shellfish assemblages occur elsewhere on the central coast around 4000 to 5000 B.C. (Erlandson 1985; Rudolph 1985), and additional investigations in the Vandenberg area may reveal some interesting temporal variation.

Data for this study come primarily from SBa-689 (Woodman and Rudolph 1988) (Figures 1 and 2). This site overlooks the floodplain of the Santa Ynez River and lies 2 km from the nearest estuary, 4 km east of the nearest sandy beach, and 5 km from the nearest rocky intertidal habitat. SAIC excavated more than 90 m^3 from the site. Despite extensive geomorphological and sedimentological investigations during the Union Project, we found no evidence that rocky intertidal habitats are less common today than they were when SBa-689 was occupied.

Radiocarbon dates from the site indicate that it has two major Middle Period components, one between 110 B.C. and A.D. 230 and another between A.D. 370 and A.D. 700. Each component appears to represent a seasonal residential base, occupied perhaps as people traveled from the coast into the interior in pursuit of deer, rabbits, acorns, and seeds.

Marine resources were a major constituent of the faunal assemblage; over 80 percent of the protein represented at the site came from shellfish. The assemblage also included rockfish, surfperch, sardine, giant kelpfish, monkey-faced eel, deer, cottontail, brush rabbit, jackrabbit, many smaller mammals, and various reptiles and amphibians.

ESTIMATING VALVE SIZE

One of the goals of the Union Project (Woodman and Rudolph 1988) was to estimate the importance of different habitats to prehistoric settlement and subsistence. Calculating the dietary role of fauna from intertidal habitats proved to be difficult because of the small size and fragmentation of mussel shells from

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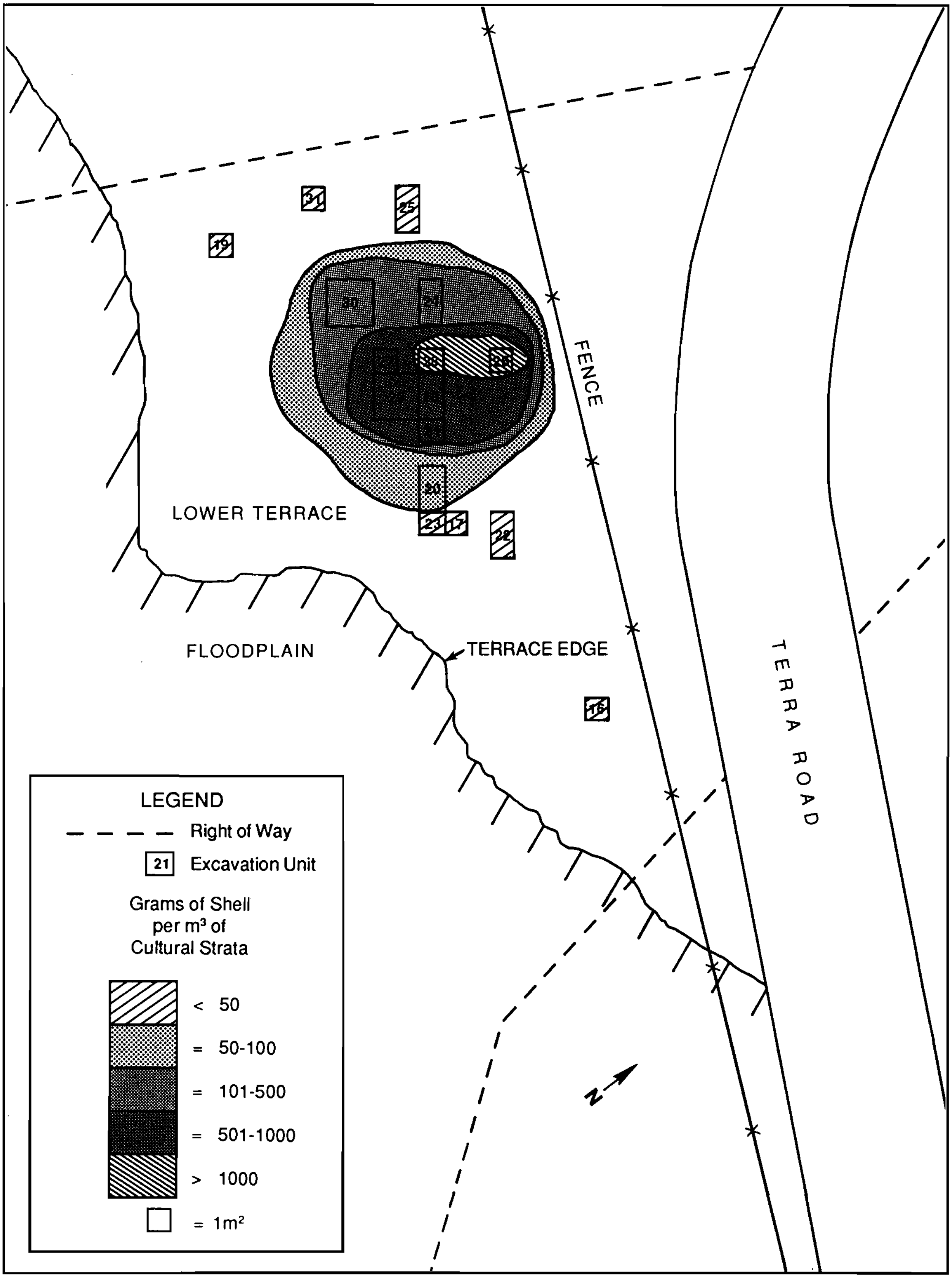

