

MEASURING RESOURCE DEPRESSION WITH ARCHAEOLOGICAL FAUNAS INSIGHTS FROM THE EMERYVILLE SHELLMOUND

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INTRODUCTION

Dr. Kowta's contributions to the field of California archaeology can only be described as multi-dimensional. One of those dimensions has been a long-standing interest in understanding ancient human behavior from an ecological perspective. I took my first archaeology class with Dr. Kowta and can vividly recall him identifying Julian Steward as the figure that had the greatest influence on him. No doubt due, in part, to this formative exposure, my own research has embraced an ecological theme ever since. In this spirit, the following paper explores some of the intricacies of applying models from foraging theory to the archeological record of past hunting behavior.

In recent years, foraging theory has been increasingly used as a framework for analyzing prehistoric *resource depression*, or declines in prey capture rates that stem from the activities of foragers. Two of the primary lines of evidence that have been used to document resource depression archaeologically are 1) temporal declines in the relative abundances of "high-return" or "high-ranked" species, and 2) declines in the mean age of harvested prey. However, it is becoming increasingly clear that resource depression may also be reflected by *increases* in both high-ranked prey abundances and mean age. These divergent signals appear to be linked to variation in the behavior and spatial structure of different prey species and are nicely illustrated with the Emeryville Shellmound faunal sequence (see Broughton 2002, from which this paper was excerpted).

RELATIVE ABUNDANCES AND RESOURCE DEPRESSION

The prey model is now commonly used to predict temporal declines in the relative abundances of high-return prey in the context of

resource depression. Moreover, detailed empirical research shows that the prey that yield the highest returns are typically those that are largest in size—although there are, of course, some interesting and important exceptions. Hence the usual expectation is that the relative abundances of large-sized prey should decline through time. But this prediction follows only if the critical assumptions of the model were met in the archeological contexts to which it is applied.

One of the model's most critical assumptions is that different potential prey types are searched for simultaneously within a homogenous resource patch. If, however, different prey types are spatially clumped across a region surrounding a site, variation in the overall net caloric returns from those clumps or patches should dictate the extent to which they are used and the abundances of different prey that end up in middens. In such cases the model's assumptions are not met, and hence predictions from it may be invalid.

An appropriate strategy to deal with this critical constraint is to examine separately the changes in differentially-ranked prey types within single "patches." These are defined as groups of prey taxa that are distributed more or less randomly within defined habitat types and which were pursued and captured with similar technologies. Resource depression and declining foraging efficiency still should be signaled by declines in the relative abundances of high-ranked prey *within* each patch.

RELATIVE ABUNDANCE INDICES FROM THE EMERYVILLE VERTEBRATES

Before it was mostly demolished in 1924, the Emeryville Shellmound was situated in a complex mosaic of terrestrial and aquatic habitat types on the east shore of San Francisco Bay. The mound itself was huge, measuring 100 x 300 m in area and extending to a depth of over 10 m. Prior to its

destruction, the mound was excavated on three occasions, each time in a different location. Most of the sediments were excavated stratigraphically and sieved with coarse-mesh screens; 10 primary strata were revealed during this work. Fourteen radiocarbon dates range from ~2600 to 700 ¹⁴C year B.P. and exhibit no stratigraphic inconsistencies. On average, each stratum took about 200 years to accumulate. During this time, the eastern San Francisco Bay region appears to have witnessed significant human population growth, at least to judge from the increase through time in the number of dated site components. Thus the Emeryville region follows the more general California trend of expanding human population densities during the late Holocene.

The excavations at Emeryville provided 17 faunal samples that could be placed into stratigraphic context. Collectively, about 24,000 fish, bird, and mammal specimens, representing 102 different species, have been identified from these samples. The Emeryville deposits thus allow a fairly high-resolution, ordinal-scale analysis of change in human foraging behavior over much of the late Holocene.

TRENDS FROM LOCAL PATCHES

As indicated above, the Emeryville site is surrounded by a number of distinct habitats so different that vertebrate prey species would have been spatially distributed in a patchy or coarse-grained manner. In order to satisfy the prey model's fine-grained search assumption, relative abundance indices should be constructed so as to include only those taxa that were derived from the same patches or hunt types. Several of the more obvious resource patches surrounding the Emeryville locality are the terrestrial mammals, the estuarine fishes, and the waterfowl (Anatidae) patch. These different patches each contain both large and small vertebrate prey types from which to derive relative abundance indices that can be analyzed separately for evidence of resource depression.

