

A CRITICAL VIEW OF THE USE OF ARCHAEOLOGICAL VERTEBRATES IN PALEOENVIRONMENTAL RECONSTRUCTION

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ABSTRACT.—Most paleoenvironmental studies based upon archaeological vertebrates have relied either upon simple presence/absence studies of environmentally sensitive taxa, or have quantified the abundances of all taxa present, to infer environmental change. It is argued that it is extremely hazardous to approach paleoenvironmental reconstruction through counts of taxonomic abundance because: 1) the units available for counting taxonomic abundance, and our understanding of the processes which transform a pile of deceased animals into a faunal collection, are not such as to allow a demonstration that the numbers provided by abundance counts have any known relationship to the number of animals in the original pile, and, 2) we rarely, if ever, have any notion of the relationship between the quantitative structure of the living populations from which the sample was drawn and about which we are trying to make inferences, and the archaeological sample itself. It is concluded that only studies which treat taxa as attributes, and not as variables, can routinely be treated as valid. Other major difficulties presented by archaeological vertebrates in paleoecological reconstruction are reviewed, with special emphasis placed upon hazards encountered in presence/absence studies.

INTRODUCTION

During the past few decades, vertebrate remains from archaeological sites have become an increasingly popular source of information about past environments. It is easy to demonstrate this increasing popularity. Assuming that the sample of paleoclimatic literature in Grayson (1975) is representative of the literature of its subject area, and that trends within the paleoclimatic literature are representative of trends within the paleoenvironmental literature as a whole, this bibliography may be used to assess the changing role of archaeological vertebrates in the analysis of past environments in North America. The bibliography lists no archaeological vertebrate faunal studies conducted for paleoclimatic purposes prior to the 1931-1940 decade. Between 1931 and 1940, 2.8% of the published paleoclimatic studies made use of archaeological vertebrates; this figure decreased to 1.0% between 1941 and 1950, then increased to 4.0% between 1951 and 1960, increased again to 4.3% between 1961 and 1970, then increased yet again during the early years of the 1970's to 10.7% (Table 1). While these data are North American, paleoclimatic literature from other parts of the world seems to exhibit the same trends, although the use of archaeological vertebrates in paleoenvironmental reconstruction began much earlier in the Old World.

Given the increasing interest in the use of archaeological vertebrates as a source of information about past environments, it is interesting to note that the critical literature concerning such studies is quite small. While vertebrate paleontology has had a critical literature on paleoenvironmental reconstruction for well over a century (e.g., Dawkins 1869; Owen 1846), and this literature is rapidly becoming quite large (e.g., Behrensmeyer 1975; Shotwell 1955, 1958, 1963; Voorhies 1969; Munthe and McLeod 1975 and references contained therein); examination of the principles and processes of paleoenvironmental reconstruction using archaeological vertebrates are quite rare (for an excellent exception, see Findley 1964).

The lack of such a critical literature might suggest paleoenvironmental reconstruction using archaeological vertebrates is relatively straightforward, and can be conducted with little concern for potential analytic hazards. Nothing could be further from the truth, as this paper demonstrates.

DISCUSSION

Basic Approaches

Of the several approaches to paleoenvironmental reconstruction which have been employed using archaeological vertebrates, 2 characterize the vast majority of the literature. In the first of these approaches, the taxa present in an archaeological fauna are identified, and the kinds of animals present are used as the basis of inferences concerning the environments of the region at the time the fauna accumulated (e.g., Guilday and Adam 1967; Guilday and Parmalee 1972; Parmalee and Oesch 1972). In the second approach, each taxon is treated not as an attribute which can be either present or absent, but as a variable whose abundance can vary discretely. In studies which treat taxa as variables, some measure of taxonomic abundance is employed to derive quantitative statements about the relative abundances of all taxa present (e.g., Bate 1937; Butler 1972; Grayson 1976, 1977b; Harris 1963). These 2 approaches are examined in detail here.

Taxa as Variables

It is not hard to see that treating taxa as variables holds a greater potential for providing paleoenvironmental information than does treating them as attributes. Let us say, for instance, that we are studying the history of a simple ecosystem which includes only 2 mammals, taxon A and taxon B. The numbers of both taxa fluctuate faithfully and only with fluctuations in temperature: when it gets hotter, A increases while B decreases, and vice versa. Let us assume we have a fauna which contains a sample of A and B which is representative of the abundances of those animals in the environment surrounding the site during the past 1,000 years. Analysis of this fauna shows both A and B have been present during this entire period of time (Table 2a). All that can be inferred from this observation is that temperature minima and maxima have not exceeded the tolerances of either taxon during the period represented. Further analysis, however, shows the abundances of taxa A and B have fluctuated widely through time. Because the sample is representative of the environment when the sample was accumulating, and because abundances of these animals vary with temperature fluctuations, some fairly detailed statements can be made about temperature in the sampled area during the past 1,000 years,— for instance, time periods 4 through 8 were much warmer than the earlier and later periods represented (Table 2b). Clearly, treating taxa as variables holds the promise of providing much more detailed information on past environments than treating taxa as attributes, for the simple reason that presence/absence analyses force the analyst to convert a ratio scale measurement of taxonomic abundance into a nominal scale. When taxa are treated as attributes, only taxonomic presences are used as the basis of paleoenvironmental inference. When taxa are treated as variables, fluctuations in abundances of each taxon, or of groups of taxa, become an additional target of study.