Figure 2. Distribution of shell (≥ .25 inch) in lower component, SBa 689.

SBa-689. The problem is widespread in the Vandenberg area and is not unique to this site.

Various archaeologists (Glassow and Wilcoxon 1988; Greengo 1952; Osborn 1977; Tartaglia 1976) have estimated the dietary contribution of mussels by assuming an average meat yield. These estimates range from 1.065 g of meat per mussel suggested by Osborn (1977) to Tartaglia's (1976) 9.06 g. Glassow and Wilcoxon (1988) argue that Osborn's estimate of just over 1.0 g is too small, but many of the mussels at SBa-689 probably provided even less than this meager offering.

Archaeologists in the Vandenberg area have also estimated average mussel size by either (1) inferring valve length and meat weight from another valve dimension or (2) inferring average shell weight per individual from the total shell weight and minimum number of individuals at a site.

Jerry Moore (personal communication 1987) has developed the first of these methods by using a preliminary allometric measure for the California mussel. Using modern specimens he collected in Santa Barbara, Moore found a strong relationship between valve length and valve width measured 1 cm from the beak (Figure 3).

I decided to perform a similar study. With the help of other SAIC personnel, I collected 118 California mussels from the southern Santa Barbara County coast at Arroyo Hondo. Valve length ranged from 2.1 to 12.4 cm. Valve width was recorded 1 cm from the beak in the manner described by Moore. In our sample, the relationship between valve width and the natural log of valve length has a Pearson's r value equal to 0.91. The regression formula is $y = 0.17x + 1.48$, where y equals the natural log of valve length in mm and x equals valve width 1 cm from the beak (Figure 4).

I should warn that there can be considerable variation in valve length for any given valve width, especially for valves more than 1.4 cm wide. For example, valves between 1.2 and 1.3 cm wide, a difference of only 1 mm, have lengths ranging from 2.4 to 4.3 cm. Valves between 1.6 and 1.7 cm wide have lengths ranging from 5.0 to 10.0 cm.

I estimated typical valve length at SBa-689 by examining all dry-screened California mussel beaks from 3 excavation units. The extent of shell fragmentation at this site prevented my obtaining a large sample of measurable valves. Many beak fragments were less than 1 cm long and others were too weathered to allow accurate measurement. Out of 1,933 beaks from those 3 units, 53 percent of the beaks from the entire excavation, only 40 were measurable using the criteria proposed by Moore. Because of the small sample, data from both components were combined. Even though few valves could be measured, it was still possible to infer from their size that many, perhaps most, unmeasured valves were narrower than those that could be measured. For this rea-