The largest taxa derived from the terrestrial mammals, waterfowl, and estuarine fishes patches are tule elk (*Cervus elaphus*), geese (*Anser*, *Branta*, *Chen*), and white sturgeon (*Acipenser transmontanus*), respectively. If resource depression occurred across the occupational

history of Emeryville, the abundances of these large prey should decline through time relative to the smaller prey types that occurred in their respective patches.

Figure 1 shows the relative abundance of elk, compared to smaller terrestrial mammals across the occupational history of Emeryville. Although there is considerable noise here, there is nonetheless a significant decline through time. Figure 2 shows the relative abundance of geese compared to smaller ducks across the occupational history of the site. Again, a significant decline through time is documented. The Emeryville fish record reveals similar patterns: the enormous white sturgeon is the largest species of fish to occur in the bay, and Figure 3 shows their relative abundance declining through time. Thus, if one looks at relative abundances of high-ranked prey separately from all of these well-defined local patches, there is a very consistent pattern of decline in large-sized taxa through time. These data are certainly consistent with resource depression and suggest that foraging returns from local patches steadily declined across the occupational history of the site.

INCREASING USE OF DISTANT PATCHES

The depression of prey within resource patches directly adjacent to a residential base may also have implications for changes in patch-use strategies in the wider environment surrounding a locality. Patch-use models predict that as once high-return patches located closer to home become depleted, more use should be made of distant, less-depleted patches, if such patches exist. Resource depression and overall reduced foraging efficiencies could thus be signaled by temporal *increases* in the abundances of high-ranked prey, if the prey were derived from distant patches.

Is there evidence for increasing use of distant patches over the Emeryville sequence? Against the background of steady declines in large prey from local patches, the relative abundance of black-tailed deer provides an intriguing contrast. Deer, compared to all other mammals, first decline over the four lower strata of the site but then increase across the upper six strata (Figure 4). Given that all signals from local patches suggest that foraging returns were steadily

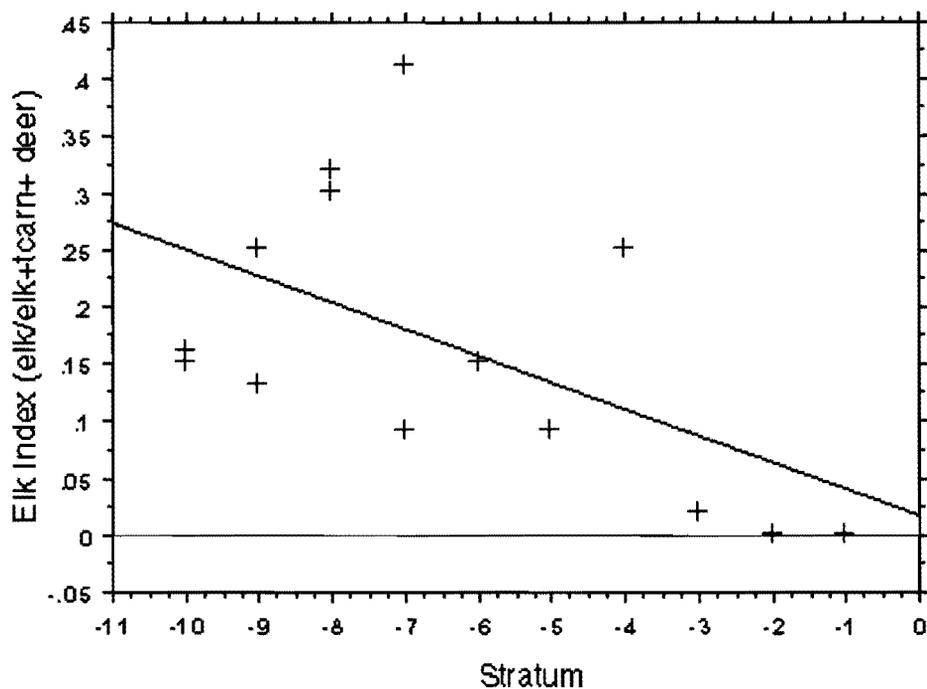


Figure 1. The distribution of the Elk Index ($\hat{\Delta}NISP\ Elk / \hat{\Delta}NISP\ Terrestrial\ Mammals$) by stratum at the Emeryville Shellmound ($r_s = -0.658, P < 0.01$). Does not include the potentially intrusive rodents and lagomorphs. A least-squares regression line indicates the direction of the trend.