It can be argued, therefore, that paleoenvironmental studies which depend upon counts of taxonomic abundance are preferred over those which treat taxa as presence/absence attributes. Unfortunately, one can argue even more forcefully that paleoenvironmental studies based upon counts of taxonomic abundance are not likely to provide demonstrably valid data about past environments (and here I use the term valid in its statistical sense: are we measuring what we think we are measuring?). There are 2 reasons for this: the nature of counts of taxonomic abundance, and, the nature of the faunal sample itself.

There are only 2 measures available for quantifying the abundances of taxa represented within an archaeological site: counts of identified specimens per taxon (NISP; in earlier publications, I have abbreviated this unit as E), and the minimum number of individuals per taxon (MNI; see Casteel 1978 and Grayson 1979 for a discussion of meat weights as a abundance measure). I have treated these units at length elsewhere (e.g., Grayson 1973, 1978a, and esp. 1979), and will not repeat those discussions here. It is, however, necessary to point out that NISP and MNI are similar in an important way: the relationship between the number provided by either measure and the actual number of animals which contributed

TABLE 1.—Numbers of paleoclimatic studies in North America using vertebrate remains from archaeological sites (data from Grayson 1975).

DECADE	STUDIES EMPLOYING		b(100)/a
	ALL STUDIES (a)	ARCHAEOLOGICAL VERTEBRATES (b)	
1881 - 1890	2	0	0.0
1891 - 1900	1	0	0.0
1901 - 1910	2	0	0.0
1911 - 1920	7	0	0.0
1921 - 1930	32	0	0.0
1931 - 1940	144	4	2.8
1941 - 1950	200	2	1.0
1951 - 1960	302	12	4.0
1961 - 1970	559	26	4.7
1971 - (*)	149	16	10.7
TOTALS	1398	60	

(*): while the latest references in Grayson (1975) are dated 1974, coverage comparable to previous decades extends only to 1973.

TABLE 2.—An example of an archaeological faunal analysis in which taxa are treated both as attributes (Table 2a) and as variables (Table 2b). See text for explanation.

a: TAXA AS ATTRIBUTES				b: TAXA AS VARIABLES (numbers represent absolute abundances)			
TIME PERIOD	TAXON			TAXON			
	A	B		A	B		
	1	x		x	1	10	90
2	x	x	2	10	90		
3	x	x	3	10	80		
4	x	x	4	40	30		
5	x	x	5	60	20		
6	x	x	6	80	10		
7	x	x	7	50	05		
8	x	x	8	40	05		
9	x	x	9	10	60		
10	x	x	10	10	80		

(x - taxon recorded as present)

bones to the collection under study is, in all but trivial instances, unknown. That is, the meaning of both these estimators of abundance is severely clouded because the relationship between estimated and actual abundances must always be unknown.

For example, time period 4 of the site presented in Table 2b provides abundances of "40" for taxon A and "30" for taxon B without mention of what measure of abundance is being used. This is clarified by noting that the figures represent minimum numbers of individuals defined from 450 identified specimens of A and 550 identified specimens of B. Knowing this, it is no longer clear what the actual abundances of A and B really are. It is possible to consult the voluminous literature on this point (see Grayson 1979 for a review), and recount the arguments for and against NISP and MNI as abundance measures. Instead, it can be pointed out that this problem cannot be solved because the relationship between both counts and the number of animals which originally contributed to the collection is unknown and unknowable. Unfortunately, it is the original number which is the target of our estimates.

There is, for instance, no reason why the original number of animals deposited in our site *could not* have been 60 of taxon A and 80 of taxon B. Continuing to assume that the numbers "60" and "80" are an accurate reflection of the abundances of these taxa in the environment surrounding the site, and that these numbers directly provide information on temperature, it is not hard to see how misleading are the NISP values (450 for taxon A and 550 for taxon B), or the MNI values (40 for taxon A, 30 for taxon B). Because there is no way of working back from an excavated collection of bones to when it was deposited, and because there is no way of relating counts of identified specimens or minimum numbers of individuals to the number of animals which contributed to the faunal collection, neither NISP nor MNI is a reasonable quantifier of taxonomic abundance in this case. We simply do not know, and cannot know, what the counts they provide mean in terms of actual abundances. Since there are no other ways available for counting abundance in this setting, it is clear that one of the bases for analyzing the taxonomic abundances of archaeological vertebrates is very weak indeed.

