Similarity Coefficients and Relationships of Wisconsin-Age Faunas New Mexico and Trans-Pecos Texas

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Abstract

Presence–absence coefficients of similarity were calculated between 23 fossil vertebrate faunas (predominantly mammals) from New Mexico and the Guadalupe Mountains of Trans-Pecos Texas, and also between these faunas and six modern regional faunas thought to possibly represent approximate modern analogues. These quantitative results are compared to past qualitative assessments with variable results. The coefficients of similarity often agree with qualitative analyses but lack the sensitivity of qualitative methods; they are potentially important adjuncts to qualitative analysis.

INTRODUCTION

The vertebrate faunas of present-day New Mexico and the adjacent Guadalupe Mountains of Trans-Pecos Texas display significant geographic differences among themselves, reflecting varying origins, different histories, and the region's varied climate and topography. Without doubt, past faunas also varied from place to place and, within a single area, through time. Interpretation of past patterns of variation, however, is particularly difficult due to spotty distribution of sites in space and time, in addition to the normal difficulties of working with fossil faunas: biases in deposition, preservation, and recovery; the difficulty of sure identification based on fragmentary material; and mixing of faunas of different ages.

The most common approach to interpretation of Pleistocene fossil faunas has been qualitative. That is, using a knowledge of present-day ecologic distributions and environmental limiting factors of extant members of the fauna and applying these data to individual taxa within the fossil faunas. The results are taken to characterize the environmental conditions at the time of faunal deposition if all treated taxa are consistent in their requirements; inconsistencies not explainable by accepted theory require further investigation or are taken as indications that the fauna is not a natural unit (e.g., is a mixed fauna or encompasses an extended time span that includes significant environmental change).

Qualitative evaluation of similarities between fossil faunas and between fossil and modern faunas has long been applied to Late Pleistocene cave faunas of the region. For example, Stearns (1942) suggested a major lowering of life zones, allowing marmots to descend from the high mountains of northern New Mexico to occupy New La Bajada Hill southwest of Santa Fe; later, Murray (1957) implied a relationship between southeastern New Mexico and the highlands of northern New Mexico based on the fauna of Burnet Cave. Similar efforts directed toward other faunas (discussed further below) have compared various Pleistocene faunas to the modern faunas of northeastern New Mexico, southeastern Idaho, or to major mixtures of more than one area of similarity (Harris, 1985, 1987, 1989; Slaughter, 1975). In terms of chronology, Harris (1977) attempted to place a series of New Mexican sites into segments of time based on faunal similarities.

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Although such qualitative efforts may be valuable, there is danger that excessive subjectivity may undermine their usefulness. There also are dangers associated with blind acceptance of quantitative methodologies, but a combination of different approaches may clarify problems not apparent when only one pathway is taken. In this study, several quantitative measures of faunal similarity were applied to a group consisting of major faunas from the terminal age of the Late Pleistocene (the Wisconsinan age), plus modern faunas of areas deemed possible approximate analogues of Wisconsinan faunas; the results are compared with published qualitative evaluations.

MATERIALS AND METHODS

Measurements of Similarity

A number of objective measures of similarity based on presence–absence data for modern and fossil faunas have been proposed—and criticized (e.g., Cheetham and Hazel, 1969; Hazel, 1970; Raup and Crick, 1979). Three measures of similarity widely used in paleontology are the coefficients of Jaccard, Dice, and Simpson (Fallaw, 1979). Where C equals the number of taxa in common and N_1 and N_2 the number of taxa in the smaller and larger faunas, respectively, the Jaccard Coefficient is $C/(N_1+N_2-C)$, the Dice Coefficient is $2C/(N_1+N_2)$, and the Simpson Coefficient is C/N_1. Of the three, the Simpson Coefficient is claimed to best compare faunas of unequal size (Fallaw, 1979), although Raup and Crick (1979) point out serious potential shortcomings to this coefficient. All three coefficients vary from 0 (no taxa in common) to 1 (complete similarity); in general, when based on the same faunas, the Simpson Coefficient is larger than the other two, and the Dice Coefficient is larger than the Jaccard.

There are, however, several different classes of data obtainable from such coefficients. One thing is the degree of similarity between the various fossil faunas. A high degree of similarity between two faunas indicates similar climatic and historic factors, while low similarity indicates differences requiring explanation. The Simpson Coefficient seems best for evaluating similarity between faunas that vary widely in size due to sampling error, as commonly is the case with fossil faunas.

A second important datum is the proportion of a fossil fauna present in a given modern fauna. The higher the proportion, the more likely that critical environmental features of the fossil and modern faunas were similar. Again, the Simpson Coefficient seems best since the smaller fauna (usually the fossil fauna) governs the number of potential matches.