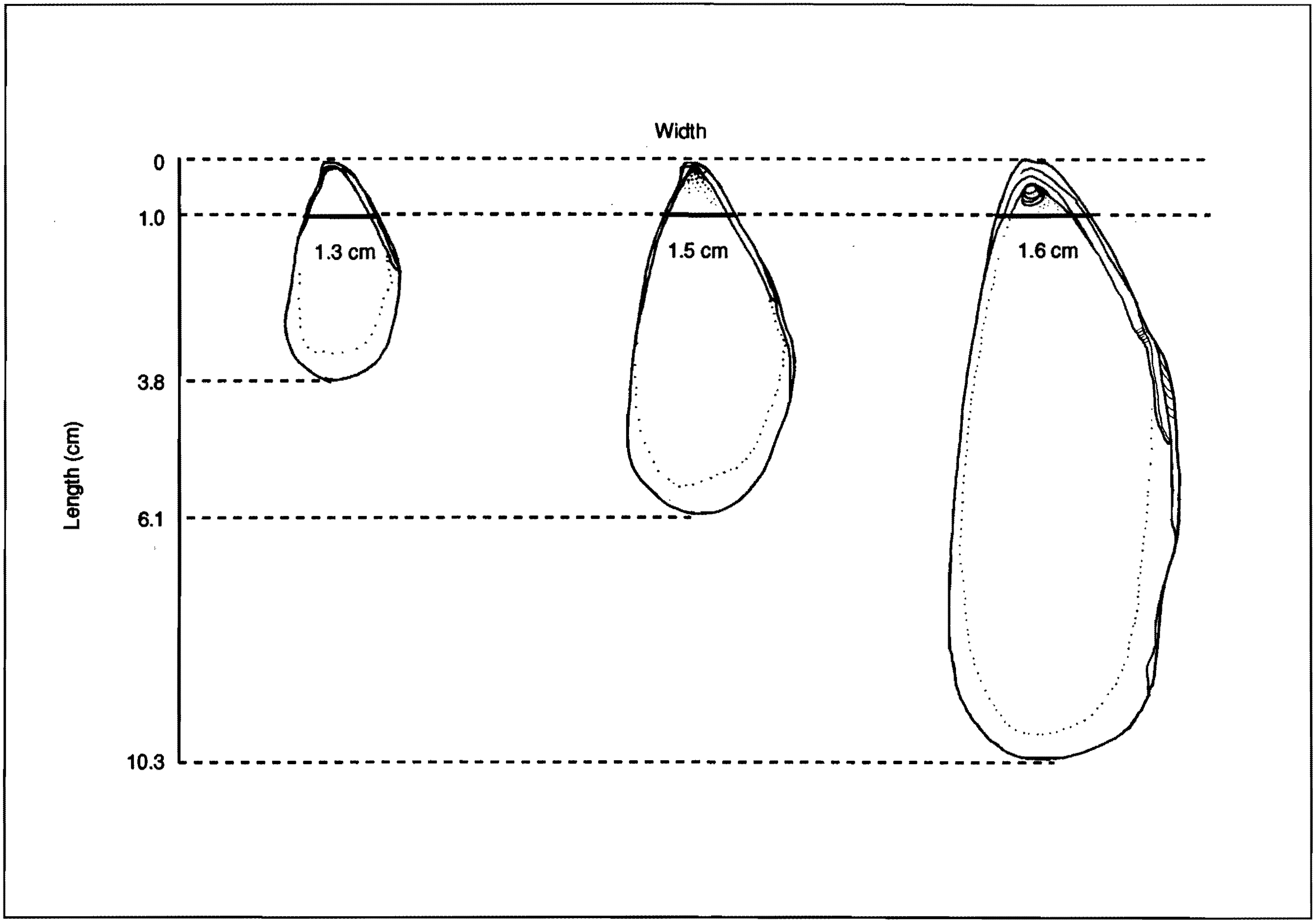

Figure 3. Valve measurement technique for *Mytilus californianus*.