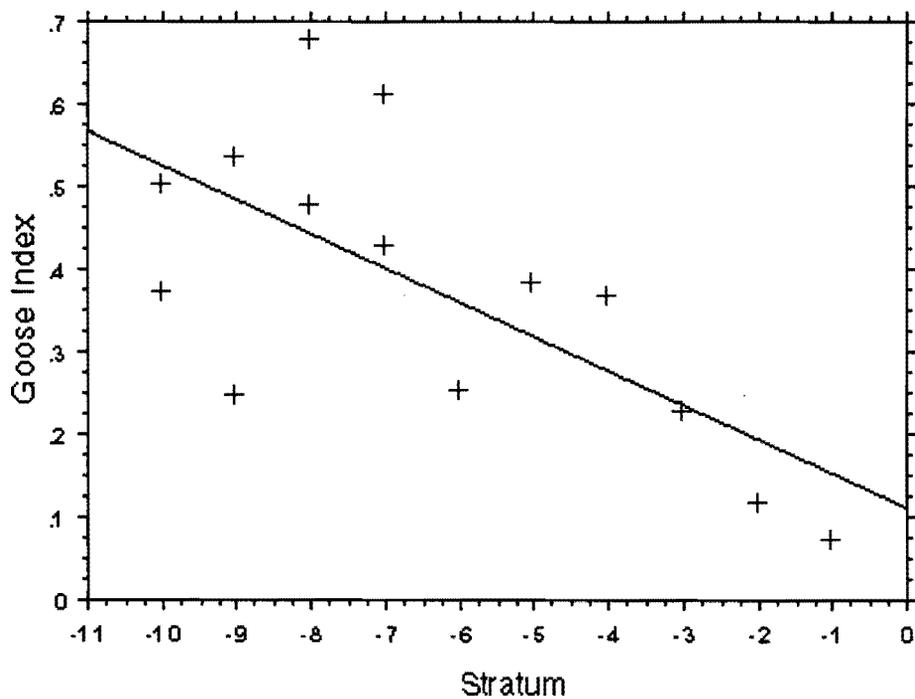


Figure 2. The distribution of the Goose Index ($\hat{\Delta}NISP\ Medium + Large\ Geese / \hat{\Delta}NISP\ Anatids$) by stratum at the Emeryville Shellmound ($r_s = -0.62, P = 0.02$). A least-squares regression line indicates the direction of the trend.