How well a fossil fauna matches an entire modern fauna also is pertinent. Once the number of taxa in common is calculated, this becomes, in large part, a question of faunal sizes: a small modern fauna with a given number of taxa in common with an ancient fauna is more similar to the latter than is a large modern fauna with the same number of shared taxa (conversely, a small fossil fauna with a given number of taxa in common with a modern fauna is more similar to that fauna than is a large fossil fauna with the same number of shared taxa). The Simpson Coefficient is inappropriate for this measure since it is governed by the size of the smaller fauna. Either the Jaccard or Dice Coefficient is suitable, though the effect of unequal sample sizes adversely affects the results. In the material considered here, there is little difference in the results of the two coefficients other than of scale, and the Dice Coefficient has been used.

Two presence/absence matrices were prepared (data available from the author). In one, 124 taxa were utilized for examination with the Dice Coefficient; these taxa included those mammals expected to be identifiable with reasonable certainty, plus taxa meeting criteria 2 and 4, below. The other matrix, for investigating the first two questions, included a more restricted set of taxa (93) meeting the following guidelines: 1) taxa common to all faunas were omitted; 2) large extinct forms that probably were ubiquitous (e.g., horses, camels, mammoths) were not used; 3) only taxa occurring in one or more fossil faunas were included, thus omitting modern-faunal elements that would not show up in the Simpson Coefficient; and 4) several non-mammalian taxa (e.g., *Gopherus*) were used that could be expected to be identifiable with fair certainty and were notably out of their range in some or all of the fossil faunas.

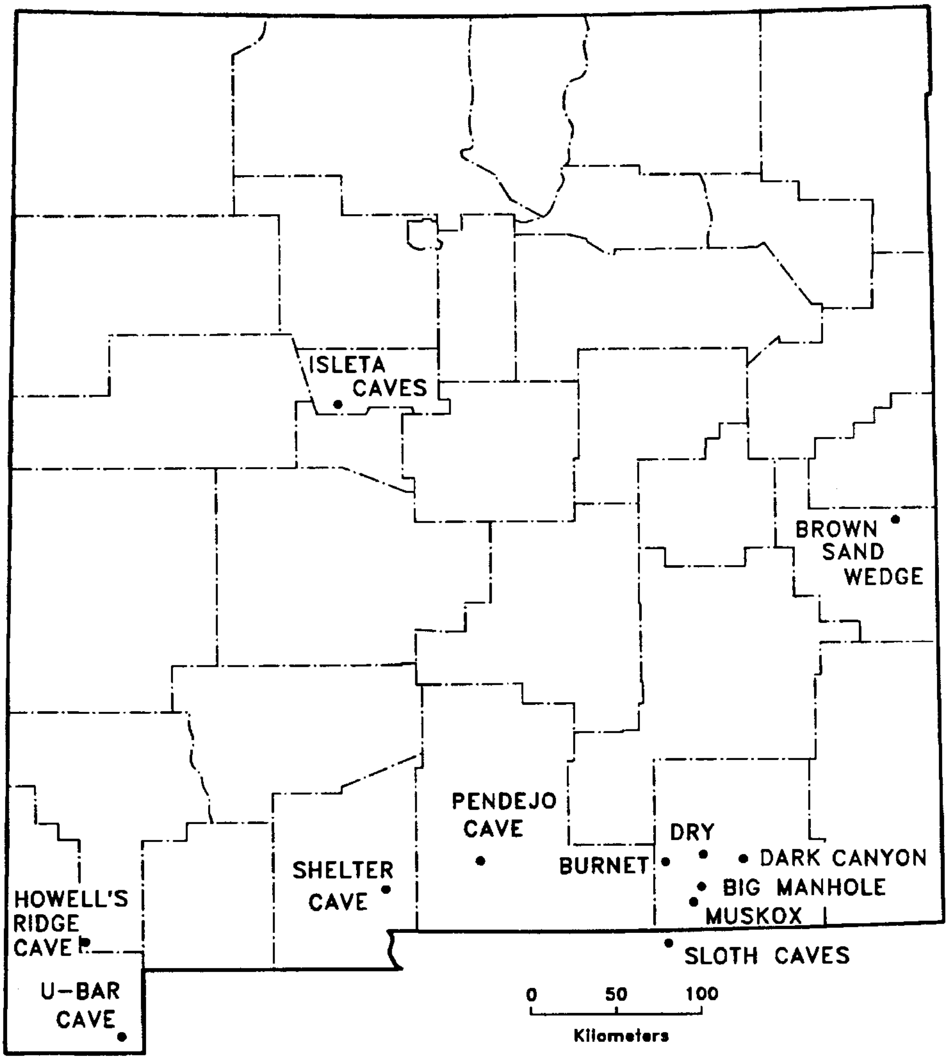

Fig. 1. Locations of Wisconsinan fossil faunas.