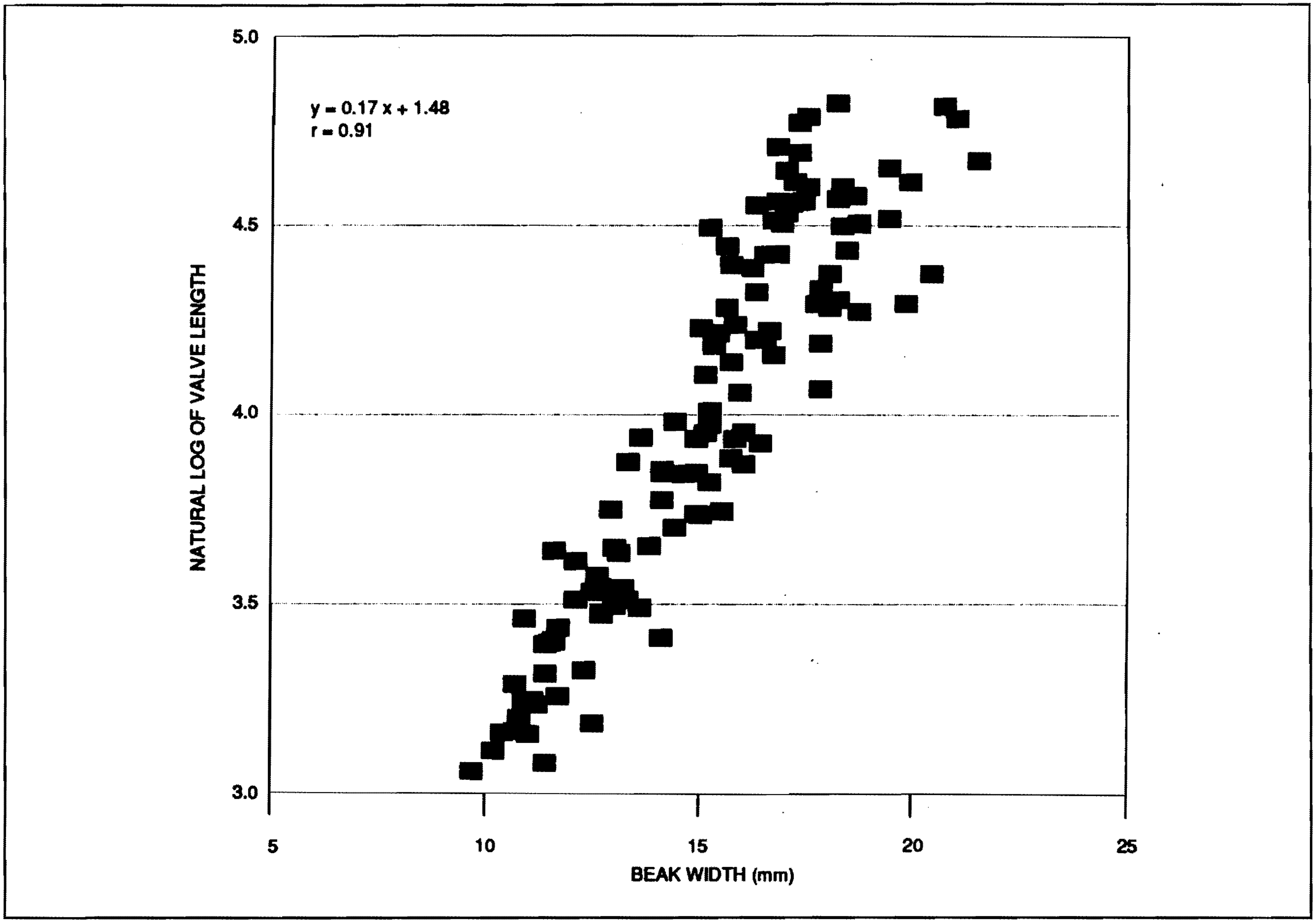

Figure 4. Relationship between beak width and valve length.

son, I feel that while the sample may not represent the typical mussel valve at SBa-689, it does give an indication of the size range for the larger valves. The average mussel shell at SBa-689 is probably much smaller.

Of the 40 measurable shells, the minimum width is 1.0 cm and the maximum width is 1.9 cm. The mean is 1.4 cm, with a standard deviation of 0.18. Using the regression formula derived from the modern specimens, we find that the minimum valve length would be 2.4 cm, the maximum valve length would be 10.8 cm, and the mean length would be 4.4 cm. The estimated valve lengths for valves falling within 1 standard deviation of the mean would be 3.3 cm to 6.0 cm. Remember that these are among the larger valves from the site.

The alternative method for estimating typical valve size requires information on shell weight and minimum number of individuals (MNI) (Serena 1984). In the combined upper and lower components at SBa-689, the MNI for all mussels is 1,815. The weight of all mussel shells larger than 1/8 inch equals 6,128 g. Therefore, the average shell weight per mussel is 3.4 g, or 1.7 g per valve.