But there is another, even more damaging, problem involved in the paleoenvironmental use of archaeological vertebrates. In the example above, it has been assumed the sample of animals deposited in the site was representative of what was living in the area at the time the sample was accumulating. Unfortunately, the relationship between the archaeological collection and the actual population — the set of animals living in the area at the time the archaeological sample was being deposited (the "target population") — is unknown, except that the animals in the collection probably came from that area. As with the relationship between NISP and MNI and actual abundances, the relationship between the sample which has accumulated in an archaeological site and the target population is usually unknown and unknowable. This presents an insurmountable difficulty for using the quantified abundances of taxa within an archaeological site as a key to past environments.

The problem seems an obvious one. To continue with the example above (Table 2), I shall drop the unrealistic assumption that the collection under study accurately represents the abundances of taxa A and B in the surrounding environment at the time the fauna was accumulating, and note instead that the numbers of animals reaching the site probably had more to do with the mechanism of accumulation than with the actual abundances of those taxa in the sampled area. The abundances of taxa A and B may have been in the ratio of 100 to 1 in the sampled environment, but if the accumulation mechanism sampled taxon B almost to the exclusion of taxon A, then the deposited abundances of 60 individuals for taxon A and 80 individuals for taxon B (as noted above) are entirely possible.

Is it unreasonable to emphasize that the relationship between the target population and the archaeological fauna is unknown? Can that situation really cause problems so severe that it becomes inappropriate in most cases to derive paleoenvironmental information from taxonomic abundances? A simple example serves to demonstrate the problem is, in fact, a severe one.

People are just one in a set of mechanisms which accumulate vertebrate remains in archaeological sites. Other organic accumulation mechanisms include a variety of non-human predators and scavengers (see, for instance, Butler 1972; Guilday and Parmalee 1972; Lundelius 1960; Mellet 1974). It seems obvious that predators and scavengers, including people, cannot be relied on to gather a representative sample of creatures in the surrounding environment. The complications introduced as a result of these varied accumulation mechanisms may be seen by examining the behavior of owls, a class of predators whose collecting behavior seems simple compared to that of humans.

The predation patterns of owls have been particularly well studied. Maser et al. (1970), for instance, studied the food habits of 3 species of owls in central Oregon — Great Horned Owl (*Bubo virginianus*), Short-eared Owl (*Asio flammeus*) and Long-eared Owl (*Asio otus*). These authors gathered and analyzed 24 sets of owl pellets from these 3 species between February and July, 1969. With the exception of 2 collections from areas adjacent to springs (one each from *B. virginianus* and *A. otus*), all collections were from habitats "similar in all areas" (Ibid. 1970:4).

TABLE 3.—Mammalian contents of pellets from 3 species of owls (from Maser et al. 1970).

	BUBO VIRGINIANUS		ASIO OTUS		ASIO FLAMMEUS	
	MNI	%	MNI	%	MNI	%
<i>Peromyscus maniculatus</i>	43	32	20	20	65	19
<i>Microtus montanus</i>	25	19	4	4	37	11
<i>Thomomys talpoides</i>	21	16	6	6	94	27
<i>Perognathus parvus</i>	19	14	64	63	101	29
<i>Reithrodontomys megalotis</i>	10	8	3	3	22	6
<i>Lagurus curtatus</i>	7	5	4	4	14	4
<i>Neotoma cinerea</i>	3	2	0	0	0	0
<i>Dipodomys ordii</i>	3	2	1	1	16	5
<i>Spermophilus beecheyi</i>	1	1	0	0	0	0
<i>S. townsendii</i>	1	1	0	0	0	0
Totals	133	100	349	99	102	101

TABLE 4.—Modern owl pellets as archaeological strata. Data from Table 3; see text for explanation.

	STRATUM		
	1	2	3
<i>Microtus montanus</i> and <i>Thomomys talpoides</i>	46	10	131
<i>Perognathus parvus</i> and <i>Dipodomys ordii</i>	22	65	117

Stratum 1 = *Bubo virginianus* (from Table 3)
 Stratum 2 = *Asio otus* (from Table 3)
 Stratum 3 = *Asio flammeus* (from Table 3)

χ^2 values: 1 - 2: 44.15 (p .01)
 2 - 3: 36.20 (p .01)

Some of the data from these 24 pellet collections are presented in Table 3, which displays the number of mammalian individuals for each owl species calculated from identified skulls and mandibles (C. Maser, personal communication). Rather than treating these data as synchronic, they are viewed as having accumulated over time, the pellets from *B. virginianus* accumulating first, then those from *A. otus*, and finally those from *A. flammeus*. Such a situation is not far-fetched; several species of owls can be found in any given patch of habitat (Bent 1938; Marti 1974), and shifts in the use of roosts by owls can be readily observed today.