Similarity coefficients were set to zero between modern faunas so that these faunas were compared only to the fossil faunas, not to each other. Clustering and dendrogram preparation, utilizing NTSYS-PC (Rohlf, 1990), was by the sequential agglomerative hierarchical non-overlapping method (SAHN) using unweighted pair-group arithmetic averages (UPGMA).

Faunas

Locations of fossil sites are shown in Fig. 1. Modern areas for comparison include regions suggested or reasonable as approximate modern analogues for Wisconsinan faunas. Each modern area is large enough to include a variety of habitats including, in the West, a large elevational range. Thus, modern faunal comparisons are regional comparisons, not comparisons with biotic communities. This strategy allows comparison with fossil sites where deposition of prey animals from some distance away from the site may have occurred and encompasses the effects of minor range fluctuations due to short-term climatic trends. Pertinent details of each fauna follow, including entry to the literature for the fossil sites (abbreviated names as used in Table 1; N is the number of taxa used in this study):

E KANSAS: Modern fauna of the eastern four tiers of counties of Kansas (N = 46).

WYOMING: Modern fauna of southeastern Wyoming: Carbon, Laramie, Goshen, Platte, and Albany counties (N = 76).

NE NM: Modern fauna of northeastern New Mexico, including those parts of Union, Harding, and Colfax counties east of the Canadian River (N = 52).

SE NM: Modern fauna of southeastern New Mexico south of the pass between the Gallinas and Jicarilla mountains; includes most of Chaves, Lea, Lincoln, Otero, and Eddy counties and the southern half of Roosevelt County (N = 71).

NO NM: Modern fauna of north–central New Mexico, including Rio Arriba, Taos, and Colfax counties; northern portions of Sandoval and Santa Fe counties; and the western halves of Mora and San Miguel counties (N = 85).

SE ID: Modern fauna of southeastern Idaho (N = 72). Based on Caribou, Bear Lake, Bannock, Franklin, and Oneida counties and the southeastern two-thirds of Power County.

FULL: Full-glacial fauna (N = 35) from Animal Fair, Grids A and B, Levels 1-4, Dry Cave, Eddy Co., NM, 1,280 m. Harris (1989, 1993b).

C PARLOR: Charlies Parlor, Dry Cave. This is a small fauna (N = 17) biased toward larger forms. A radiocarbon date of 15,030 ± 210 B.P. (before present) is from near the base of the deposits; the date, based on bone collagen, may be somewhat too recent.

HARRIS P: Harris' Pocket (N = 30). This is a Dry Cave fauna radiocarbon dated on rodent feces at 14,470 ± 250 B.P. Harris (1970, 1993b); (Holman, 1970).

BISON CH: Bison Chamber, Dry Cave (N = 23). By interpolation with dated strata, this fauna is believed to be < 14,470 and > 10,730 ^{14}C-years B.P. Harris (1970, 1993b); Holman (1970).

LESS 13: Several pre-Holocene Dry Cave sites dating to < 13,000 B.P. (N = 43); includes TTII, Human Corridor, Camel Room, Boulder Room, and Stalag 17. Harris (1989, 1993b).

HOWELLS: Howell's Ridge Cave, Grant Co., NM, 1,675 m. A mixed, late Wisconsinan–Holocene fauna (N = 28) encompassing a span from > 13,600 radiocarbon years B.P. to the present. Harris (1985; 1993b); Howard (1962); Van Devender and Worthington (1977).

UB18 20: U-Bar Cave full glacial, approximately 18-20 ka (thousands of years ago), Hidalgo Co., NM, 1,570 m (N = 26). All Pleistocene U-Bar Cave dates are based on radiocarbon dating of bulk samples of matrix; the organic portion of the matrix is believed to consist largely of decomposed bat guano and other organic debris. Harris (1989).

UB15 18: U-Bar Cave, approximately 15-18 ka (N = 32). Harris (1989).

UB14 15: U-Bar Cave, approximately 14-15 ka (N = 45). Harris (1989).

UB13 14: U-Bar Cave, approximately 13-14 ka (N = 23). Harris (1989).

UBAR MID: A number of radiocarbon dates are available, ranging from 26,150 ± 1450 to 35,890 ± 2640 B.P. Harris (1987). N = 33.

