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On Late Holocene Variability in Bison Populations in the Northeastern Great Basin

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Bison (Bison bison) are believed to have constituted a primary prey of prehistoric populations occupying portions of the northeastern Great Basin. This article presents evidence from archaeological sites along the northeastern shores of the Great Salt Lake that suggests bison populations may have fluctuated through time and become less abundant after A.D. 1300, possibly in response to paleoenvironmental conditions. The localized unpredictability and irregularity of this resource may have resulted in the adoption of flexible hunting strategies involving expansion of diet breadth, logistical trips to areas where bison persisted, and/or trade with neighboring peoples for bison products. These latter strategies were documented among historic populations occupying these areas, and evidence presented herein suggests that these strategies may have been in place by the fourteenth century or possibly earlier.

A key issue in the prehistory of the northeastern Great Basin concerns variability in Fremont subsistence strategies. The Fremont occupied sites in portions of the eastern Great Basin and Colorado Plateau between approximately A.D. 350 and 1300, and have been traditionally characterized as horticulturists who also practiced hunting and gathering. Recent views, however, have stressed the dynamic nature of Fremont subsistence patterns, which varied in response to the availability of local resources and ecological circumstances (e.g., Marwitt 1970; Simms 1986, 1990, 1994; Madsen 1989; Smith 1992; Coltrain 1993).

This article discusses temporal fluctuations in the prehistoric availability of bison in the northeastern Great Basin. Several lines of archaeofaunal evidence from sites on the northeastern shores of the Great Salt Lake suggest that bison availability fluctuated during Fremont times and generally declined sometime after A.D. 1300. Further evidence in additional faunal assemblages from sites adjacent to the Great

Salt and Utah lakes reflects a similar pattern of temporal variation in bison availability.

Fluctuations in bison availability are significant because given their large body size and gregarious nature, bison would have been one of the highest-ranked animal preys in this area. Theoretically based optimality models predict that the relative frequency of the highest-ranked prey types selected by groups is a function of their availability or encounter rate. Consequently, the rarity of bison in some Fremont and most Late Prehistoric assemblages in the northeastern Great Basin suggests limited availability of bison rather than the vagaries of taste. Fluctuations in the availability of bison correspond to paleoenvironmental conditions which suggest that favorable conditions for bison herd growth prevailed during Fremont times. Changes in precipitation patterns after A.D. 1300, coupled with continued hunting by aboriginal populations, may have limited the growth potential of bison herds, especially during times when they were at low densities. The unpredictability and irregularity

of this highly ranked prey resource may have resulted in the adoption of flexible hunting strategies by foraging and/or farming populations to take advantage of short-term abundances.

ARCHAEOFAUNAS FROM THE NORTHEASTERN GREAT SALT LAKE WETLANDS

The impetus for this research is based on the analysis of several archaeofaunas from the northeastern shores of the Great Salt Lake. This wetland area has been, and continues to be, the focus of archaeological investigations (Steward 1937; Pendergast 1961; Aikens 1966, 1967; Fry and Dalley 1979; Simms et al. 1990; Simms et al. 1991; Fawcett and Simms 1993). On the northeastern shores of the Great Salt Lake, wetlands adjacent to Willard Bay consist of a broad silt plain drained by the Bear and Weber rivers, with minor topographic relief created by relict river and creek channels. This area is advantageously situated in close proximity to a variety of habitats rich in wild resources. Scattered patches of wetlands, broken by small oxbow lakes and water channels along the river floodplains and shores of the Great Salt Lake, are a natural nexus for a variety of plants and animals. Arable lands suitable for corn agriculture are limited, but available (e.g., Fawcett and Simms 1993). Only 15 km. to the east, the Wasatch Mountains provide fresh water and a unique set of high altitude resources. Not surprisingly, lands adjacent to the northeastern shore of the Great Salt Lake were attractive to prehistoric and historic human populations.

As part of the recent Great Salt Lake Wetlands project (Simms et al. 1990, Simms et al. 1991; Fawcett and Simms 1993), faunal assemblages from sites in the Willard Bay area (Fig. 1) were analyzed to examine flexibility in Fremont and Late Prehistoric subsistence strategies. While many sites exist in and around the Willard Bay wetlands, only those archaeofaunas containing more than 100 identifiable bones

from sites that were absolutely dated are considered in detail here. This sample includes faunas from 42Wb32 and Orbit Inn, excavated as part of the Great Salt Lake Wetlands project (see Lupo 1990; Simms and Heath 1990; Fawcett and Simms 1993), as well as faunal assemblages from six previously excavated sites: Bear River 1 (Aikens 1966), Bear River 2 (Aikens 1967), Bear River 3 (Shields and Dalley 1978), Levee (Fry and Dalley 1979), Knoll (Fry and Dalley 1979), and Injun Creek (Aikens 1966). The latter faunal assemblages were retrieved from the Utah Museum of Natural History and reanalyzed. Table 1 lists the sample of sites discussed here, their site type, age ranges, dating methods utilized, and, if known, estimated season(s) of utilization.

Before considerations of faunal patterning in these assemblages can be discussed, known and probable sources of collection bias need to be examined, as they can influence the size and composition of faunal assemblages. Table 2 shows that comparable excavation and recovery techniques were not used for this sample of sites. For example, excavated matrix at the Orbit Inn was screened through 1/8-in. mesh and bones were recovered from flotation samples. By contrast, only a small sample of units at Bear River 1 was screened through 1/4-in. mesh, and none of the fill from Bear River 2, Bear River 3, Levee, Knoll, or Injun Creek was screened. As a result, smaller-sized fauna probably are underrepresented in some assemblages. Even so, small-sized mammals, birds, fish, and even mollusks were recovered from most sites, suggesting that collection biases were not completely directed toward larger-sized animal bones.

The area and volume excavated can also shape the size and diversity of recovered faunal assemblages (e.g., Grayson 1984; Sharp 1989; O'Connell 1993:22). The actual volume of sediment removed from many of these sites is not known, and we acknowledge the potential effects on assemblage composition, especially

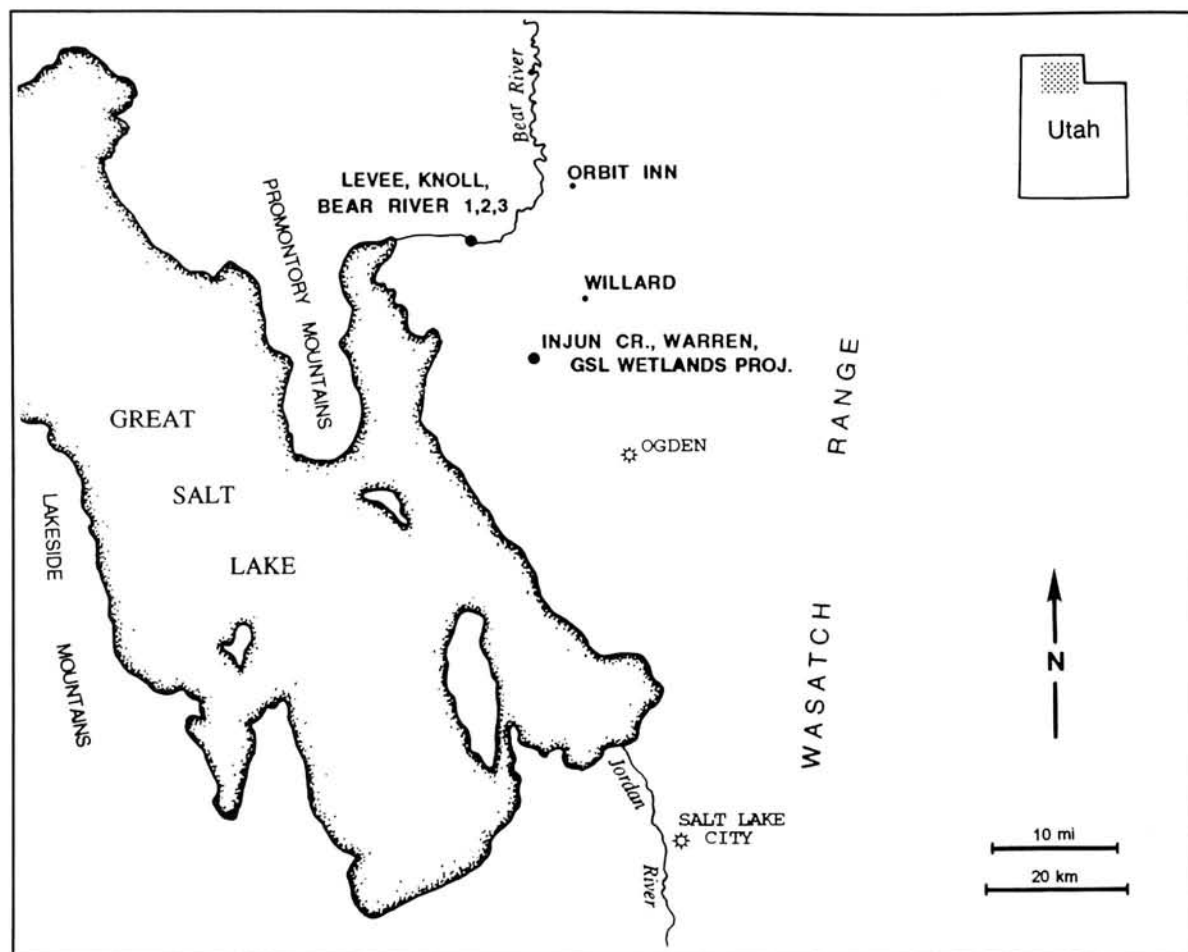


Fig. 1. Location of sites adjacent to the Great Salt Lake and Willard Bay in the northeastern Great Basin.