A stratified faunal collection from the pellets of 3 species of owls, all of which hunt the same habitat, has now been constructed. Using this collection of pellets as the basis of inferences concerning past environments in the area surrounding the site is accomplished by following the lead of the archaeological literature (Butler 1972; Grayson 1977b; Harper and Alder 1970), and by considering the Montane Vole (*Microtus montanus*) and the Northern Pocket Gopher (*Thomomys talpoides*) as indicators of mesic environments, and the Great Basin Pocket Mouse (*Perognathus parvus*) and Ord's Kangaroo Rat (*Dipodomys ordii*) as indicators of xeric environments.

Statistical analysis of this stratified collection of owl pellets shows the proportion of mesic and xeric rodents change significantly between strata, with greater numbers of xeric rodents in stratum 2 than can be accounted for by chance, a fewer number of mesic rodents than any hypothesis of randomness would allow in that stratum (Table 4). The conclusion of such an analysis would be: stratum 1 accumulated during a time of relatively high effective precipitation, producing a greater abundance of mesic habitats, while stratum 2 accumulated during a time of relatively low effective precipitation which produced a greater abundance of xeric habitats. Stratum 3, in turn, saw a return to conditions approaching those of stratum 1 times. Yet, all that has happened is that I have constructed a fauna using modern data under the reasonable assumption that different species of owl can, through time, use the same roost. That is, it is assumed that accumulation mechanisms can change through time. What this analysis has detected is not environmental change through time, but different predation patterns by a set of sympatric owls. It is perhaps, one of the reasons why these owls can be sympatric.

The relationship between owl pellet accumulations and archaeological faunas is not a forced one. It is true that many archaeological faunas from rockshelters are in part composed of vertebrates from owl pellets. But more important is the fact that owls, and other non-human predators and scavengers, represent one of a myriad of accumulation mechanisms which account for the deposition of bones in archaeological sites, and that changes in the accumulation mechanisms lead to changes in composition of the fauna which faunal analysts ultimately study. Clearly, any paleoenvironmental analysis of archaeological vertebrates must take into account that the relationship between the taxonomic abundances which characterized the living community at the time a fauna accumulated, and the abundances of animals which became incorporated in that accumulating fauna is dependent upon the accumulation mechanisms. Because those mechanisms are rarely known, the relationship between the population of animals in the site and the target population cannot be known with any precision. This is true even when problems relating to differential preservation of deposited materials are set aside. As a result, the validity of any paleoenvironmental reconstruction based on counts of abundance must always be in question.

There are 2 reasons, then, why paleoenvironmental reconstruction based upon the quantification of taxonomic abundances is exceedingly hazardous. First, the units available for counting taxonomic abundances, and our understanding of the processes which transform a pile of deceased animals into a faunal collection, do not allow a demonstration that the numbers provided by those units have much relationship to the number of animals in the original pile. Second, we rarely, if ever, have any notion of the relationship between the quantitative structure of the target population, from which the sample was drawn and about which we are trying to make inferences, and the archaeological sample. Because of these problems, it is rare that counts of taxonomic abundance can tell us anything about known environmental parameters. If this is the case, taxa should be treated as attributes which can be either present or absent, rather than trying to interpret taxonomic abundances as if they necessarily provided information concerning known environmental parameters. This position is very similar to that taken by Sir Richard Owen (1846:XXVII) over a century ago:

The multitude of coexisting individuals is not to be reckoned from the absolute quantity of their fossil remains in a given locality. As reasonably might we infer the former populousness of a deserted village from the quantity of human bones in its churchyard.

The Taphonomic Solution?—In 1940, Efremov suggested that greater attention be paid to “the study of the transition (in all of its details) of animal remains from the biosphere to the lithosphere” (Efremov 1940:85), a study which he termed taphonomy. Since that time, a wealth of studies on the taphonomy of archaeological and paleontological sites has appeared (Behrensmeyer 1975, 1978; Brain 1969; Clark and Guensburg 1970; Gifford and Behrensmeyer 1977; Dodson 1973; Noe-Nygaard 1977; Shotwell 1955, 1958; Voorhies 1969; Wolff 1973). These studies accept as a working principle that the solution of taphonomic

problems is logically prior to the use of archaeological and paleontological vertebrates for the extraction of paleoenvironmental information.

It is difficult to disagree with this principle. However, it would be optimistic indeed to think that taphonomic approaches will ever become sufficiently refined to allow the easy interpretation of taxonomic abundances from archaeological sites. Returning to the modern owls, and the fauna which they provided, makes this point more forcefully.