DRY EARL: Dry Cave faunas (N = 33) from University of Texas at El Paso (UTEP) localities 1 and 17 (Lost Valley), 2 and 5 (Sabertooth Camel Maze), and 26 and 27 (Rm of the Vanishing Floor). Radiocarbon dates on bone carbonates (which are considered unreliable for dating) run from 25,160 ± 1730 (Locs. 2, 5) to 29,290 ± 1060 (Locs. 1, 17) and 33,590 ± 1500 (Locs. 26, 27); until recently, the faunas were considered to be later mid-Wisconsinan in age, in keeping with the radiocarbon dates and comparable to the mid-Wisconsinan U-Bar Cave fauna in age (Harris, 1987). These sites are now thought to have been deposited earlier, possibly even in the early Wisconsinan. N = 33.

PEND MID: Middle Wisconsinan faunas from Pendejo Cave, Otero Co., NM, 1,470 m (N = 43). Radiocarbon dates range from about 26 to > 55 ka. The fauna is currently under study and further refinements are expected. Harris (1991).

ISLETA 1: Isleta Cave No. 1, Bernalillo Co., NM, 1,716 m. This is a mixed late Wisconsinan–Holocene fauna (N = 27). Two ^{14}C-dates on bone collagen are 17,240 ± 260 (AA 1208) and 16,430 ± 205 (AA 1209). Harris (1993b); Harris and Findley (1964).

Table 1. Simpson Coefficient similarity matrix comparing all fossil faunas with each other.

		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
FULL	A	1.00																						
C PARLOR	B	0.82	1.00																					
HARRIS P	C	0.83	0.59	1.00																				
BISON CH	D	0.74	0.59	0.74	1.00																			
LESS 13	E	0.77	0.94	0.77	0.96	1.00																		
HOWELLS	F	0.39	0.47	0.39	0.48	0.61	1.00																	
UB18 20	G	0.35	0.35	0.35	0.44	0.58	0.46	1.00																
UB15 18	H	0.44	0.59	0.40	0.44	0.66	0.50	0.89	1.00															
UB14 15	I	0.60	0.65	0.57	0.52	0.61	0.75	0.89	0.94	1.00														
UB13 14	J	0.48	0.35	0.39	0.35	0.61	0.48	0.74	0.78	0.91	1.00													
UBAR MID	K	0.55	0.53	0.37	0.52	0.58	0.61	0.73	0.72	0.91	0.70	1.00												
DRY EARL	L	0.39	0.41	0.30	0.35	0.49	0.36	0.46	0.56	0.70	0.65	0.52	1.00											
PEND MID	M	0.57	0.82	0.57	0.52	0.56	0.61	0.69	0.78	0.79	0.65	0.61	0.70	1.00										
ISLETA 1	N	0.48	0.59	0.37	0.48	0.70	0.52	0.39	0.41	0.56	0.44	0.48	0.48	0.67	1.00									
ISLETA 2	O	0.52	0.47	0.48	0.35	0.56	0.44	0.32	0.48	0.56	0.35	0.44	0.40	0.68	0.72	1.00								
SHELTER	P	0.36	0.36	0.21	0.14	0.57	0.29	0.43	0.64	0.71	0.50	0.36	0.36	0.71	0.29	0.29	1.00							
BIGMAN C	Q	0.60	0.59	0.56	0.48	0.68	0.40	0.40	0.60	0.72	0.35	0.44	0.56	0.76	0.48	0.52	0.50	1.00						
BURNET C	R	0.48	0.65	0.37	0.35	0.52	0.37	0.31	0.41	0.56	0.30	0.33	0.44	0.56	0.44	0.44	0.36	0.48	1.00					
BROWN	S	0.33	0.12	0.22	0.22	0.44	0.39	0.11	0.17	0.33	0.06	0.22	0.33	0.33	0.28	0.17	0.07	0.17	0.44	1.00				
MUSKOX	T	0.54	0.53	0.57	0.70	0.51	0.50	0.50	0.47	0.62	0.48	0.49	0.61	0.54	0.56	0.36	0.36	0.60	0.52	0.39	1.00			
UP SLOTH	U	0.55	0.24	0.60	0.05	0.50	0.40	0.50	0.55	0.80	0.50	0.40	0.60	0.55	0.25	0.25	0.14	0.45	0.45	0.11	0.90	1.00		
LO SLOTH	V	0.48	0.35	0.48	0.44	0.52	0.36	0.50	0.52	0.72	0.39	0.35	0.55	0.52	0.30	0.28	0.36	0.52	0.33	0.17	0.86	0.85	1.00	
DARK CAN	W	0.72	0.59	0.72	0.61	0.72	0.48	0.32	0.48	0.72	0.35	0.40	0.52	0.80	0.48	0.52	0.29	0.52	0.48	0.28	0.56	0.40	0.36	1.00