taxonomic diversity. However, it should be noted that many of these sites were excavated in large, contiguous, areal exposures that focused on feature and nonfeature areas. Consequently, the relative taxonomic abundances, especially for larger-sized taxa with durable bones, were probably only minimally affected.

Results of Analysis

Taxonomic abundances for all faunal classes from these sites, as measured by the number of identifiable specimens (NISP; e.g., Grayson 1984), are presented in Table 3. Note that the Great Salt Lake faunal assemblages contain a variety of mammals, birds, fish, shellfish, reptiles, and amphibians. Some of these latter faunal

classes undoubtedly represent subsistence refuse, but the focus of this discussion is on the relative abundance of bison (see Parmalee [1979, 1980] for an analysis of the avifauna from selected sites). Disparities exist among these sites in bison NISP, minimum number of individuals (MNI; e.g., Klein and Cruz-Urbe 1984), age group composition, and skeletal part representation, which may reflect information about bison availability during Fremont and Late Prehistoric times.

Bison NISP and MNI

Two of the assemblages do not contain bison bones. One of these, 42Wb32, is a short-term residential camp dating to the Fremont Period

Table 1
SAMPLE OF ASSEMBLAGES FROM THE GREAT SALT LAKE WETLANDS

Site Number/Name	Function/Type	Season(s) of Use	Age Range	Reference
Bear River 1 (42Bo55)	bison processing	spring/fall	A.D. 765 to 1005 ^a	Pendergast 1961; Aikens 1966
Bear River 2 (42Bo57)	short-term residential	late summer/early fall	A.D. 850 to 1060 ^b	Aikens 1967
Bear River 3 (42Bo98)	short-term residential	spring/summer	A.D. 390 to 610 ^c	Shields and Dalley 1978
Levee (42Bo107)	short-term residential	spring/summer	A.D. 1090 ^d A.D. 1140 ^d A.D. 1240 ^d	Fry and Dalley 1979
Knoll (42Bo109)	short-term residential	summer	A.D. 1310 ^e	Fry and Dalley 1979
Orbit Inn (42Bo120)	short-term residential	spring/fall	A.D. 1450 to 1500 ^f	Simms and Heath 1990
42Wb32	short-term residential	spring/summer	A.D. 451 to 694 ^g A.D. 782 to 1012 ^g A.D. 885 to 1156 ^g	Fawcett and Simms 1993
Injun Creek (42Wb34)	long-term residential	winter/year-round	A.D. 1275 to 1455 ^h A.D. 1505 to 1705 ^h	Aikens 1966

^a Based on radiocarbon dating of bison bone.

^b Based on radiocarbon dating of charcoal from feature.

^c Based on radiocarbon dating of charred bulrush seeds associated with a broken pot (see also Madsen and Rowe 1988).

^d Based on radiocarbon dating of carbonized timbers found within structures from late component village. Archeomagnetic dates from late component hearths indicate that the last firing was A.D. 1150 (Shuey 1979). An earlier occupation of Levee dates between A.D. 700 and A.D. 780, but most of the faunal assemblage is from the late component occupation (Parmalee 1979).

^e Based on radiocarbon dating of charcoal from hearth in structure.

^f Based on radiocarbon dating of wood charcoal associated with features.

^g Based on radiocarbon dating of charcoal from three superimposed structures that overlap the time span A.D. 1035 to 1155 (Fawcett and Simms 1993).

^h Based on radiocarbon dating from charcoal samples from two mound features. Injun Creek consists of some 17 mounds spread over a 3/4-mile area (Aikens 1966). It should be noted that many of the artifacts associated with the Injun Creek site are classified as Fremont and reflect more than one period of occupation (see also Madsen and Rowe 1988).

(Fawcett and Simms 1993). The other is Injun Creek, a long-term residential base with Late Prehistoric radiometric dates and a probable earlier Fremont occupation (Aikens 1966; Madsen and Rowe 1988). Two sites, Knoll and Orbit Inn, contain only small quantities of bison remains measured in both NISP and MNI (Table 4). Knoll has an early and very late Fremont occupation, while Orbit Inn dates to the fifteenth century. Four Fremont sites, Bear River 1, Bear River 2, Bear River 3, and Levee, have a substantial number of specimens (NISP: 600 to 1,800) representing more individual animals than Knoll or Orbit Inn.

The marked disparity in bison bone frequencies among these sites may be the result of cultural and/or natural attrition. For example, historical accounts of Native Americans on the Plains report that bison bones were often crushed and made into soup or rendered for grease (see Wheat 1972). This activity produces many small unidentifiable or minimally identifiable bones (Turney-High 1937; Leechman 1951; Wheat 1972; Vehik 1977; Frison 1982). Similarly, nonhuman agents, such as wolves or coyotes, often destroy or remove bones in the process of scavenging (e.g., Binford 1981; Marean et al. 1992). Consequently, differences

Table 2
RECOVERY TECHNIQUES AND SIZE AND AREA EXCAVATED
FOR GREAT SALT LAKE WETLAND SITES

Site	Screen Size	Site Size (m. ²)	Area Excavated (m. ²)
Bear River 1 (42Bo55)	1/4 in.	2,683	588
Bear River 2 (42Bo57)	no screen used	4,573	1,791
Bear River 3 (42Bo98)	no screen used	17,155	3,201.2
Levee (42Bo107)	no screen used	unknown	2,271
Knoll (42Bo109)	no screen used	2,881	442
Orbit Inn (42Bo120)	1/4 in. and 1/8 in.	1,250	325
42Wb32	1/4 in.	577,500	372
Injun Creek (42Wb34)	no screen used	unknown	unknown

in the number of bison bone pieces among these sites may reflect more information about taphonomic histories than about prey availability and human subsistence strategies.

High degrees of cultural and natural attrition often result in assemblages dominated by very durable or dense bones (Brain 1967, 1969, 1981; Binford and Bertram 1977; Lyman 1984, 1985; Schmitt and Lupo 1995). For example, an assemblage that has undergone attrition usually contains low proportions of proximal humeri, a low density bone, when compared to the more durable distal end. To examine this possibility, correlation coefficients were calculated between bison bone frequencies, as measured by NISP, and published measures of bison bone density (Kreutzer 1992). Table 5 shows that the correlation coefficients (Kendall's tau) for all sites are low and nonsignificant, indicating that for the assemblages discussed here, the resulting bison bone frequencies are not significantly shaped by attrition.

Age Group Composition of Bison

Contrasting bison age group composition among the sites correspond to known bison social groups (Table 4). Bison typically form two types of social groups: mixed herds comprised of females, calves and young bulls, and mature bull groups (McHugh 1958). Mixed herds tend

to be larger and less mobile than the bull groups, and the two social units often remain separated from each other until the rut (Hanson 1984). Several Fremont assemblages (Bear River 1, Bear River 2, Bear River 3, and Levee) are comprised of age groups representing mixed herds (with calves), suggesting that breeding populations were at least intermittently indigenous to this area. In contrast, Knoll and Orbit Inn contain only the remains of adult animals that may represent solitary individuals, such as solitary bulls. Differences in age group composition, such as these, may be linked to the season of site occupation. However, there is an overlap in seasonal use between those sites containing mixed herds and those with only adult animals, suggesting periodic absences of breeding herds.