For the Arroyo Hondo sample, the relationship between mussel valve length and shell weight is $y = 0.34x + 3.2$, where y equals the natural log of valve length in mm and x equals the natural log of valve weight in g. Pearson's r has a value of 0.99. Using this equation, the average shell weight at SBa-689 of 1.7 g would translate to an average length of 2.9 cm. This estimate for valve length is about 33 percent smaller than that derived from beak width measurements. The discrepancy could have arisen for several reasons. First, using the valve width method required valves that were relatively large compared to others on the site so that short valves were underrepresented. Second, Serena (1984) suggests that the loss in shell weight from small fragments passing through screens, from leaching, and from dehydration may be as high as 30 to 50 percent. This loss in shell weight would not be reflected by a corresponding decrease in MNI.

According to data on California mussel growth rates provided by Dodd (1964), mussels 4.5 cm long would generally be 1 to 2 years old in a climate like that of the central California coast; they might be 3 to 4 years old in colder climates. Therefore, it is likely that the mussels collected by the inhabitants of SBa-689 were less than 2 years old and that many of the smaller mussels were less than 1 year old.

Jones and Stokes (1981) note that after disruption intertidal invertebrate communities take several years to recover to a normal population. Along the California coast, they found that even after 2.5 years, succession in a mussel habitat is far from over. Complete succession may require 5 to 7 years. If mussel valves from SBa-689 and other sites in the Vandenberg area were collected consistently when they were less than 2 or 3 years old, then the mussel habitats may have been in a state of early to mid-succession.

ALTERNATIVE EXPLANATIONS

The apparent aboriginal emphasis on consuming small mussels has led some archaeologists working in the area to assume that mussels may have been subject to overexploitation by humans. However, as mentioned above, there are other explanations that have not been investigated adequately (cf. Claassen 1986). Small valve size can be a consequence also of environmental changes that inhibit mussel survival; size selection by prehistoric shellfish collectors; or intensive predation or size selection by other animals.

Alternative 1

According to James McClintock (personal communication 1988), on certain sections of the California coast, modern mussels tend to be small partly because older individuals are removed by storms. Older mussels are larger than younger mussels and are more often encrusted with barnacles, which increase drag and the chance of dislodgement by strong waves. Also, the longer a mussel is attached to a particular rock, the greater the likelihood of its experiencing an unusually strong storm. One could argue, therefore, that an increase in storm frequency or storm intensity in the Vandenberg area could have led to a decline in the size of mussels available to collectors.

Alternative 2

Size selection by humans is generally associated with a preference for larger fauna, but under certain conditions smaller animals might be preferred. Mussel collecting is generally an easy activity, but some mussels are more easily collected than others. By using an aluminum tripod equipped with a spring scale, McClintock and Robnett (1986) found that the force required to pull a mussel off a rock increased exponentially with the length of the mussel. The force required increased particularly rapidly with mussels longer than 5 cm and eventually exceeds the force that many people can exert with their bare hands (Heyward 1984).

Of course, humans do not rely solely on brute strength. They can also use pry bars and can twist, cut, or tear the byssal threads holding the shell to the substrate. Nevertheless, considerable force may be required to remove large mussels. If the primary collectors were women, children, and the elderly, or if people collected shellfish only casually while performing other tasks, then the force required to collect large mussels might account for their scarcity in the deposits at SBa-689.

Also, as Erlandson (1988) points out, clusters of densely intertwined mussels can be pulled off a rock at one time. This too may lead to unintentional size selection favoring very small mussels lodged between their larger neighbors (Michael Glassow, personal communication 1989).

Alternative 3

Sea otters can rapidly deplete mussel beds and they also practice size selection (VanBlaricom 1988). This has been observed in Prince William Sound in Alaska and at Point Piedras Blancas, 130 km north of the Santa Ynez River.

Sea otters exploit mussels by diving below the surface to clear a small patch of the animals and then floating on the surface where they break them open to remove the meat. Recent studies suggest that in certain areas adult females and young are more likely than adult males to consume mussels, the males preferring larger invertebrates (VanBlaricom 1988).