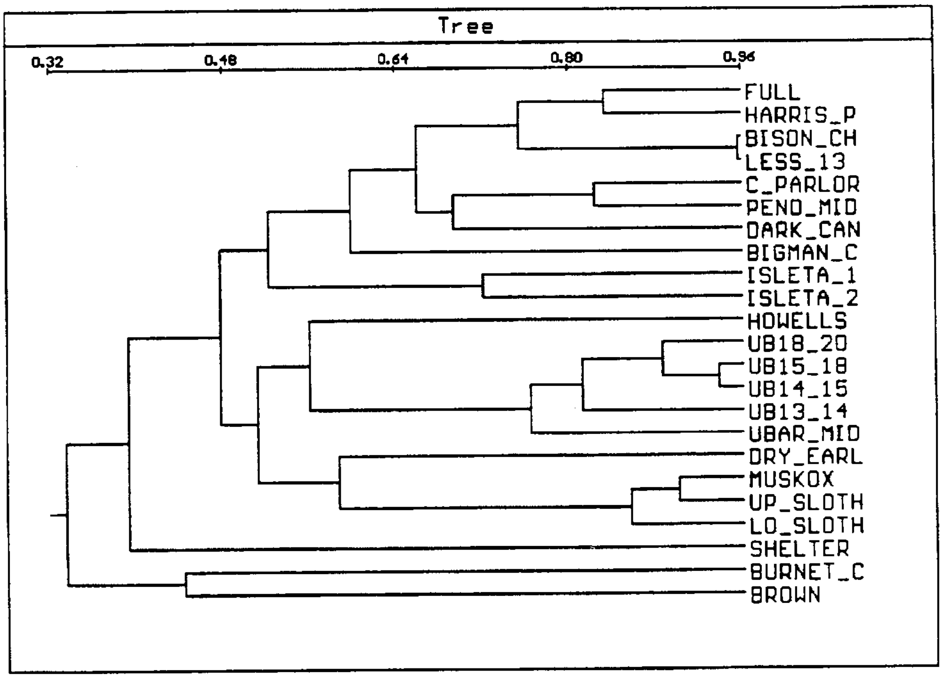

Fig. 2. Dendrogram showing similarities among Wisconsinan fossil faunas. Abbreviations as in text.

ISLETA 2: Isleta Cave No. 2, Bernalillo Co., NM, 1,716 m. Adjacent to Isleta Cave No. 1, this cave likewise has a mixed Wisconsinan-Holocene fauna (N = 25). The sole date available is 11,230 ± 140 on bone collagen (AA 1207). Harris (1993b); Harris and Findley (1964).

SHELTER: Shelter Cave, Dona Ana Co., NM, 1,435 m (N = 14). This cave was excavated in the late 1920s and the material never properly worked up. Packrat midden dates (Thompson et al., 1980) indicate that deposition likely started during the mid-Wisconsinan (31,250 ± 2200, A-2140); other dates and archaeological material indicate deposition into the Holocene and probably to the present.

BIGMAN C: Big Manhole Cave lies at 1,388 m just north of the boundary of Carlsbad Cavern National Park, Eddy Co., NM. Most material is late Wisconsinan (< 20,000 B.P.); some may be several thousands of years older. This fauna (N = 25) is currently under study. Harris (1993b).

BURNET C: Burnet Cave is a mixed late Wisconsinan-Holocene fauna west of Dry Cave in Eddy Co., NM, 1,435 m (N = 27). Harris (1985); Murray (1957); Schultz and Howard (1935).

BROWN: Brown Sand Wedge, Blackwater Loc. No. 1, Roosevelt Co., NM, ca. 1,280 m. A date of 11,170 ± 360 B.P. appears to apply to this late Wisconsinan fauna (N = 18). This is the only non-cave site considered here. Paleodrainage was to the east. Slaughter (1975).

MUSKOX: Muskox Cave, Eddy Co., NM, 1,600 m (N = 39). Dates range from 15,500 ± 1100 to 18,140 ± 200 for much of the deposit (Logan, 1981). Unfortunately, a full report with stratigraphic data has never been published.

UP SLOTH: Upper Sloth Cave, Hudspeth Co., TX, 2,000 m (N = 20). Located in the southern Guadalupe Mountains, this cave and the nearby Lower Sloth Cave were excavated by Logan. A small portion of the fauna may be Holocene. Logan and Black (1979).

LO SLOTH: Lower Sloth Cave, Hudspeth Co., TX, 2,000 m (N = 29). Some Holocene material may be present. Logan (1983).