Bison Skeletal Part Representation

Bison skeletal part representation varies among the sites and may reflect differences in the body part transport decisions of hunters as a function of changes in local bison availability. A variety of factors can influence the transport decisions of contemporary and prehistoric hunters, such as carcass sex, age, nutritional condition, reproductive status, desired animal products, and other factors (see Frison 1973; Binford 1978; Speth 1983; Frison and Todd

Table 3
NISP^a OF DIFFERENT ANIMAL SIZE CLASSES^b FROM THE ANALYZED SITES

Taxon/Class	BR1^c (42Bo55)	BR2 (42Bo57)	BR3 (42Bo98)	Levee (42Bo107)	Knoll (42Bo109)	Orbit Inn (42Bo120)	42Wb32	Injun Creek (42Wb34)
bison (<i>Bison bison</i>)	1,798	1,220	632	624	54	29	0	0
elk (<i>Cervus elaphus</i>)	2	1	0	0	0	3	0	5
deer (<i>Odocoileus hemionus</i>)	4	7	8	0	7	89	34	1,281
mountain sheep (<i>Ovis canadensis</i>)	1	3	0	0	0	25	1	15
pronghorn (<i>Antilocapra americana</i>)	4	0	2	15	0	4	0	7
porcupine (<i>Erethizon dorsatum</i>)	5	8	2	8	1	3	1	7
marmot (<i>Marmota flaviventris</i>)	5	2	1	0	0	0	0	0
badger (<i>Taxidea taxus</i>)	0	3	0	0	0	3	0	1
skunk (<i>Mephitis mephitis</i>)	0	0	5	1	0	1	2	0
beaver (<i>Castor canadensis</i>)	2	6	1	0	0	4	5	54
otter (<i>Lutra canadensis</i>)	0	0	0	0	0	0	2	8
muskrat (<i>Ondatra zibethicus</i>)	33	10	70	122	6	1,325	241	34
hare (<i>Lepus</i> sp.)	2	2	5	40	3	13	6	106
rabbit (<i>Sylvilagus</i> sp.)	1	4	2	11	0	21	9	16
weasel (<i>Mustela frenata</i>)	0	0	2	0	1	7	0	2
mink (<i>Mustela vison</i>)	2	0	6	4	0	1	0	0
bear (<i>Ursus</i> sp.)	0	0	0	0	0	0	0	1
wolf (<i>Canis lupus</i>)	0	0	0	0	0	2	0	12
coyote (<i>Canis latrans</i>)	0	0	0	0	0	148	0	0
dog (<i>Canis familiaris</i>)	0	0	0	2	0	0	0	0
undiff. canid (<i>Canis</i> sp.)	0	2	0	0	0	2	1	2
red fox (<i>Vulpes fulva</i>)	0	0	1	0	2	2	0	0
kangaroo rat (<i>Dipodomys ordii</i>)	0	1	0	2	0	0	0	0
pocket gopher (<i>Thomomys talpoides</i>)	0	1	0	8	0	29	12	5
sage vole (<i>Lagurus curtatus</i>)	0	0	0	1	0	12	0	0
meadow vole (<i>Microtus longicaudus</i>)	0	0	0	0	0	0	0	1
Microtine rodent	1	4	1	5	0	25	32	1
Class I-IIa	5	1	9	10	0	114	16	6
Class III	10	20	34	14	4	196	68	30
Class IV	0	0	11	2	0	0	5	11
Class V	239	36	85	2	2	1,615	282	1,256
Class VI	574	425	394	527	6	9	2	5
bird	387	662	803	1,259	154	2,730	928	449
fish	3	41	6	392	2	1,937	1,061	537
amphibian	0	2	3	8	0	32	3	7
reptile	0	0	0	0	0	213	2	25
shellfish	3	175	245	0	66	68	60	0
unidentified	1,628	553	1,797	0	2	1,952	692	21
Totals	4,709	3,189	4,125	3,057	310	10,614	3,465	3,905

^a Number of identified specimens.

^b Mammalian size classes adapted from Thomas (1969).

^c BR1 = Bear River 1; BR2 = Bear River 2; BR3 = Bear River 3.

Table 4
MINIMUM NUMBER OF INDIVIDUAL ANIMALS
AND BISON AGE GROUPS IN THE ANALYZED SITES

Site	NISP ^a	MNI ^b	Age Groups Represented ^c
Bear River 1 (42Bo55)	1,798	22	adult, juvenile, and neonate
Bear River 2 (42Bo57)	1,220	21	adult, juvenile, and neonate
Bear River 3 (42Bo98)	632	7	adult, juvenile, and neonate
Levee (42Bo107)	624	6	adult and neonate
Knoll (42Bo109)	54	3	adult
Orbit Inn (42Bo120)	29	1	adult

^a Number of identified specimens.

^b Minimum number of individuals (based on the most common element).

^c Age groups based on tooth eruption sequences from complete maxillary and/or mandibular dentition and degree of bone fusion. Age criteria developed and derived from Fuller (1959), Frison and Reher (1970), Reher (1970), Duffield (1973), and Todd and Hoffman (1987).

1986; Lyman 1987; Todd 1987; Bunn et al. 1988; O'Connell et al. 1988, 1990). Given their large size, bison carcasses may be difficult to move from kill/butchering sites to base camps, especially if the transport capacity of hunters is limited. Under these circumstances, hunters may transport selected skeletal elements to residential camps and discard others in the field. Consequently, two factors might especially influence transport decisions for large-sized taxa: distance between base camps and kill sites, and the number of carcasses synchronously acquired. Empirical data suggest that for larger-sized taxa, such as bison, as the distance between kill site and base camp increases, the proportion of bones transported decreases (Bunn et al. 1988; O'Connell et al. 1988, 1990). For large-sized, gregarious animals, the synchronous acquisition of many carcasses also may influence transport decisions because hunters with excessive amounts of meat may display a high degree of part selectivity (e.g., Binford 1978).

Of the Fremont sites with large quantities of bison bones, Bear River 1 is interpreted as a butchering/processing site that contains the re-

mains of a small herd of bison that were locally procured. The remains may be the result of a single hunting episode or possibly several episodes that occurred within a short period of time (Aikens 1966). It is not clear where these bison were actually killed, since there is no evidence of a constructed pound or drive and few natural traps exist in the immediate area. However, the site is situated on the south bank of the Bear River, and it is possible that the bison were dispatched at a favored river crossing. At Bear River 1, nearly every part of the bison skeleton is represented, but some parts are more abundant than others, especially lower front and hind limb bones (Table 6). Clearly, meat and some skeletal parts were transported away from Bear River 1 to some other unknown location(s).

Interestingly, there is a positive and significant correlation between the skeletal element abundances in Bear River 1 as compared with Bear River 2, Bear River 3, and Levee, respectively (Table 7). This is unexpected, because the latter three sites are short-term, residential locations and none reflects specialized bison procurement locations. Unlike Bear River 1, these

Table 5
CORRELATION COEFFICIENTS BETWEEN BISON BONE
FREQUENCIES (NISP^a) AND VOLUME DENSITY^b

Site	Kendall's Tau	Probability
Bear River 1 (42Bo55)	-.092	p = .181
Bear River 2 (42Bo57)	-.162	p = .057
Bear River 3 (42Bo98)	-.073	p = .238
Levee (42Bo107)	-.01	p = .153
Knoll (42Bo109)	.023	p = .424
Orbit Inn (42Bo120)	-.133	p = .142

^a Number of identified specimens.

^b From Kreutzer (1992).

three sites are accretional; the bones did not accumulate from a single hunting episode. It is not clear why these sites show similar bison skeletal part representation, but such a situation may reflect comparable underlying transport decisions, such as short distances between kill sites and residential camps or similar carcass exploitation strategies.

Bison skeletal part representation at Knoll and Orbit Inn show no correlation to Bear River 1 (Table 7), suggesting that different contingencies influenced body part transport decisions. Unlike Bear River 1, Knoll and Orbit Inn contain fewer bison bones from fewer individual animals, and many skeletal elements are absent. Body part transport patterns at Knoll and Orbit Inn reflect different bison carcass exploitation patterns and/or transport decisions from those Fremont sites containing large numbers of animals. These patterns may have resulted from decreased encounters with bison as a consequence of lower densities and/or greater distances between encounters.