The disappearance of sea otters from most of the California coast as a result of the fur trade led to increased populations of many shellfish species. The otter's ecological role is illustrated by the fact that once flourishing rock crab, abalone, urchin, and Pismo clam fisheries have been eliminated in areas where otters have become re-established since hunting was banned in 1913 (VanBlaricom and Estes 1988).

The importance of sea otters in regulating nearshore communities has been addressed by Simenstad, Estes, and Kenyon (1978). They found that the hunting of sea otters by prehistoric Aleuts apparently had profound effects on the number and size distribution of sea urchins, the robustness of kelp beds, and the populations of limpets, fish, birds, and other sea mammals.

Prehistorically otters in some areas could have limited the availability and quality of shellfish in mussel-dominated rocky intertidal communities (VanBlaricom 1988). It should be noted that otters do not eliminate shellfish populations. Rather, they preferentially consume the larger, more accessible individuals. Shellfish populations subject to otter predation tend to be dominated by smaller individuals or to be concentrated in crevices and other locations that otters cannot reach (Hines and Pearse 1982; Simenstad et al. 1978).

VanBlaricom (1988) found or the Alaskan coast that bay mussels, Mytilus edulis, more than 4.0 cm long are preferred by otters. The bay mussel is somewhat smaller than the California mussel, but the size preference seems to be the same in both cases. Otters have been observed readily eating California mussels as large as 15 cm. VanBlaricom (1988) adds that from a sea otter's perspective, otters practice size selection because small mussels are collected less often and very small mussels are either not collected at all or are discarded immediately. However, from a mussel's perspective, sea otters are entirely non-selective. When they clear a patch, the otters remove all size and age categories and discard uneaten mussels in areas where their survival is unlikely. Taking a point of view less subjective than either an otter's or a mussel's, the researchers at Point Piedras Blancas found that in areas continually exploited by otters, mussel beds that were not completely depleted contained very few individuals longer than 4.4 cm, the average length of mussel valves from SBa-689.

Otter bones are not common but have been found at prehistoric sites along the coast of Vandenberg, and otters could have been important competitors of Native Americans for shellfish resources. The effects of otter predation could have been to limit the overall productivity of mollusc populations and to shift the size distributions of populations toward smaller individuals (Hines and Pearse 1982; VanBlaricom 1988). The effect on size distributions could be similar to the result one would expect under conditions of overharvesting by humans.

VanBlaricom cautions, however, that there is significant spatial, seasonal, annual, gender specific, age specific, and individual variation in how otters exploit mussels. Therefore, "one cannot predict patterns of response in a mussel community simply by knowing that sea otters are present or absent" (VanBlaricom 1988:85).

DISCUSSION

Optimal foraging theory assumes that resources will be ranked by hunter-gatherers according to their efficiency in providing protein, energy, or other desirable attributes. If protein is the most important consideration, then deer, which provide a large amount of protein in a single package, will be ranked higher than rabbits, and rabbits higher than ground squirrels. Shellfish would usually be ranked relatively low, although mussels might be ranked higher than other fauna because they occur in dense clusters, they can be removed from the rocks without tools, and they occur in predictable locations. As Pyke, Pulliam, and Charnov (1977:141) remind us, "...whether or not a food type should be eaten is independent of the abundance of the food type and depends only on the absolute abundances of food types of higher rank." However, the ranking of a species is not a constant. The ranking should consider changes in the probable size of the animals being exploited for this affects the relative costs and benefits of their exploitation.

Many of the mussels found at SBa-689 were probably not mature. Their small size has been attributed to overexploitation and has been used as evidence for human population pressure. As I have discussed, there are alternative explanations. Yet despite their small size, mussels contributed a substantial portion of the protein represented at SBa-689 and others sites in the region. Understanding why these small animals were worth bringing to a site nearly 5 km from the nearest rocky intertidal habitat will require data concerning regional and temporal variation in mussel size and in the composition of shellfish assemblages.

Finally, VanBlaricom admonishes biologists that "...if we are to argue that community models are incomplete without consideration of effects of sea otters or other predators, we must make the same argument for aboriginal man, given that the latter was a known consumer of both sea otters and mussels" (VanBlaricom 1988:88). In the same vein, archaeologists need to remember that humans are not the only predators.

NOTES

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