DARK CAN: Dark Canyon Cave, Eddy Co., NM, 1,100 m (N = 25). Probably (on subjective faunal grounds) pre-pleniglacial late Wisconsinan and/or late mid Wisconsinan. Harris (1985, 1993b); Howard (1971).

RESULTS AND DISCUSSION

The Simpson Coefficient similarity matrix is shown in Table 1 and a dendrogram based on it is shown in Fig. 2; Table 2 includes the portion of the Dice Coefficient similarity matrix relating the fossil faunas to modern faunas. Pertinent points are discussed below.

Full Glacial

Southeastern Idaho, northeastern New Mexico, northern New Mexico, and Wyoming form a compact group of modern faunas varying in similarity (in that order) by the Dice Coefficient with the full-glacial fauna from 0.52 to 0.48. On qualitative criteria, Harris (1989:216) placed the area of most similarity as

Table 2. Similarity matrix (Dice Coefficient) based on 129 taxa, comparing modern faunas with fossil faunas.

	E KANSAS	WYOMING	NE NM	SE NM	NO NM	SE ID
FULL	0.365	0.482	0.500	0.425	0.495	0.518
C PARLOR	0.187	0.319	0.428	0.288	0.291	0.355
HARRIS P	0.311	0.429	0.409	0.388	0.448	0.427
BISON CH	0.257	0.340	0.394	0.375	0.366	0.333
LESS 13	0.488	0.533	0.604	0.568	0.573	0.500
HOWELLS	0.266	0.323	0.469	0.415	0.438	0.316
UB18 20	0.191	0.233	0.455	0.404	0.392	0.202
UB15 18	0.329	0.330	0.588	0.495	0.457	0.304
UB14 15	0.413	0.426	0.673	0.559	0.610	0.406
UB13 14	0.257	0.260	0.421	0.375	0.348	0.250
UBAR MID	0.350	0.327	0.581	0.452	0.487	0.377
DRY EARL	0.425	0.363	0.558	0.528	0.436	0.320
PEND MID	0.444	0.483	0.666	0.551	0.558	0.465
ISLETA 1	0.324	0.403	0.475	0.460	0.442	0.360
ISLETA 2	0.309	0.356	0.363	0.350	0.400	0.350
SHELTER	0.200	0.266	0.242	0.209	0.242	0.232
BIGMAN C	0.333	0.392	0.461	0.428	0.432	0.367
BURNET C	0.324	0.365	0.425	0.440	0.407	0.380
BROWN	0.461	0.273	0.309	0.285	0.269	0.241
MUSKOX	0.372	0.448	0.500	0.553	0.560	0.446
UP SLOTH	0.208	0.185	0.301	0.365	0.339	0.215
LO SLOTH	0.263	0.301	0.463	0.490	0.469	0.294
DARK CAN	0.277	0.372	0.461	0.367	0.414	0.346

the southeastern Idaho region "with a secondary area of sympatry in northeastern New Mexico." Thus, the two methods agree in this case (however, similarities by the Simpson Coefficient do not). Within the fossil suite, the most similar faunas are the subsequent faunas from Dry Cave and the fauna from nearby Dark Canyon Cave (0.83–0.72). Most different are the Brown Sand Wedge fauna (0.33) and the full-glacial fauna from U-Bar Cave (0.35).

Charlies Parlor

This fauna shows the most similarity among the modern faunas to that of northeastern New Mexico (0.43). Among the late Wisconsinan faunas, affinity is to the late (< 13,000 B.P.) Dry Cave fossil faunas (0.94), although there is also a rather strong similarity (0.82) to the mid-Wisconsinan Pendejo Cave fauna. The small size and bias toward larger animals, however, likely distorts relationships.

Harris' Pocket

This fauna is very similar to the full-glacial fauna of Dry Cave (0.83) and other glacial Dry Cave faunas; as might be expected, relationships to modern faunas are similar to those of the Dry Cave full-glacial faunas.

Bison Chamber

This fauna follows the general pattern of the late-Wisconsinan Dry Cave faunas in showing high relationships to northern modern faunas; however, these relationships, in general, are somewhat weaker with the greatest similarity to the northeastern New Mexico fauna (0.39). The probable approach in time (or even chronological overlap) with the < 13,000 B.P. faunas shows up in the near identity with that group (0.96).

Less Than 13,000 B.P.