Bison Population Dynamics in the Northeastern Great Basin

Although the sample of sites from the Great Salt Lake wetlands is modest, these data appear to indicate marked fluctuations in the availability of bison in this portion of the northeastern Great Basin during Fremont times and a general de-

crease in availability after A.D. 1300. To further investigate this phenomenon, archaeofaunal data from 34 additional sites surrounding the Great Salt and Utah lakes in the northeastern Great Basin were examined for temporal patterning in relative bison abundances (Table 8).¹ This sample includes only those excavated Fremont and Late Prehistoric age sites where faunal frequencies were reported (as NISP, MNI, or faunal lists). Additionally, only sites dated with absolute techniques or associated with secure temporal markers (e.g., known historic artifacts or structural features) were considered. While many Fremont sites have been recorded in this area, far fewer sites dating to the post A.D. 1300 interval have been investigated, making temporal comparisons difficult. Furthermore, of those Late Prehistoric sites that have been excavated and dated, associated faunal assemblages are often small (< 100 NISP). Nevertheless, a temporal pattern in the occurrence of bison bones among these sites does emerge. Bison bone is less commonly associated with Late Prehistoric (and Protohistoric) sites than Fremont Period sites. A chi-square calculated between the number of Fremont and Late Prehistoric sites containing bison bone (Table 9) suggests that these samples are significantly dissimilar ($\chi^2 = 4.10$, $df = 1$, $p < .05$).

There also is a difference between Fremont and Late Prehistoric sites with respect to the

Table 6
BISON SKELETAL PART REPRESENTATION AS MEASURED BY %MAU^a

Element/Site	Bear River 1 (42Bo55)	Bear River 2 (42Bo57)	Bear River 3 (42Bo98)	Levee (42Bo107)	Knoll (42Bo109)	Orbit Inn (42Bo120)
cranium	39	25	57	50	--	100
mandible	23	20	71	62	100	--
atlas	3	10	57	25	--	--
axis	7	15	--	25	--	--
cervical vertebrae	18	18	28	25	--	--
thoracic vertebrae	8	5	31	12	7	--
lumbar vertebrae	13	18	31	32	--	16
rib	5	12	22	19	3	--
scapula	21	28	57	87	100	--
proximal humerus	18	7	--	12	--	--
humerus shaft	25	10	57	37	--	--
distal humerus	20	18	57	37	25	--
proximal radius/ulna	100	74	100	100	--	50
radius/ulna shaft	48	38	57	100	--	--
distal radius/ulna	59	38	86	50	50	--
carpal	18	8	26	43	4	--
proximal metacarpal	7	7	43	12	--	--
metacarpal shaft	7	5	--	50	--	--
distal metacarpal	7	5	57	75	25	--
innominate	25	10	28	25	--	--
proximal femur	48	49	71	62	50	--
femur shaft	18	25	71	62	--	--
distal femur	21	10	71	12	50	--
patella	76	66	100	100	100	--
proximal tibia	48	25	71	12	--	--
tibia shaft	30	9	57	25	50	--
distal tibia	57	100	100	62	50	--
tarsal	2	18	22	16	--	10
astragalus	35	13	71	12	15	--
calcaneus	25	2	14	37	--	--
proximal metatarsal	12	10	57	25	25	--
metatarsal shaft	11	2	--	12	25	--
distal metatarsal	5	7	43	37	--	--
phalanx 1	18	7	17	100	31	25
phalanx 2	19	5	28	80	12	25
phalanx 3	16	5	25	28	6	25

^a %MAU (as defined in Binford 1978) is derived by setting the largest MAU (minimum animal unit) at 100 and scaling all smaller values in relationship to it. MAU is derived by dividing the MNE (minimum number of elements) for each element by the number of times it occurs anatomically.

Table 7
CORRELATION COEFFICIENTS BETWEEN BISON
SKELETAL PARTS FOR PAIRS OF SELECTED SITES

Site Pairs	Kendall's Tau	Probability
Bear River 1/Bear River 2 (42Bo55/42Bo57)	.577	p < .0001
Knoll/Orbit Inn (42Bo109/42Bo120)	-.182	p = .140
Bear River 1/Levee (42Bo55/42Bo107)	.366	p = .024
Bear River 1/Bear River 3 (42Bo55/42Bo98)	.55	p < .001
Bear River 1/Knoll (42Bo55/42Bo109)	.198	p = .119
Bear River 1/Orbit Inn (42Bo55/42Bo120)	-.076	p = .326

proportional representation of bison relative to other mammalian taxa. Table 10 shows the percentage of bison (as measured by NISP) relative to all mammal bones in those archaeological assemblages where NISP was reported. Note that few Fremont assemblages contain high proportions of bison remains (NISP > 50% of the total assemblage). These include the only known bison jump in northeastern Utah, the Woodruff Bison Jump (Shields 1978), and the bison processing site at Bear River 1. Fremont sites described here and by others (Janetski 1990a; Schmitt et al. 1994) document high proportions of bison remains and suggest that small herds of bison once ranged along the shores of the Great Salt Lake and as far south as the eastern shores of Utah Lake.

Despite these finds, there are Fremont sites which contain low proportions of bison bones, with some containing none at all. Some of these are permanent habitation sites, suggesting that periodic bison absences were probably not seasonal. These data indicate that bison availability may have been irregular, characterized by brief periods when relatively high numbers of animals were locally available, punctuated by periods when bison were encountered at lower frequencies, or were entirely unavailable. In contrast, sites dating to the Late Prehistoric Period tend to have low proportions of bison bones (or none) relative to other mammalian taxa. There are no Late Prehistoric Period assemblages where bison represents more than 7% of the total mammalian NISP. Furthermore, no bison kill/processing

sites analogous to Bear River 1 or the Woodruff Bison Jump dating to this time period have been found in this area.

The paucity of bison in this portion of the northeastern Great Basin is further documented by the earliest historical records dating from the early nineteenth century, which report that bison were rarely encountered (Lupo 1996). Although historical accounts place bison along the northeastern shores of the Great Salt Lake between 1805 and 1840 (e.g., Seton 1929; Butler 1978), none are actual eyewitness accounts (Lupo 1996). Most historical sources that mention bison near the Great Salt Lake are secondhand accounts (e.g., Burton 1862; Russell 1965), and some are based on the discovery of bison skeletal remains rather than the sightings of live animals (Allen 1877; Hornaday 1889; Svihla 1931; Presnall 1938; Simpson 1983).

One of the few firsthand accounts is from the journals of Peter Skene Ogden, who encountered bison in the northern portion of the Cache Valley in northeastern Utah in May of 1825 (Miller 1952). A few years later in 1828-1829, after he crossed the territory just north of the Great Salt Lake, Ogden (1971:138-139) reported:

So far as I have seen of the north side is truly a barren country, buffalo have travelled thus far, but not in numbers nor do I believe they visit here annually of course not to be depended on by travelers who may desire to follow their tracks.

Bison were probably only sporadically encountered until 1833 in the Cache Valley and north and east of the Great Salt Lake (see Lupo