As Maser et al. (1970) point out, fresh owl pellets from their study area were easily recognized as they were whole, held together by shiny mucous covering. After about a month, the pellets were rapidly disintegrated, in part because of the activities of a tineid moth which feeds on the mucous covering on the pellets, and what remains is not an owl pellet, but the often fragmented contents of that pellet. In analyzing owl pellet remains from archaeological sites, there are 2 immediate difficulties: first is a need to recognize bones that were once part of an owl pellet; second, in order to establish continuity in accumulation mechanisms, there is a need to recognize that all owl pellets did, or did not, come from the same species of owl. If these difficulties could be solved and bones could be separated from pellets of different and known species of owls, there would still be no usable information about taxonomic abundances except that a given taxon was present. This is true because owls take non-random samples of what is in the environment (Errington et al. 1940; Marti 1974). In the study examined here, Maser et al. (1970:5-6) note that "although the deer mouse is generally the most common small mammal in central Oregon . . . the owls caught far more pocket mice than deer mice." In other words, it is impossible to go from the data presented by Maser et al. (1970) to the abundances of the captured mammals in the hunted environment. Since that is the case, it would clearly be impossible to do so in the archaeological setting. Indeed, it may even be difficult to use the number of individuals represented in an owl pellet to the number of individuals which were eaten to produce that pellet (Raczynski and Ruprecht 1974). The only reliable information about the local mammalian population in either the modern or the archaeological setting is the simple observation that since a taxon was present in the faunal collection, it was probably present in the immediate vicinity.

Owls have been used as examples here because they are well-studied. The behavior of other raptors (Craighead and Craighead 1956), and of carnivores, wood rats, streams, and other mechanisms — including people — which accumulate faunas are no less complex. No matter how precise taphonomic statements become, there is one question which they can not answer: what is the relationship between the abundances of taxa in an accumulating fauna and the abundances of those taxa in the surrounding environment? This is no criticism of the taphonomic literature as taphonomists do not have this goal in mind. It is, however, a criticism of any attempt to facilely interpret taxonomic abundances in archaeological faunas which requires something be known of the relationship between those abundances and the abundances of the animals in the area from which those faunas were derived.

Taxa as Attributes

Since the paleoenvironmental meaning of taxonomic abundances from single archaeological faunas can never be known, presence/absence studies become the only acceptable approach to the paleoenvironmental analysis of those faunas.

Such studies are actually quite simple; in fact, it is this simplicity which accounts for much of their value. In presence/absence faunal studies, one simply identifies what is present in a fauna and interprets the paleoenvironmental meaning. Even if abundances are calculated, as they usually are, they are not interpreted (e.g., Guilday and Adam 1967; Parmalee and Oesch 1972). Instead, the attributes of the represented animals are used as the basis for statements about the environment surrounding the site of deposition at the time of deposition. Guilday and Adam (1967) provide a good example of such a study. After noting the presence of the collared lemming, *Dicrostonyx*, at Jaguar Cave, southern Idaho, they note this animal is "an obligatory tundra form with a long evolutionary association with a

boreal climate" (1967:29), whose presence in the Pleistocene deposits of Jaguar Cave "is indicative of a former tundra biome" (1967:29).

It would be hard to disagree with Guilday and Adam's statement. In fact, presence/absence studies (which are asymmetrical in that the interpretive emphasis is usually placed on presences) are usually quite sound. However, these studies are not trouble free. There are hazards in conducting presence/absence paleoenvironmental analyses of archaeological vertebrates, most of which are shared with approaches that treat taxa as variables. Among these hazards are:

1) Assuming that the present ecology of specific mammals is the same as the ecology of those mammals in the past. It is extremely difficult to reconstruct the ecology of ancient mammals, though there have been attempts (e.g., Shotwell 1955, 1958, 1963; but, see also Grayson 1978b). If faunal analysts had to demonstrate the present ecologies of mammals were the same in the past for each time and place they conduct a paleoenvironmental study, they would not get very far. The ecologies of past animals may not be directly knowable, but this problem can in part be circumvented if suites of taxa, which have the same relationship to a given environmental parameter today, are used as the basis of statements concerning that parameter in the past. While habitat preferences of a single taxon might change through time, it is less likely that all members of a suite of taxa would change, and that all would change in the same direction. Findley (1964) has discussed this issue as well.

2) Assuming that ecological relationships remain stable across space and competitive settings. However, these relationships are not stable. In Oregon, for instance, the White-tailed Antelope Squirrel (*Ammospermophilus leucurus*) is an inhabitant of "the open, barren valleys far from timber, but usually where tufts of greasewood, sagebrush, and low desert shrubs furnish cover, protection, and food" (Bailey 1936:142). Not far to the south in central Nevada, they are seen in a different setting, pinyon-juniper woodland well above valley floors (Hall 1946). To infer an area "treeless" or "treed" from these squirrels would be hazardous. Such adaptational plasticity may often be due to changing competitive relationships. As Cody (1974:131) noted, "often no compelling innate-genetic or physiological constraint restricts a species to a particular section of the resource gradient, but rather ... its position is flexible, and is determined by the restraints of its competitors." Thus, on Bear Island, Iceland, Brunnich's Guillemot (*Uria lomvia*) nests on cliff ledges, while the Common Guillemot (*U. aalge*) rests on flat ground. To the south, in Europe, where only *U. aalge* is present as a breeder, this species nests on both cliff ledges and flat ground (Lack 1968). Such examples of *competitive release* are common and well known. Much of what animals do is determined by competitive relations; and this lability in adaptation must be recognized in paleoenvironmental studies. Again, the danger of error from this source decreases as the number of animals used as the basis of inferences concerning some environmental parameter in the past increases. When possible, suites of taxa, not single taxa, should be used as the basis of any paleoenvironmental argument.