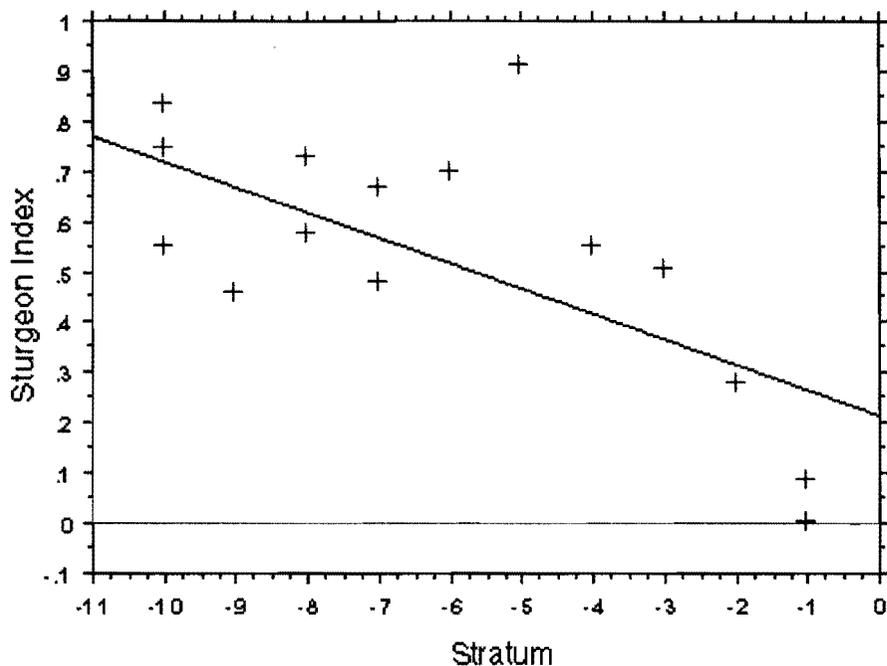


Figure 3. The distribution of the Sturgeon Index ($\delta^{15}N$ Sturgeon / $\delta^{15}N$ Estuarine Fishes) by stratum at the Emeryville Shellmound ($r_s = -0.49$, $P = 0.05$). A least-squares regression line indicates the direction of the trend.

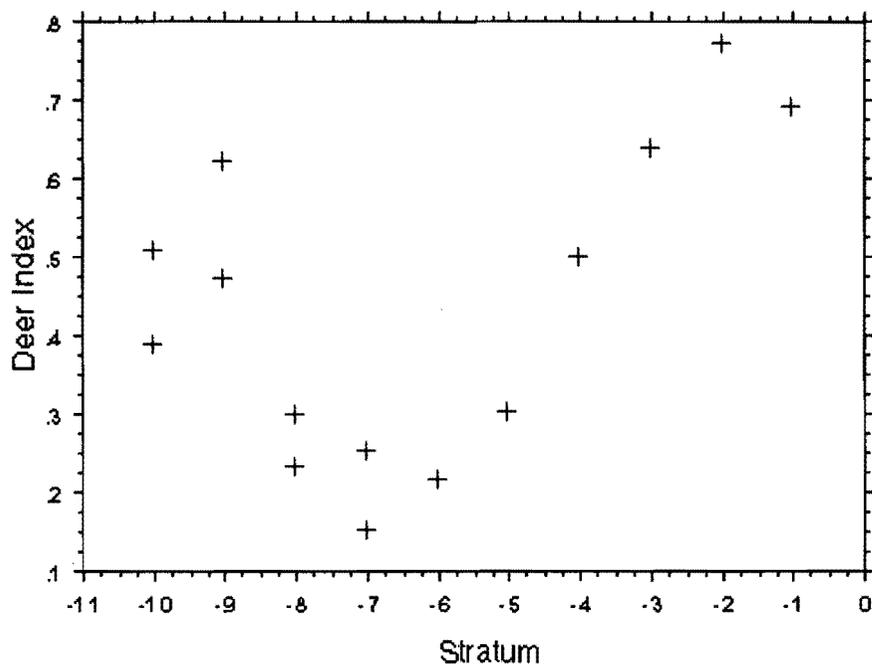


Figure 4. The distribution of the Deer Index ($\delta^{15}N$ Deer / $\delta^{15}N$ Mammals) by stratum at the Emeryville Shellmound. Does not include the potentially intrusive rodents and lagomorphs. The Deer Index declines across the lower four strata (strata ten through seven: $r_s = -0.721$, $P = 0.04$) but increases over the upper six strata (strata six through one: $r_s = 0.68$, $P = 0.01$).

declining across the mound's history, could the resurgence in deer use be reflecting the increasing use of less-depleted deer patches located far away?

Analyses of anatomical-part representation have informed on this question. Recent empirical research suggests that as the distance from kill-site to home-base increases, so should the degree of field processing to remove low-utility parts from the transported carcass. It follows that if the resurgence in deer documented across the upper strata at Emeryville is reflecting an ever-increasing use of distant deer patches, it should be associated with increasing relative frequencies of high-utility body parts, or an increase in the "mean utility." As Figure 5 shows, that is exactly the pattern we get.

Thus, the complex set of signals in relative abundance indices documented at Emeryville — all of the largest prey from local patches steadily decline through time, but large prey with a more extensive regional distribution first decline and then increase — seems to be linked to the unique spatial structure of the available vertebrate species. I emphasize too, that none of these patterns appear to be correlated with regional climate-based environmental changes (see, for instance, Byrne et al. 2001; Benson et al. 2002).

AGE STRUCTURE AND RESOURCE DEPRESSION

Patterns in the age composition of exploited prey species are one of the most frequently used means of corroborating evidence of resource depression derived from abundance data. For several reasons, resource depression is commonly argued to cause declines in the mean ages of individuals in exploited populations. This is because increasing mortality rates causes both decreases in average longevity and increases in population-recruitment rates due to the relaxation of intraspecific competition.