Table 8
SELECTED FREMONT AND LATE PREHISTORIC SITES IN THE NORTHEASTERN GREAT BASIN

Site Number/Name	Total NISP ^a	Bison NISP ^b	Type ^c	Age Range ^d (Mid Points)	Primary Reference ^e
Promontory Point Cave 1 (42Bo1)	200	20	UN	A.D. 640, 1110, 1630	Stewart 1937
Willard Mounds (42Bo3)	143	94	LRB	A.D. 779, 882	Judd 1926; Stewart 1933
42Bo73	158	11	SC	A.D. 870, 926	Simms et al. 1990
Hogup Cave (42Bo36)	303 (MNI)	7 (MNI)	SC	A.D. 420, 740, 1330 (Strata 12-14)	Aikens 1970
	59	2	SC	A.D. 1650 (Stratum 16)	
Kimber Shelter (42Bo45)	247	0	SC	Fremont	Dalley 1976
	33	0	SC	Protohistoric	
Swallow Shelter (42Bo268)	636 (MNI)	4 (MNI)	SC	A.D. 830 (Stratum 9)	Dalley 1976
Remnant Cave (42Bo365)	10 (MNI)	0	SC	A.D. 950	Berry 1976
	1 (MNI)	0	SC	A.D. 1545	
42Bo702	30	0	SC	Late Prehistoric	Fawcett and Simms 1993
Thomas Shelter (26Ek658)	158	0	SC	Fremont	Dalley 1976
Pharo Village (42Md180)	1,029	18	LRB	A.D. 460, 1190, 1260	Marwitt 1968
42Md974	197	0	LRB	A.D. 850, 975, 1290	Schmitt and Lupo 1994
Nephi Mounds (42Jb2)	3,474	0	LRB	A.D. 780, 860, 920	Sharrock and Marwitt 1967
42Ri641	1,162	1,150	BJ	A.D. 641	Shields 1978
Deadman Cave (42Si11)	UN	0	UN	Fremont	Smith 1952
42Si197	49	40	UN	A.D. 790	Schmitt et al. 1994
Bulldozer Dune (42Si146)	16	0	SC	Fremont	Madsen 1976
Backhoe Village (42Sv662)	1,058	0	LRB	A.D. 940, 1160, 1290	Madsen and Lindsay 1977
42To2	UN	0	SC	Fremont	Jameson 1958
42Ut698	34	0	SC	A.D. 1600	Schmitt and Lupo 1994
Spotten Cave (42Ut104)	> 1,877	Present	SC	A.D. 728, 1228 (Zone III)	Mock 1971; Cook 1980
Woodard Mound (42Ut102)	380	0	LRB	A.D. 1035, 1285	Richens 1983
Hinkley Mounds (42Ut110/111)	1,000	Present	LRB	A.D. 685, 891, 1030	Green 1961; Cook 1980
Smoking Pipe (42Ut150)	1,913	1,831	SC	A.D. 1163, 1295, 1486	Forsyth 1984; Billat 1985
Fox (42Ut573)	24	0	SC	A.D. 1590, 1650	Janetski 1990a, 1990b
Heron Springs (42Ut591)	175	13	SC	A.D. 1330, 1370, 1420	Janetski 1990b
Sandy Beach (42Ut592)	649	1	SC	A.D. 1385, 1480	Janetski 1990a
42Wb54	33	0	SC	A.D. 1740	Stuart 1993
Warren (42Wb57)	159	75	LRB	A.D. 843	Enger and Blair 1947
42Wb185	273	5	SC	A.D. 612, 958, 1363	Simms et al. 1990
42Wb304	UN	Present	SC	A.D. 1038	Russell et al. 1989
42Wb317	384	6	SC	A.D. 1029, 1031, 1407	Simms et al. 1990
42Wb330	26	0	SC	Late Prehistoric	Fawcett and Simms 1993
Tooele (42To000)	UN	Present	LRC	Fremont	Gillin 1941
Ephraim (42Sp000)	UN	Present	LRC	Fremont	Gillin 1941

^a Number of identified specimens. Unless specified, this is the total mammalian NISP. MNI = minimum number of individuals. UN = unknown; this designation was used in cases where the number of bones recovered was not presented but a species list was provided.

^b Number of bison bones in the assemblage. "Present" is used to designate sites where bison were included in the species list.

^c LRB = long-term residential base; SC = short-term camp; BJ = bison jump; LRC = long-term residential camp; UN = unknown.

^d ¹⁴C midpoints.

^e Main sources of site description. Faunal identifications of 42Bo1, 42Bo3, 42Bo73, 42Bo702, 42Wb57, 42Wb185, 42Wb317, 42Wb318, and 42Wb330 were made by Karen Lupo.

Table 9
FREMONT AND LATE PREHISTORIC SITES CONTAINING BISON

	Fremont	Late Prehistoric
with bison	22	4
without bison	11	8

1996), although they apparently persisted in portions of southeastern Idaho, southwestern Wyoming, and along the Green River in northern Utah until at least 1840 (Roe 1951; Butler 1978). By the time the Mormon pioneers arrived in the Great Salt Lake Valley in 1847, bison were locally extinct (Roe 1951).

Implications for Prehistoric Hunting Strategies

Fluctuations in the availability of bison have implications for Fremont, as well as Late Prehistoric, hunting strategies and prey resource selection. According to evolutionary based models drawn from optimal foraging theory, food selection can be predicted by resource rank (MacArthur and Pianka 1966; Bayham 1979; Smith 1983; Simms 1984, 1987). Foragers rank food resources along a single dimension of profitability, such as calories returned per unit of handling time (e.g., in pursuit, capture, preparation, and consumption) invested after the prey is encountered.

Although the return rate of a resource can vary according to density (Smith 1983; see also Madsen and Kirkman 1988) and efficiency of the capture technique utilized (e.g., Hawkes et al. 1982), for most prey body size (as measured by kg.) is positively and significantly correlated with caloric return rate (Simms 1984, 1987; Broughton 1994). Bison live weights vary by age, sex, reproductive status, forage productivity, season of the year, and other factors, but growth for both sexes levels off after five years. Average live-weights for adult males and females (five years and up) are 820.4 kg. and 476 kg., respectively, making them the largest terrestrial prey in the northeastern Great Basin (Emerson 1990). Consequently, in comparison

to other options, bison are the highest-ranked prey item among the available suite of terrestrial mammalian resources in the northeastern Great Basin.²

While resource rankings predict the order in which items are added to or deleted from the diet, the commonness of a particular resource in the diet depends on its encounter rate or availability. Diet breadth predicts that high-ranked resources will always be taken by a forager whenever encountered. However, fluctuations in the availability or encounter rate of more highly ranked resources will result in changes in the diet breadth. Decreases in the availability of high-ranked resources result in the inclusion of lower-ranked resources into the diet in rank order. Increased encounters with high-ranked resources, such as bison, should result in foragers ignoring lower-ranked resources. Infrequent encounters with high-ranked resources will result in a broadening of the diet.

While prehistoric prey encounter rates are notoriously difficult to discern (e.g., Simms 1984), several lines of evidence suggest that environmental conditions were favorable for increased bison availability during Fremont times (c.f., Van Vuren 1987). Although localized increases in bison populations can result when formerly dispersed animals aggregate at particular locations due to environmental stress (Hanson 1984), bison herd productivity is linked to precipitation patterns and the availability of forage (Van Vuren and Bray 1986). Documented regressions in the level of the Great Salt Lake between 2,000 and 400 years ago expanded wetland habitats along its shores (Currey and James 1982; Murchison 1989) and may be associated with increased summer moisture, creating a fa-

Table 10
PERCENT BISON NISP^a FOR FREMONT AND LATE PREHISTORIC SITES

% Bison NISP	Fremont Sites	Late Prehistoric Sites
None	10	5
> 10%	4	3
10-50%	4	0
50-99%	7	0

^a Number of identified specimens. Includes only those sites where NISP is known. Percent bison NISP derived by dividing NISP bison by NISP for all mammals.

avorable situation for grassland expansion and limited corn farming in the northeastern Great Basin (Simms and Stuart 1993).

Several archaeological sites in the eastern Great Basin, such as Hogup Cave, show an increase in upland grass pollen coinciding with this time interval (Harper and Alder 1970; Simms and Stuart 1993). The soils along the northeastern shores of the Great Salt Lake were developed in a grassland habitat that was one of the "most extensive and best developed grasslands of Utah" and probably was contiguous with the Snake River Plains in Idaho during Fremont times (Harper 1967:63). Additional sources (Weaver 1917; Stoddart 1941; Christensen 1961; Daubenmire 1992) reported the existence of a palouse grassland remnant dominated by bluebunch wheatgrass (*Agropyron spicatum*), a common graze for bison, in parts of northeastern Utah, which probably persisted up until historic times (Stoddart 1941).

Bison declines are less easily attributable to environmental conditions. While a shift from summer to winter dominant precipitation patterns emerged around A.D. 1350 (e.g., Grove 1988; Enzel et al. 1992), it is not clear how this may have affected bison forage and herd productivity. This shift may have resulted in a decrease in corn productivity and temporarily diminished the amount of available graze for bison (Simms and Stuart 1993). It is possible that the emergence of the modern mosaic habitats with discontinuous

grasslands could have supported only small, isolated bison populations which could not readily recover from localized extinctions resulting from overhunting and other factors (Van Vuren 1987).

Whatever the cause for fluctuating bison encounter rates, prehistoric human populations in the vicinity of the Great Salt Lake must have adopted strategies to accommodate an unpredictable and irregular, but highly ranked, resource. Local human populations may have developed highly flexible hunting patterns which involved incorporating other prey resources into the diet when bison were not available. For prey resources, it may have involved the inclusion of smaller-sized artiodactyls (deer, mountain sheep, pronghorn), as well as other medium and small-sized mammals. Russell et al. (1989), for example, argued that freshwater shellfish might enter the diet when bison decline. Given the biases affecting the representation of smaller-sized mammals (as well as shellfish) in the Great Salt Lake wetland assemblages examined herein, it is not possible to specify which taxa increase when bison bones are rare or absent. However, high proportions of small-sized artiodactyls and muskrats occur in some assemblages where bison bones are rare or absent, especially those dating to the post-A.D. 1300 period.