3) Stratigraphic mixture. Any study based upon analysis of presence/absence data from archaeological sites must be conducted with the realization that such studies are extraordinarily prone to error as a result of stratigraphic mixture; i.e., a single element identified for a given taxon carries as much weight as a thousand of those elements. Although it is appropriate to point out that only careful excavation can prevent such difficulties, it is also true that many sites are so stratigraphically complex that even the most careful excavations may not be able to detect all instances of mixture. Once again, the use of suites of taxa can help avoid errors due to this source.

4) Poor stratigraphic resolution. While mixing of contents from originally separate strata can cause difficulties, so can the analysis of materials from deposits which never had detailed stratigraphic resolution. Interpretive difficulties arise in this instance because statements are made which require finer stratigraphic resolution than was present or documented. This issue is becoming more important and increased attention is paid to the argument that Pleistocene climates were more equable than Holocene climates (Axelrod 1967; Dalquest

1965; Hibbard 1970; Slaughter 1967); since one of the arguments used to support this hypothesis is that currently allopatric animals were sympatric during the Pleistocene. For example, Pleistocene sympatry of boreal and deciduous forest species has been argued to support the hypothesis of Pleistocene climatic equability (Graham 1976; Graham and Semken 1976). Yet, it is extremely difficult to argue that "stratigraphically sympatric" taxa in a single stratum of an archaeological or paleontological site were truly sympatric animals, and not actually allopatric or allochronic. A convincing demonstration of sympatry in this setting would take remarkably fine stratigraphic resolution of a sort which is rarely encountered in either archaeological or paleontological sites.

5) Long distance transport of skeletal remains. The ethnographic literature abounds with examples of animals transported by humans to areas outside of their natural range. Other forms of long distance transport are also possible: movement by water provides one obvious mechanism. Although some instances of transport are readily detected (as the transport of *Haliotis* from the Pacific coast of North America to interior localities as Arizona [Haury 1976]), others will not be. The use of a suite of taxa, all of which inform on a single environmental variable, provides one means of circumventing this difficulty, as does the reasonable application of the principle of parsimony. For instance, it is far simpler to suggest that Guilday and Adam's *Dicrostonyx* was a local resident than it is to argue that long distance transport was involved. In many cases, however, the local presence of a taxon whose historic range was not far removed from that area might be of concern for strictly biogeographic reasons (e.g., Grayson 1977a). Here, it might be considerably more difficult to convincingly argue that long distance transport did not play a role in bringing the animal to an area in which it would not otherwise have occurred (see, for instance, the discussion by Alcorn [1940] of the introduction by man of *Spermophilus townsendii* into areas outside of its natural range).

Clearly, these and other potential difficulties demonstrate that paleoenvironmental analyses of archaeological faunas which depend only upon presence/absence data are not trouble free. Nonetheless, the hazards associated with these studies are of a lesser magnitude than those which necessarily accompany studies which proceed by quantifying taxonomic abundances. Unlike the latter, the basic unit with which analyst deals in presence/absence studies — the demonstrated presence of a taxon — often presents little interpretive difficulty.

CONCLUSIONS

Two approaches to the paleoenvironmental analysis of vertebrate faunas from archaeological sites are in common use. In one of these approaches, the abundances of the taxa in the fauna are quantified using either counts of identified specimens or minimum numbers of individuals, and changing abundances through time are examined for paleoenvironmental meaning. This approach, while seeming to offer great precision in paleoenvironmental analyses, has 2 debilitating attributes:

1) The relationship between the abundance measure (NISP or MNI) and the actual numbers of animals which contributed skeletal remains to the collection is always unknown; as a result, the meaning of these abundance measures is, with trivial exceptions, always unknown;

2) The relationship between taxonomic abundances in the environment surrounding the site at the time of fauna accumulated and the abundances of the animals present in an archaeological fauna is always unknown. As a result, even if the relationship between NISP or MNI and the number of animals originally deposited in a site were known, the meaning of changes in these abundances through time would not be interpretable. This is because it is rarely known if changing abundances are reflecting actual changes in taxonomic abundance in the surrounding environment, or if these abundances are reflecting changes in the mechanisms of accumulation which are unrelated to the environment changes the analyst is attempting to monitor.