But these arguments do not account for the reality that archaeological faunas often result from foragers who encounter different-aged individuals within species in a coarse-grained manner. That is, some prey species occur in clumps or patches that are disproportionately comprised of, say, juvenile versus adult individuals. Differential use of such patches would thus have an important effect on the age composition of exploited prey.

The standard prediction also takes no account of the potential for prey "behavioral" or "micro-habitat" depression. These phenomena refer to the behavioral responses that prey species can

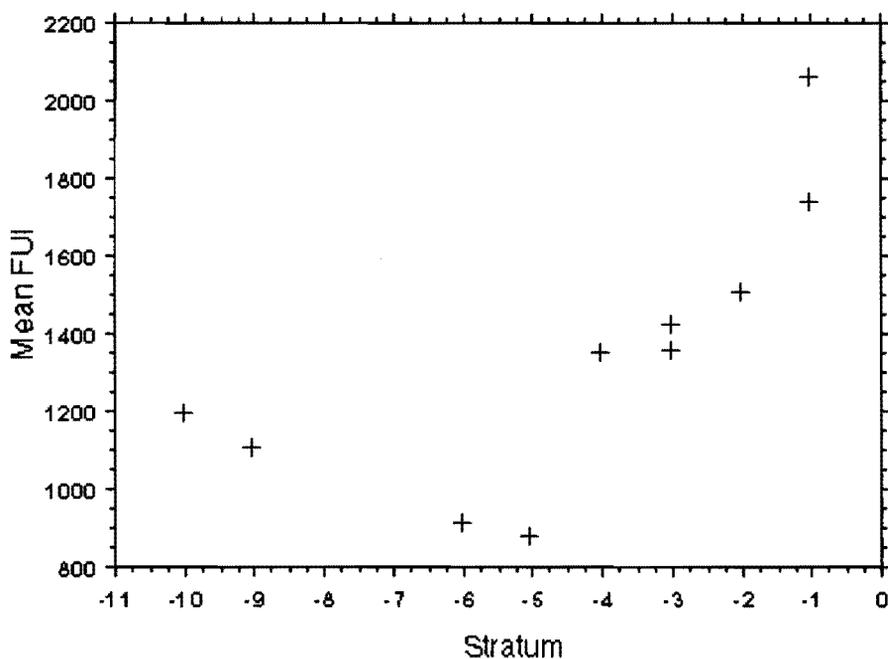


Figure 5. Mean utility of artiodactyl skeletal parts across the Emeryville strata. Samples showing a significant correlation between part density and part representation have been excluded (see Broughton 1999 for details).

make to increasing predation risk. Such responses may involve greater alertness or the abandonment of areas that have high-predator densities.

Pinnipeds and colonial waterbirds provide the best examples of taxa that are characterized both by patchy, age-related spatial structure and by the propensity to respond behaviorally to predation. High-density, seasonally based breeding colonies are typical components of the reproductive strategies of these animals. Such colonies are often quite sensitive to predation and even to the mere presence of predators. Sustained persecution will cause survivors to abandon colonies and form new ones in areas offering higher security — out of reach to human foragers. Regions that lose breeding colonies not only lose the highest-return patches for the species but also the major local source of sub-adult animals. If colonies are abandoned due to human hunting pressure, the effect would be relative increases in the encounter rates with adults and thus an increase in the mean age of exploited individuals.

So, there should be very different responses to harvest pressure depending on the nature of the prey species. Species that do not form patches characterized by different proportions of young and old individuals, and those that are behaviorally non-responsive to predators, should show the standard decline in mean age through time. This probably should apply to most molluscs and many fishes. The opposite pattern would be expected for colonial breeders, for the reasons described above.

Turning back to the Emeryville sequence, recall that the largest species derived from the estuarine fishes patch type is the white sturgeon, and that the relative abundance of this species declines steadily over the period that the site was occupied. This species does not form seasonal, high-density breeding congregations and exhibits no detectable spatial structure by age/size within the bay. It is also unlikely that sturgeon could perceive a human fishing threat in such a way that might lead them to abandon particular areas of the bay. White sturgeon then, probably like most fishes and molluscs, is a prey species for which

resource depression should cause decreases, rather than increases, in mean age. As Figure 6 shows, both the mean and maximum size of measured sturgeon dentaries decline significantly with the relative abundance of this high-ranked fish across the occupational history of the site.