Alternately, prehistoric populations may have obtained bison products by making logistical hunting trips to areas where bison persisted, such as southwestern Wyoming or southeastern

Idaho, or trading with human populations living in these areas. This is a pattern documented historically (Hafen and Hafen 1954) among some western Ute bands occupying the Uintah Basin (Harris 1909:151, 167) and Utah Valley (Steward 1938), and among the Shoshoni in southeastern Idaho (Simpson 1983:460) and northeastern Utah (Steward 1938). Mounted western Ute were making bison hunting trips into southwestern Wyoming to procure meat and other products by 1776 and probably earlier (Harris 1909). This historic pattern of bison product procurement may have initially emerged during the Fremont period, partly in response to the unpredictability of local bison. Smith (1992) recently documented sites containing Fremont ceramics in parts of southwestern Wyoming, suggesting that these sites may reflect a wider settlement and subsistence round of foraging and/or farming Fremont populations from the Great Salt Lake area. A final set of options for populations prior to the introduction of the horse could involve making hunting or trading trips over shorter distances or making fewer trips.

CONCLUSIONS

Several lines of evidence suggest that bison populations in the vicinity of the Great Salt Lake fluctuated during Fremont times and may have been generally lower during the Late Prehistoric. A similar situation may characterize portions of the Utah Valley. Archaeological data suggest that bison were encountered in lower numbers after A.D. 1300, a situation which apparently persisted up until historic contact. The dynamic nature of prehistoric bison populations has been documented in other portions of the American west (Schroedl 1973; Butler 1978; McDonald 1981; Van Vuren and Bray 1986; Van Vuren 1987), and the temporal fluctuations in the availability of bison suggested herein may have extended to other adjacent parts of the Great Basin. In a recent review of bison remains from archaeological and paleontological sources, Murphy

and Hockett (1994) argued that small herds of bison persisted in favorable habitats in northeastern Nevada. Although archaeological evidence for bison in northeastern Nevada extends back approximately 12,000 years, most of the securely dated sites fall between 4,900 and 700 years B.P., with only a few more recent finds (see also Van Vuren and Deitz 1993).

If bison availability fluctuated in the northeastern Great Basin, then Fremont and Late Prehistoric hunters could not have relied exclusively on this prey. Hunters must have developed different strategies to take advantage of irregular and unpredictable windfalls in bison, including an increased reliance on trading, making logistical hunting trips, and/or hunting smaller-sized game. The data presented herein suggest that bison population booms were few. Periods when bison occurred in low densities or were entirely absent may have more often characterized this area.

NOTES

1. An additional Late Prehistoric site with bison remains, 42Ut13, is located on the shores of Utah Lake (Beeley 1946), but the temporal designation is based on artifact associations. The site is suspect because it has been flooded several times since occupation and some bones show signs of water transport (K. Lupo, personal observation 1993). For this reason, 42Ut13 is not included in Table 8.

2. The average live-weight of an adult female elk (two years and up) is 202 kg. and for a male it is 196.3 kg., but some individuals reach as much as 350 kgs. (Thomas and Toweill 1982).

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REFERENCES

- Aikens, C. Melvin
 1966 Fremont-Promontory-Plains Relationships. University of Utah Anthropological Papers No. 82.
 1967 Excavations at Snake Rock Village and the Bear River No. 2 Site. University of Utah Anthropological Papers No. 87.
 1970 Hogup Cave. University of Utah Anthropological Papers No. 93.
- Allen, Joel A.
 1877 History of the American Bison. In: 9th Annual Report of the United States Geological and Geographical Survey of the Territories, Embracing Colorado and Parts of Adjacent Territories Being a Report of Progress of the Exploration for the Year 1875, by F. V. Hayden, Part III, pp. 443-589. Washington: Government Printing Office.
- Bayham, Frank E.
 1979 Factors Influencing the Archaic Pattern of Animal Utilization. *The Kiva* 44(3):219-235.
- Beeley, Stephen J.
 1946 The Archaeology of a Utah Lake Site. Master's thesis, University of Utah.
- Berry, Michael S.
 1976 Remnant Cave. In: Sudden Shelter and Associated Sites, by Gardiner F. Dalley, pp. 115-127. University of Utah Anthropological Papers No. 96.
- Billat, Scott E.
 1985 A Study of Fremont Subsistence at the Smoking Pipe Site. Master's thesis, Brigham Young University.
- Binford, Lewis R.
 1978 *Nunamiut Ethnoarchaeology*. New York: Academic Press.
 1981 *Bones: Ancient Men and Modern Myths*. New York: Academic Press.
- Binford, Lewis R., and J. B. Bertram
 1977 Bone Frequencies and Attritional Processes. In: *For Theory Building in Archaeology*, Lewis R. Binford ed., pp. 77-153. New York: Academic Press.
- Brain, C. K.
 1967 Hottentot Food Remains and Their Meaning in the Interpretation of Fossil Bone Assemblages. *Scientific Papers of the Namib Desert Research Station* No. 32:1-11.
 1969 The Contribution of the Namib Desert Hottentots to an Understanding of Australopithecine Bone Accumulations. *Scientific Papers of the Namib Desert Research Station* No. 39:13-22.
 1981 *The Hunters or the Hunted?* Chicago: University of Chicago Press.
- Broughton, Jack M.
 1994 Late Holocene Resource Intensification in the Sacramento Valley, California: The Vertebrate Evidence. *Journal of Archaeological Science* 21(4):501-514.
- Bunn, Henry, Larry Bartram, and Ellen Kroll
 1988 Variability in Bone Assemblage Formation From Hadza Hunting, Scavenging, and Carcass Processing. *Journal of Anthropological Archaeology* 7(4):412-457.
- Burton, Sir Richard
 1862 *City of the Saints and Across the Rocky Mountains to California*. New York: Harper & Bros.
- Butler, Robert B.
 1978 Bison Hunting in the Desert West Before 1800: The Paleoecological Potential and Archaeological Reality. In: *Bison Procurement and Utilization: A Symposium*, Leslie B. Davis and M. Wilson, eds., pp. 106-112. *Plains Anthropological Memoir* 14(2).
- Christensen, S. M.
 1961 The Agropyron-Poa Bunchgrass Vegetation in Central Utah. *Utah Academy of Science Proceedings* 38:113.
- Coltrain, Joan Brenner
 1993 Fremont Corn Agriculture: A Pilot Stable Carbon Isotope Study. *Utah Archaeology* 6(1):49-56.
- Cook, Clayton
 1980 Faunal Analysis From Five Utah Valley Sites: A Test of a Subsistence Model From the Sevier Fremont Area. Master's thesis, Brigham Young University.
- Currey, Donald, and Steven R. James
 1982 Paleoenvironments of the Northeastern

- Great Basin and Northeastern Basin Rim: A Review of Geological and Biological Evidence. In: *Man and Environment in the Great Basin*, David B. Madsen and James F. O'Connell, eds., pp. 27-52. Society for American Archaeology Papers No. 2.
- Dalley, Gardiner F.
1976 Swallow Shelter and Associated Sites. University of Utah Anthropological Papers No. 96.
- Daubenmire, Rexford
1992 Palouse Prairie. In: *Ecosystems of the World: Natural Grasslands 8A*, Robert T. Coupland, ed., pp. 297-312. New York: Elsevier.
- Duffield, Lathel F.
1973 Aging and Sexing Post-Cranial Skeleton of Bison. *Plains Anthropologist* 18(60):132-139.
- Emerson, Alice Marie
1990 Archaeological Implications of Variability in the Economic Anatomy of *Bison bison*. Ph.D. dissertation, Washington State University.
- Enger, Walter D., and William Blair
1947 Crania from the Warren Mounds and Their Possible Significance to Northern Periphery Archaeology. *American Antiquity* 13(2):142-146.
- Enzel, Yehouda, W. J. Brown, R. Y. Anderson, L. D. McFadden, and S. G. Wells
1992 Short Duration Holocene Lakes in the Mojave River Drainage Basin, Southern California. *Quaternary Research* 38(1):60-73.
- Fawcett, William B., and Steven R. Simms
1993 Introduction. In: *Archaeological Test Excavations in the Great Salt Lake Wetlands and Associated Analyses: Weber and Box Elder Counties, Utah*. Utah State University Contributions to Anthropology No. 14:1-4.
- Forsyth, Donald W.
1984 Preliminary Report of Archaeological Investigations at the Smoking Pipe Site (42Ut150), Utah Valley, Utah—The 1983 and 1984 Seasons. Brigham Young University Museum of Peoples and Cultures Technical Series No. 84-92.
- Frison, George C.
1973 The Wardell Buffalo Trap 48SU301: Communal Procurement in the Upper Green River Basin, Wyoming. University of Michigan, Anthropological Papers of the Museum of Anthropology, No. 48.
- 1982 The Agate Basin Site: A Record of Paleoindian Occupation of the Northwestern Plains. New York: Academic Press.
- Frison, George C., and Charles A. Reher
1970 Age Determination of Buffalo by Tooth Eruption and Wear. In: *The Glenrock Buffalo Jump, 48Co304, Late Prehistoric Period Buffalo Procurement and Butchering on the Northwestern Plains*, by George Frison, Appendix I. *Plains Anthropologist* Memoir 7.
- Frison, George C., and Lawrence C. Todd
1986 The Colby Mammoth Site: Taphonomy and Archaeology of a Clovis Kill in Northern Wyoming. Albuquerque: University of New Mexico Press.
- Fry, Gary F., and Gardiner F. Dalley
1979 The Levee Site and the Knoll Site. University of Utah Anthropological Papers No. 100.
- Fuller, William A.
1959 The Horns and Teeth as Indicators of Age in Bison. *Journal of Wildlife Management* 23(3):342-344.
- Gillin, John
1941 Archaeological Investigations in Central Utah. Papers of the Peabody Museum of American Archaeology and Ethnology 12(2).
- Grayson, Donald K.
1984 Quantitative Zooarchaeology. Orlando: Academic Press.
- Green, Dee F.
1961 Archaeological Investigations at the G. M. Hinkley Farm Site, Utah County, Utah, 1956-1960. Provo: Brigham Young University Press.
- Grove, Jean M.
1988 The Little Ice Age. New York: Methuen.
- Hafen, Leroy, and Anne W. Hafen
1954 The Old Spanish Trail, Far West and Rockies Series, Vol. 1. Glendale: Arthur Clark & Co.
- Hanson, Jeffery
1984 Bison Ecology in the Northern Plains and a Reconstruction of Bison Patterns for the North Dakota Region. *Plains Anthropologist* 29(104):93-113.