These faunas show a notable change from the faunas thus far considered in affinity to modern faunas, not in decreased similarities to northern faunas (which remain high), but in increased likeness to eastern faunas (eastern Kansas, 0.49; southeastern New Mexico, 0.57). Features of the Dry Cave faunas similar to those displayed here were noted by Harris (1989:213): "Most of the extant fauna earlier characterized as cognate with that of southeastern Idaho was maintained from the pleniglacial to the end of the Pleistocene . . . . During the post-pleniglacial, southern and eastern species were added." Affinity with Dry Cave and southeastern New Mexico late-Wisconsinan faunas is high.

Howell's Ridge Cave

Similarity with the three New Mexican modern faunas is relatively high (0.42-0.47), while the northern faunas form a distinctly lower-similarity cluster (0.32). Highest value with the fossil faunas is with the geographically nearby 14-15 ka U-Bar Cave fauna (0.75). Also, there are fairly high values with the mid-Wisconsinan faunas of U-Bar and Pendejo caves; intermixture of some modern taxa into the Howell's Ridge Cave fauna undoubtedly influences these values to some degree.

U-Bar Cave, Late Wisconsinan

The northeastern New Mexico fauna is the modern fauna most similar to all of the U-Bar Cave Wisconsinan faunas; similarities of the fossil faunas to other modern faunas are low except that the U-Bar 14-15 ka fauna is rather similar to both northern (0.61) and southeastern (0.56) New Mexico faunas.

The four late Wisconsinan U-Bar Cave samples are similar among themselves (0.89–0.94) and, secondarily, to the U-Bar and Pendejo Cave mid-Wisconsinan faunas (0.65–0.91). The 14-15 ka fauna consistently shows higher similarity to all but the terminal Dry Cave faunas than do the other three and also to most other faunas in the Guadalupe Mountains area. In part, this may be due to the relatively large size of the fauna.

Harris (1989) interpreted the late-Wisconsinan faunas of U-Bar Cave as a mixture of taxa showing no strong affinity with any one modern area. Northeastern New Mexico is the only geographic area represented in this study by a modern fauna that Harris (1989:Fig 1) showed as a source area.

U-Bar Cave, Mid-Wisconsinan

The pattern of affinity with modern faunas is similar to that of other U-Bar Cave faunas. Among fossil faunas, the U-Bar Cave late-

Wisconsinan sites are most similar (topping out at 0.91 at 14-15 ka); moderate similarity with the Pendejo Cave fauna (0.70) also is displayed. The more subjective assessment of Harris (1987) was that, with the possible exception of winters being some colder, there was no major change from mid-Wisconsinan through late-Wisconsinan times at U-Bar Cave. The findings appear concordant.

Pendejo Cave, Mid-Wisconsinan

The modern relationships are similar to those of the U-Bar Cave middle-Wisconsinan fauna except that similarities to all five other modern faunas are somewhat greater. Among the larger fossil faunas, the similarities to all of the U-Bar Cave faunas are moderate; the Isleta Caves, Shelter Cave, and Big Manhole Cave also show moderate affinities, though the Holocene components of the Isleta Caves may be skewing the figures. Dark Canyon Cave, which may be late mid-Wisconsinan, has the highest similarity value (0.80).

Dry Cave, Early Fauna

Greatest similarity with modern faunas is to northeastern New Mexico (0.56) and southeastern New Mexico (0.53). This fauna differs strongly from all late-Wisconsinan faunas except the terminal U-Bar Cave faunas (0.65–0.70); there also is some affinity with the Pendejo Cave mid-Wisconsinan (0.61). Harris (1987) hypothesized greatest similarity with northeastern New Mexico.

Isleta Caves

No one modern fauna stands out as notably similar to these two caves; northeastern New Mexico is most similar to the Isleta Cave No. 1 fauna (0.48) and northern New Mexico to the second cave (0.40). Presence of Holocene taxa undoubtedly biases the similarity values.

The two faunas most closely resemble each other (0.72), though Isleta Cave No. 1 also is quite similar to the latest Dry Cave faunas (0.70). The only other nearly comparable similarity values are with the Pendejo Cave fauna.

Harris and Findley (1964) suggested that the fauna was most similar to that of present-day southeastern Wyoming and adjacent Colorado; the Dice Coefficients do not agree with this assessment.

Shelter Cave

This very small fauna (14 taxa considered) shows only weak affinity with any modern fauna; Wyoming has a slight edge on the others. The only relatively large similarity values with fossil faunas are with the 14-15 and 15-18 ka U-Bar Cave faunas and with the Pendejo Cave mid-Wisconsinan. Small faunas consisting largely of widespread taxa (taxa most likely to be absent from other faunas solely because of sampling error) tend to have those few faunal members that do have a high informational content overwhelmed by the common members. This appears likely to be the case here.