Other well-represented vertebrate species in the Emeryville assemblage clearly form seasonal breeding congregations and are susceptible to behavioral/micro-habitat depression. Cormorants are perhaps the best example. These birds, including double-crested, Brandt's, and pelagic cormorants, are the most abundant avian taxa in the Emeryville fauna, next to the anatids. These birds form large rookeries during the spring and summer months in central California, typically on small islands within estuaries or off the coast. In no other contexts do chicks and sub-adult birds attain such high proportional abundances, and cormorant colonies are well known for their sensitivity to disturbance; vandalized or disturbed colonies are routinely abandoned.

Figure 7 displays the changing abundance of cormorants relative to all other birds in the Emeryville fauna. As the figure shows, cormorants increase steadily over the initial 800 years of site occupation. It is clear that cormorant rookeries were exploited here, as the remains of baby chicks and sub-adults are very abundant. Cormorant exploitation, however, falls off dramatically, to judge from the significant decline in their abundance across the upper six strata of the mound. If this decline reflects resource depression and the loss of local breeding colonies, it should be reflected by an increase in the proportion of adult birds. This is in fact the pattern revealed in the data: the relative abundances of cormorants is negatively correlated with the proportion of adults in the collection (Figure 8). In other words, the average age of the harvested cormorants *increases* as the local population appears to decline—there are proportionately more adults encountered in the bay as local breeding colonies are abandoned.

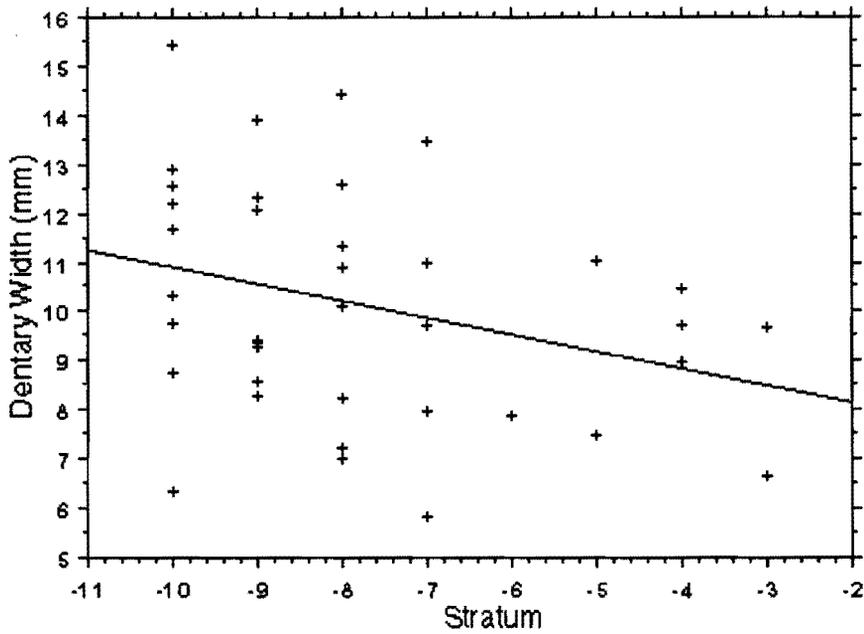


Figure 6. Dentary widths by stratum for the Emeryville Shellmound sturgeon (*Acipenser*).