- Harper, K. T.
1967 The Vegetational Environment of the Bear River No. 2 Archaeological Site. In: Excavations at Snake Rock Village and the Bear River No. 2 Site, by C. Melvin Aikens, pp. 63-65. University of Utah Anthropological Papers No. 87.
- Harper, K. T., and G. M. Alder
1970 The Macroscopic Plant Remains of the Deposits of Hogup Cave, Utah, and Their Paleoclimatic Implications. In: Hogup Cave, by C. Melvin Aikens, Appendix I. University of Utah Anthropological Papers No. 93.
- Harris, W. R.
1909 The Catholic Church in Utah 1776-1909. Salt Lake City: Intermountain Catholic Press.
- Hawkes, Kristen, Kim Hill, and James F. O'Connell
1982 Why Hunters Gather: Optimal Foraging and the Aché of Eastern Paraguay. *American Ethnologist* 9(2):379-398.
- Hornaday, William
1889 The Extirpation of the American Bison. In: Annual Report of the Board of Regents of the Smithsonian Institution for 1887, Part II, pp. 367-548.
- Jameson, Sydney
1958 Archaeological Notes on Stansbury Island. University of Utah Anthropological Papers No. 34.
- Janetski, Joel C.
1990a Wetlands in Utah Valley Prehistory. In: Wetland Adaptations in the Great Basin, Joel C. Janetski and David B. Madsen, eds., pp. 233-258. Brigham Young University Museum of Peoples and Cultures Occasional Papers No. 1.
1990b Utah Lake: Its Role in the Prehistory of Utah Valley. *Utah Historical Quarterly* 58(1):5-31.
- Judd, Neil M.
1926 Archaeological Observations North of the Rio Colorado. *Bureau of American Ethnology Bulletin* 82.
- Klein, Richard G., and Kathryn Cruz-Uribe
1984 The Analysis of Animal Bones From Archaeological Sites. Chicago: University of Chicago Press.
- Kreutzer, Lee Ann
1992 Bison and Deer Bone Mineral Densities: Comparisons and Implications for the Interpretation of Archaeological Faunas. *Journal of Archaeological Science* 19(3):271-294.
- Leechman, D.
1951 Bone Grease. *American Antiquity* 16(4):355-356.
- Lupo, Karen D.
1990 Analysis of the Fauna From the Orbit Inn Site, Weber County, Utah. Report on file at the University of Utah and at Utah State University.
1996 The Historical Occurrence and Demise of Bison in Northeastern Utah. *Utah Historical Quarterly* 64(2):168-180.
- Lyman, R. Lee
1984 Bone Density and Differential Survivorship of Fossil Classes. *Journal of Anthropological Archaeology* 3(4):259-299.
1985 Bone Frequencies: Differential Transport, *In Situ* Destruction, and the MGUI. *Journal of Archaeological Science* 12(3):221-236.
1987 Archaeofaunas and Butchery Studies: A Taphonomic Perspective. In: *Advances in Archaeological Method and Theory*, Vol. 10, Michael B. Schiffer, ed., pp. 249-337. San Diego: Academic Press.
- MacArthur, Robert H., and Eric R. Pianka
1966 On Optimal Use of a Patchy Environment. *American Naturalist* 100(916):603-609.
- Madsen, David B.
1976 Bulldozer Dune, 42Sl46. Utah Historical Society, Division of State History, Antiquities Section Selected Papers No. 6.
1989 Exploring the Fremont. Salt Lake City: Utah Museum of Natural History.
- Madsen, David B., and James E. Kirkman
1988 Hunting Hoppers. *American Antiquity* 53(3):593-604.
- Madsen, David B., and La Mar Lindsay
1977 Backhoe Village. Utah Historical Society, Division of State History, Antiquities Section Selected Papers No. 12.
- Madsen, David B., and Dyan Rowe
1988 Utah Radiocarbon Dates I: Pre-1970 Dates. *Utah Archaeology* 1(1):52-56.
- Marean, Curtis W., Lillian Spencer, Robert Blumen-schne, and Sal Capaldo
1992 Captive Hyaena Bone Choice and Destruction, the Schleppe Effect, and Olduvai Ar-

- chaeofaunas. *Journal of Archaeological Science* 19(1):101-121.
- Marwitt, John P.
 1968 Pharo Village. University of Utah Anthropological Papers No. 91.
 1970 Median Village and Fremont Culture Regional Variation. University of Utah Anthropological Papers No. 95.
- McDonald, Jerry
 1981 North American Bison: Their Classification and Evolution. Berkeley: University of California Press.
- McHugh, Tom
 1958 Social Behavior of the American Buffalo (*Bison bison bison*). *Zoologica* 43(1):1-40.
- Miller, David E.
 1952 Peter Skene Ogden's Journal of His Expedition to Utah, 1825. *Utah Historical Quarterly* XX (April 1952):168-175.
- Mock, James M.
 1971 Archaeology of Spotten Cave, Utah County, Central Utah. Master's thesis, Brigham Young University.
- Murchison, Stuart B.
 1989 Fluctuation History of the Great Salt Lake, Utah, During the Last 13,000 Years. Ph.D. dissertation, University of Utah.
- Murphy, Timothy W., and Bryan Scott Hockett
 1994 Bison Remains From Northeastern Nevada. Paper presented at the Great Basin Anthropological Conference, Elko.
- O'Connell, James F.
 1993 What Can Great Basin Archaeologists Learn From the Study of Site Structure? An Ethnoarchaeological Perspective. *Utah Archaeology* 6(1):7-26.
- O'Connell, James F., Kristen Hawkes, and Nicholas Blurton Jones
 1988 Hadza Hunting, Butchering, and Bone Transport and Their Archaeological Implications. *Journal of Anthropological Research* 44(2):113-161.
 1990 Reanalysis of Large Mammal Body Part Transport Among the Hadza. *Journal of Archaeological Science* 17(3):301-316.
- Ogden, Peter Skene
 1971 Peter Skene Ogden's Snake Country Journals, 1827-1828 & 1828-1829, Glyndwr Williams, ed. London: Hudson's Bay Record Society.
- Parmalee, Paul W.
 1979 A Preliminary Report on the Birds from the Levee and Knoll Sites, Box Elder County, Utah. In: The Levee Site and the Knoll Site, by Gary F. Fry and Gardiner F. Dalley, Appendix III. University of Utah Anthropological Papers No. 100.
 1980 Utilization of Birds by the Archaic and Fremont Cultural Groups of Utah. In: Papers in Avian Paleontology Honoring Hildegard Howard, Kenneth E. Campbell, ed., pp. 237-250. Los Angeles: Contributions in Science, Natural History Museum of Los Angeles County, No. 330.
- Pendergast, David
 1961 Excavations at the Bear River Site, Box Elder County, Utah. *Utah Archaeology Newsletter* 7(2):14-18.
- Presnall, C. C.
 1938 Evidence of Bison in Southwestern Utah. *Journal of Mammology* 19(1):111-112.
- Reher, Charles
 1970 Population Dynamics of the Glenrock *Bison bison* Population. In: The Glenrock Buffalo Jump, 48Co304, Late Prehistoric Period Buffalo Procurement and Butchering on the Northwestern Plains, by George Frison, Appendix II. Plains Anthropologist Memoir 7.
- Richens, Lane D.
 1983 Woodard Mounds: Excavation at a Fremont Site in Goshen Valley, Utah County, Utah, 1980-1981. Master's thesis, Brigham Young University.
- Roe, Frank Gilbert
 1951 The North American Buffalo: A Critical Study of the Species in its Wild State. Toronto: University of Toronto Press.
- Russell, Kenneth W., Mark E. Stuart, James A. Brannan, and Heather M. Weymouth
 1989 Archaeological Reconnaissance in the Ogden/Weber River Marshes. Weber State College Reports of Investigations No. 89-1.
- Russell, Osborne
 1965 Journal of a Trapper: 1834-1843, Aubrey L. Haines, ed. Lincoln: University of Nebraska Press.
- Schmitt, Dave N., and Karen D. Lupo
 1994 Zooarchaeological Analysis of Selected