Because of these shortcomings, it is difficult to have faith in the validity of these studies. As a result, analyses which depend only upon the taxa recorded as present within a fauna are to be preferred. While such studies also have pitfalls, they are by far and large pitfalls associated with all paleoenvironmental studies dealing with fossil or subfossil remains. Most importantly, presence/absence studies are not characterized by the 2 major and seemingly insurmountable shortcomings associated with vertebrate faunal studies which treat taxa as variables. Until ways of eliminating these shortcomings are found, it is difficult to see that it will be possible to improve paleoenvironmental studies of archaeological vertebrates which proceed simply on the basis of treating vertebrates as belonging to taxa which can either be present or absent, but whose abundance cannot be meaningfully counted.

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LITERATURE CITED

- ALCORN, J.R. 1940. Life history notes on the Piute ground squirrel. *J. Mamm.* 21:160-170.
- AXELROD, D.I. 1967. Quaternary extinctions of large mammals. *Univ. California Publ. Geol.* 74:1-42.
- BAILEY, V. 1936. The mammals and life zones of Oregon. *N. Amer. Fauna* 55.
- BATE, D.M.A. 1937. Paleontology: The fossil fauna of the Wady El-Mughara Caves. Pp. 136-227, in *The Stone Age of Mount Carmel. Excavations at the Wady El-Mughara. Vol. 1* (by D.A.E. Garrod and D.M.A. Bate), Clarendon Press, Oxford.
- BEHRENSMEYER, A.K. 1975. Taphonomy and paleoecology of Plio-Pleistocene vertebrate assemblages east of Lake Rudolf, Kenya. *Harvard Mus. Comp. Zool. Bull.* 146(10):473-578.
- . 1978. Taphonomic and ecologic information from bone weathering. *Paleobiology* 4:150-162.
- BENT, A.C. 1938. Life histories of North American birds of prey (Part 2). Orders Falconiformes and Strigiformes. *U.S. Natl. Mus. Bull.* 170.
- BRAIN, C.K. 1969. The contribution of Namib Desert Hottentots to an understanding of Australopithecine bone accumulations. *Scient. Papers Namib Desert Res. Sta.* 39:13-22.
- BUTLER, B.R. 1972. The Holocene or postglacial ecological crisis on the eastern Snake River Plain. *Tebiwa* 15(1):49-63.
- CASTEEL, R.W. 1978. Faunal assemblages and the "weigemethode" or weight method. *J. Field Arch.* 5:71-77.
- CLARK, J., AND T.E. GUENSBURG. 1970. Population dynamics of *Leptomeryx*. *Fieldiana-Geol.* 16(16):411-451.
- CODY, M.L. 1974. Competition and the structure of bird communities. *Monogr. Pop. Biol.* 7. Princeton Univ. Press, Princeton.
- CRAIGHEAD, J.J., AND F.C. CRAIGHEAD, JR. 1956. Hawks, owls and wildlife. Stackpole, Harrisburg, and Wildlife Mgmt. Inst., Washington.
- DALQUEST, W.W. 1965. New Pleistocene formation and local fauna from Hardeman County, Texas. *J. Paleontol.* 39:63-79.
- DAWKINS, B.W. 1869. On the distribution of the British postglacial mammals. *Quart. J. Geol. Soc. London* 25:192-217.
- DODSON, P. 1973. The significance of small bones in paleoecological interpretation. *Univ. Wyoming Contrib. Geol.* 12(1):15-19.
- EFREMOV, J.A. 1940. Taphonomy: a new branch of paleontology. *Pan-Amer. Geol.* 74:81-93.
- ERRINGTON, P.L., F. HAMERSTROM, AND F.N. HAMERSTROM, JR. 1940. The Great Horned Owl and its prey in north-central United States. *Agric. Exp. Sta., Iowa State College Agric. Mech. Arts, Entomol. Econ. Zool. Section, Res. Bull.* 277.
- FINDLEY, J.S. 1964. Paleoecologic reconstruction: vertebrate limitations. Pp. 23-25, in *The reconstruction of past environments* (J.J. Hester and J. Schoenwetter, eds.), Fort Burgwin Res. Center Publ. 3.
- GIFFORD, D.P., AND A.K. BEHRENSMEYER. 1977. Observed formation and burial of a recent human occupation site in Kenya. *Quat. Res.* 8:245-266.
- GRAHAM, R.W. 1976. Late Wisconsin mammalian faunas and environmental gradients of the eastern United States. *Paleobiology* 2:343-250.
- . AND H.A. SEMKEN. 1976. Paleoecological significance of the short-tailed shrew (*Blarina*) with a systematic discussion of *Blarina brevicauda*. *J. Mamm.* 57:433-449.
- GRAYSON, D.K. 1973. On the methodology of faunal analysis. *Amer. Antiquity* 38:432-439.
- . 1975. A bibliography of the literature on