Big Manhole Cave

This fauna shows a rather diffuse pattern of affinities among the modern; northeastern New Mexico is most similar at 0.46. The fauna shows moderately high similarities to the latest Wisconsinan Dry Cave faunas and to two of the U-Bar Cave faunas, but most closely resembles the middle Wisconsinan of Pendejo Cave (0.76). A relative paucity of small-sized faunal elements may well be biasing the fauna.

Burnet Cave

Although perhaps the most famous of the New Mexican sites, affinities with other Pleistocene sites are relatively low, except with the very small Charlies Parlor fauna at 0.65 (otherwise, the highest similarity value is 0.56 with the 14-15 ka U-Bar Cave fauna and with the middle Wisconsinan Pendejo Cave fauna). Modern affinities are strongest with southeastern New Mexico (0.44) and northeastern New Mexico (0.43). The mixing of Holocene materials with those of Pleistocene origin introduces bias.

Brown Sand Wedge

This is the most distinctive of the fossil faunas studied, grouping with the eastern Kansas modern fauna (0.46) and, next, with northeastern New Mexico (0.31). Affinity with fossil faunas is low, reaching a high of 0.44 with Burnet Cave and with the < 13 ka Dry Cave fauna. Slaughter (1975) appeared most impressed by the combination of taxa now found only to the north with those now found only to the south. Harris (1985) noted a distinctly eastern riparian element.

Muskox Cave

This cave has several apparently anomalous taxa for the time period involved (Harris, 1985), leading to the suspicion that it is temporally mixed. Strongest modern affinities are to northern New Mexico (0.56) and southeastern New Mexico (0.55); presence of the out-of-place taxa may be reflected in the affinity to the latter. Similarity with most fossil faunas is moderate (e.g., 0.70 with the Bison Chamber fauna). However, the other two sites with faunas identified by Logan (both relatively high-elevation sites for the region) are high at 0.90 and 0.86. Logan (1981) interpreted the habitat as spruce-fir forest and meadows; Harris (1985) suggested open coniferous forest with a boreal aspect, grasslands, and possibly woodland elements.

Sloth Caves

Both of these sites were excavated by Logan, who also did the faunal identifications (Logan, 1983; Logan and Black, 1979). There is some suggestion that the faunas may be mixed, in part, with Holocene elements (Harris, 1985). The most similar modern faunas are those of southeastern New Mexico for both (0.37, 0.49). The faunas are similar to each other (0.85), to Muskox Cave (0.90, 0.86), and to U-Bar Cave 14-15 ka (0.80, 0.72), but otherwise are fairly distinctive. Logan and Black (1979) compared the climatic conditions represented by the Upper Sloth Cave fauna with those of the modern Black Hills of South Dakota.

Dark Canyon Cave

Modern faunas most like that of Dark Canyon Cave are those of northeastern New Mexico (0.46) and northern New Mexico (0.41). The fauna is moderately similar to the Dry Cave late-Wisconsinan faunas (0.72 for most) and to the U-Bar Cave 14-15 ka fauna (also 0.72), but shows most in common with the Pendejo Cave mid-Wisconsinan (0.80).

CONCLUSIONS

The quantitative methods, as used here, tend to agree with qualitative assessments to a considerable degree, but with notable exceptions. For example, sensitivity seems to be notably less: there are very important things that purely quantitative analysis is not showing. Sensitive faunal indicators of various environmental aspects have no more weight than insensitive taxa in the quantitative analyses. For example, both *Lemmiscus curtatus* and *Brachylagus idahoensis* are far out of range at Isleta Cave No. 2, generally being considered typically Great Basin forms—yet, no hint of this appears in the quantitative treatment.

The coefficients of similarity do appear to be a useful adjunct to qualitative interpretation in guiding attention to features otherwise submerged in an extensive database. As a case in point, the relatively high similarity values of the 14-15 ka U-Bar Cave fauna with southeastern New Mexico glacial faunas compared to the lower values for other U-Bar Cave faunas indicate further interpretation is necessary: Are the U-Bar Cave dates skewed? Did climatic change to conditions more typical of the southeastern New Mexico Wisconsinan occur at that time? Or is this an artifact caused by the somewhat larger sample size of this fauna?

Although in theory information-laden taxa could be weighted in quantitative studies, both the subjectivity involved in determining weights and the labor involved in adjusting these weights for geographic and ecological positions would seem to make such schemes impractical. A melding of relatively simple quantitative methods, such as those utilized here, with qualitative data should result in inferences more useful than either alone. On the other hand, quantitative methods involving relative frequencies of taxa within faunas joined with interpretation of qualitative data may give results superior to those produced by these simpler methods (Harris, 1993a), but their labor intensive nature may prevent widespread use.

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