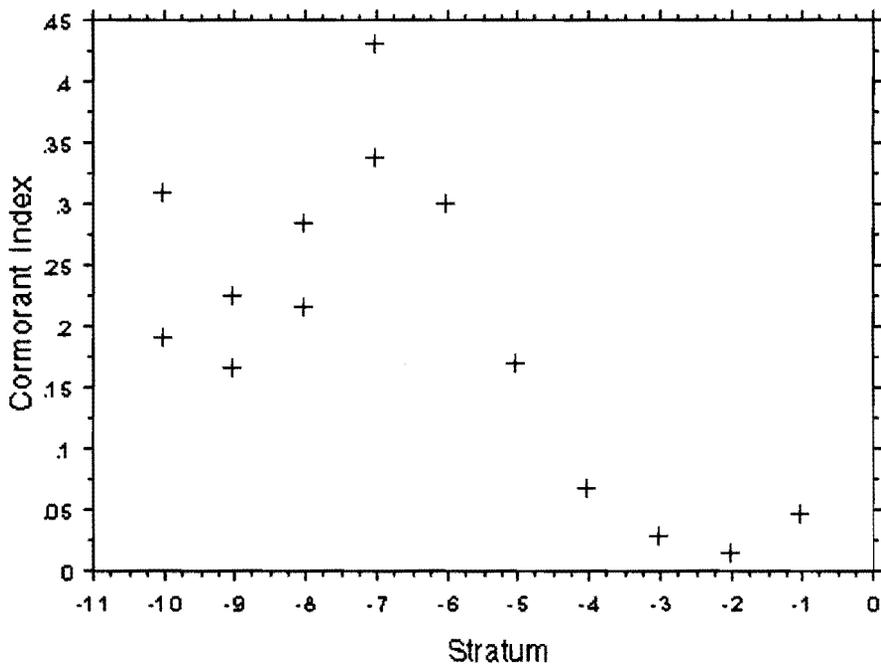


Figure 7. The distribution of the Cormorant Index ($\hat{\Delta}NISP\text{Phalacrocorax}/\hat{\Delta}NISP\text{Birds}$) by stratum at the Emeryville Shellmound. The Cormorant Index increases across the lower four strata (strata ten through seven: $r_s = 0.595$, $P = 0.11$) but declines over the upper six strata (strata six through one: $r_s = -0.77$, $P < 0.02$).

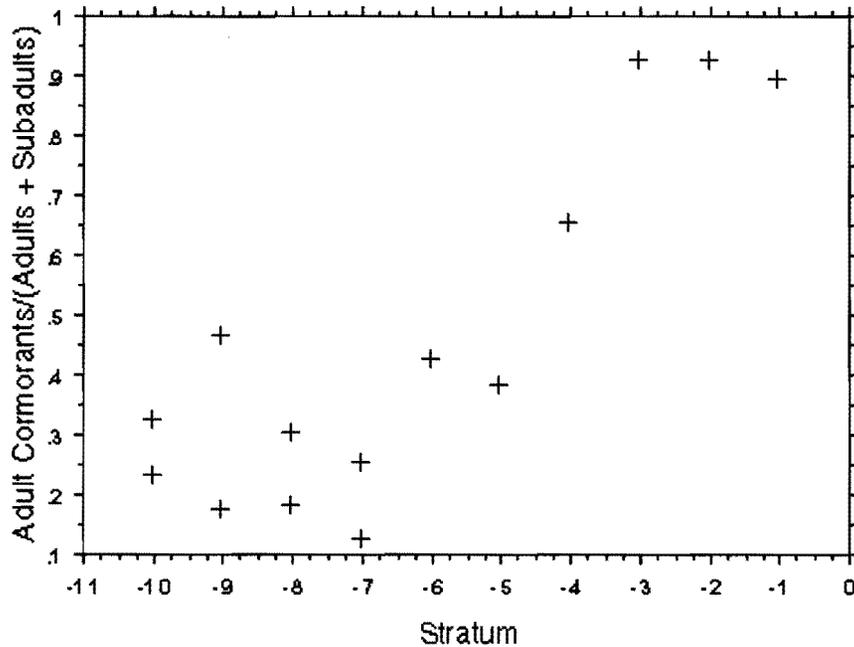


Figure 8. Changes in the proportional contribution of adult cormorants (Adult Cormorants / [Adults + Subadults]) across the Emeryville Shellmound strata. Subadults includes chicks. (Does not include stratum U1, that was represented by less than 10 cormorant specimens for which age could be determined).

CONCLUSION

In sum, two of the most commonly used indicators of prehistoric resource depression are temporal declines in the relative abundances of high-ranked species, and declines in the mean age of harvested prey. However, in certain contexts, resource depression may also be reflected by *increases* in both high-ranked prey abundances and in mean age. The rich vertebrate sequence from Emeryville uniquely displays each of these different patterns that seem to reflect systematic differences in the behavior and spatial distributions of the represented prey species. We may need to pay more detailed attention to these variables in applications of foraging models to the archaeological record in the future, especially in complex environments.

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