- Sites. In: Kern River Pipeline Cultural Resources Data Recovery Report: Utah, W. Geoffrey Spaulding, ed., pp. 11-111-66. Report on file at Utah Division of State History, Salt Lake City.
- 1995 On Mammalian Taphonomy, Taxonomic Diversity, and Measuring Subsistence Data in Zooarchaeology. *American Antiquity* 60(3):496-514.
- Schmitt, Dave N., Steven R. Simms, and Gabrielle P. Woodbury
- 1994 Archaeological Salvage Investigations at a Fremont Site in the Jordan River Delta. *Utah Archaeology* 7(1):69-80.
- Schroedl, G. F.
- 1973 The Archaeological Occurrence of Bison in the Southern Plateau. Laboratory of Anthropology, Washington State University, Report of Investigations No. 51.
- Seton, Ernest Thompson
- 1929 *Lives of Game Animals*. Vol 3, Pt. 2. Garden City: Doubleday.
- Sharp, Nancy D.
- 1989 Redefining Fremont Subsistence. *Utah Archaeology* 2(1):19-31.
- Sharrock, Floyd, and John Marwitt
- 1967 Excavations at Nephi, Utah, 1965-1966. University of Utah Anthropological Papers No. 88.
- Shields, Wayne F.
- 1978 The Woodruff Bison Kill. Miscellaneous Paper No. 21, University of Utah Anthropological Papers No. 99.
- Shields, Wayne F., and Gardiner F. Dalley
- 1978 The Bear River No. 3 Site. Miscellaneous Paper No. 22, University of Utah Anthropological Papers No. 99.
- Shuey, Ralph T.
- 1979 Archeomagnetic Dating at the Levee Site. In: *The Levee and the Knoll Site*, by Gary F. Fry and Gardiner F. Dalley, Appendix I. University of Utah Anthropological Papers No. 100.
- Simms, Steven R.
- 1984 Aboriginal Great Basin Foraging Strategies: An Evolutionary Analysis. Ph.D. dissertation, University of Utah.
- 1986 New Evidence for Fremont Adaptive Diversity. *Journal of California and Great Basin Anthropology* 8(2):204-216.
- 1987 Behavioral Ecology and Hunter-Gatherer Foraging: An Example From the Great Basin. *British Archaeological Reports International Series* 381.
- 1990 Fremont Transitions. *Utah Archaeology* 3(1):1-18.
- 1994 Farmers and Foragers in the Late Holocene Eastern Great Basin. Paper presented at the Great Basin Anthropological Conference, Elko.
- Simms, Steven R., and Katherine Heath
- 1990 Site Structure of the Orbit Inn: An Application of Ethnoarchaeology. *American Antiquity* 55(4):797-813.
- Simms, Steven R., and Mark E. Stuart
- 1993 Prehistory and Past Environments of the Great Salt Lake Wetlands. In: *Archaeological Test Excavations in the Great Salt Lake Wetlands and Associated Analyses: Weber and Box Elder Counties, Utah*, by Bill Fawcett and Steven Simms, pp. 5-31. Utah State University Contributions to Anthropology No. 14.
- Simms, Steven R., Carol Loveland, and Mark E. Stuart
- 1991 Prehistoric Human Skeletal Remains and the Prehistory of the Great Salt Lake Wetlands. Utah State University Contributions to Anthropology No. 6.
- Simms, Steven R., Mark E. Stuart, Sheila Beckstead, Eva Jensen, and Suzanne Sarver
- 1990 Archaeological Reconnaissance in the Lower Bear River Marshes, Utah. Utah State University Contributions to Anthropology No. 13.
- Simpson, James H.
- 1983 Report of Explorations Across the Great Basin of the Territory of Utah for a Direct Wagon-Route from Camp Floyd to Genoa in Carson Valley in 1859. Reno: University of Nevada Press.
- Smith, Craig S.
- 1992 The Fremont: A View From Southwest Wyoming. *Utah Archaeology* 5(1):55-75.
- Smith, Elmer R.
- 1952 Archaeology of Deadman Cave. University of Utah Anthropological Papers No. 10.
- Smith, Eric Alden
- 1983 Anthropological Applications of Optimal Foraging Theory: A Critical Review. *Current Anthropology* 24(5):625-651.

- Speth, John D.
1983 *Bison Kills and Bone Counts*. Chicago: University of Chicago Press.
- Steward, Julian
1933 *Early Inhabitants of Western Utah*. Bulletin of the University of Utah 23(7):1-34.
1937 *Ancient Caves of the Great Salt Lake Region*. Bureau of American Ethnology Bulletin 116.
1938 *Basin-Plateau Aboriginal Sociopolitical Groups*. Bureau of American Ethnology Bulletin 120.
- Stoddart, L. A.
1941 *The Palouse Grassland Association in Northern Utah*. Ecology 22:158-163.
- Stuart, M.
1993 *Salvage Excavations at the Fire Guard Hearth 42WB54, Weber County, Utah*. Utah Archaeology 6(1):71-78.
- Svihla, Ruth Dowell
1931 *Mammals of the Uinta Mountain Region*. Journal of Mammology 12(3):256-265.
- Thomas, David Hurst
1969 *Great Basin Hunting Patterns: A Quantitative Method for Treating Faunal Remains*. American Antiquity 34(4):392-401.
- Thomas, Jack Ward, and Dale E. Toweil (eds. and comps.)
1982 *Elk of North America: Ecology and Management*. Harrisburg: Stackpole Books.
- Todd, Lawrence C.
1987 *Analysis of Kill Butchery Bonebeds and Interpretations of Paleoindian Hunting*. In: *The Evolution of Human Hunting*, Matthew H. Nitecki, ed., pp. 225-266. New York: Plenum Press.
- Todd, Lawrence C., and Jack L. Hoffman
1987 *Bison Mandibles from the Horner and Finley Sites*. In: *The Horner Site: The Type Site of the Cody Cultural Complex*, George C. Frison and Lawrence C. Todd, eds., pp. 493-539. Orlando: Academic Press.
- Turney-High, Harry H.
1937 *The Flathead Indians of Montana*. American Anthropological Association Memoir No. 48.
- Van Vuren, Dirk
1987 *Bison West of the Rocky Mountains: An Alternative Explanation*. Northwest Science 61(2):65-69.
- Van Vuren, Dirk, and Martin P. Bray
1986 *Population Dynamics of Bison in the Henry Mountains, Utah*. Journal of Mammalogy 67(3):503-511.
- Van Vuren, Dirk, and Frank C. Deitz
1993 *Evidence of *Bison* in the Great Basin*. Great Basin Naturalist 53(3): 318-319.
- Vehik, Susan
1977 *Bone Fragments and Bone Grease Manufacturing: A Review of Their Archaeological Use and Potential*. Plains Anthropologist 22(77):169-182.
- Weaver, J. E.
1917 *A Study of Vegetation in Southeastern Washington and Adjacent Idaho*. University of Nebraska Studies 17(1).
- Wheat Joe Ben
1972 *The Olsen-Chubbuck Site: A Paleo-Indian Bison Kill*. Society for American Archaeology Memoir No. 26.