- North American climates of the past 13,000 years. Garland Publ., New York.
- _____. 1976. The Nightfire Island avifauna and the Aluthermal. Pp. 74-102, in *Holocene environmental change in the Great Basin* (R. Elston, ed.), Nevada Archaeol. Survey Res. Reports 6.
- _____. 1977a. On the Holocene history of some Northern Great Basin lagomorphs. *J. Mamm.* 58:507-513.
- _____. 1977b. Paleoclimatic implications of the Dirty Shame Rockshelter mammalian fauna. *Tebiwa: Misc. Papers Idaho State Univ. Mus.* 9.
- _____. 1978a. Minimum numbers and sample size in vertebrate faunal analysis. *Amer. Antiquity* 43:53-65.
- _____. 1978b. Reconstructing mammalian communities: a discussion of Shotwell's method of paleoecological analysis. *Paleobiology* 4:77-81.
- _____. 1979. On the quantification of vertebrate archaeofaunas. Pp. 199-239, in *Advances in Archaeological Method and Theory*, Vol. 2 (M.B. Schiffer, ed.), Academic Press, New York.
- GUILDAY, J.E., AND E.K. ADAM. 1967. Small mammal remains from Jaguar Cave, Lemhi County, Idaho. *Tebiwa* 10(1):26-37.
- _____. AND P.W. PARMALEE. 1972. Quaternary periglacial records of voles of the genus *Phenacomys* Merriam (Cricetidae:Rodentia). *Quat. Res.* 2:170-175.
- HALL, E.R. 1946. *Mammals of Nevada*. Univ. California Press, Berkeley and Los Angeles.
- HARPER, K.T., AND G.M. ALDER. 1970. The macroscopic plant remains of the deposits of Hogup Cave, Utah, and their paleoclimatic implications. Pp. 215-240, in *Hogup Cave* (by C.M. Aikens), Univ. Utah Anthrop. Papers 93.
- HARRIS, A.H. 1963. Vertebrate remains and past environmental reconstruction in the Navajo. Reservoir district. *Mus. New Mexico Press Papers Anthropol.* 11.
- HAURY, E.W. 1976. *The Hohokam: desert farmers and craftsmen*. Univ. Arizona Press, Tucson.
- HIBBARD, C. 1970. Pleistocene mammalian local faunas from the Great Plains and Central Lowland provinces of the United States. Pp. 395-433, in *Pleistocene and Recent environments of the Central Great Plains* (W. Dort, Jr., and J.K. Jones, Jr., eds.), Dept. Geol. Univ. Kansas Spec. Publ. 3.
- LACK, D. 1968. *Ecological adaptations for breeding in birds*. Chapman and Hall, London.
- LUNDELIUS, E., JR. 1960. Post Pleistocene faunal succession in western Australia and its climatic interpretation. *Proc. Internat. Geol. Congress* 21: IV, 142-153.
- MARTI, C.D. 1974. Feeding ecology of four sympatric owls. *Condor* 76:45-61.
- MASER, C., E.W. HAMMER, AND S.H. ANDERSON. 1970. Comparative food habits of three owl species in central Oregon. *The Murrelet* 51: 53:29-33.
- MELLET, J.S. 1974. Scatological origin of micro-vertebrate fossil accumulations. *Science* 185:349-350.
- MUNTKE, K., AND S.A. McLEOD. 1975. Collection of taphonomic information from fossil and recent vertebrate specimens with a selected bibliography. *PaleoBios* 19.
- NOE-NYGAARD, N. 1977. Butchering and marrow fracturing as a taphonomic factor in archaeological deposits. *Paleobiology* 3:218-237.
- OWEN, R. 1846. *A history of British fossil mammals, and birds*. J. Van Voorst, London.
- PARMALEE, P.W., AND R.D. OESCH. 1972. Pleistocene and recent faunas from the Brynjulfson Caves, Missouri. *Illinois State Mus. Reports Invest.* 25.
- RACZYNSKI, J., AND A.L. RUPRECHT. 1974. The effect of digestion on the osteological composition of owl pellets. *Acta Ornithologica* 14(2):25-28.
- SHOTWELL, J.A. 1955. An approach to the paleoecology of mammals. *Ecology* 36:327-337.
- _____. 1958. Inter-community relationships in Hemphillian (mid-Pliocene) mammals. *Ecology* 39:271-282.
- _____. 1963. The Juntura Basin: studies in earth history and paleoecology. *Amer. Philosoph. Soc. Trans.* 53(1).
- SLAUGHTER, B.H. 1967. Animal ranges as a clue to late-Pleistocene extinctions. Pp. 155-168, in *Pleistocene extinctions: the search for a cause* (P.S. Martin and H.E. Wright, eds.), Yale Univ. Press, New Haven.
- VOORHIES, M.R. 1969. Taphonomy and population dynamics of an early Pliocene vertebrate fauna, Knox County, Nebraska. *Univ. Wyoming Contrib. Geol. Spec. Paper* 1.
- WOLFF, R.G. 1973. Hydrodynamic sorting and ecology of a Pleistocene mammalian assemblage from California (U.S.A.). *Palaeogeogr., Palaeoclimatol., Palaeoecol.* 13:91-101.