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TOWARD DISTINGUISHING HUMAN AND RAPTOR PATTERNING ON LEPORID BONES

Bryan Scott Hockett

Prehistoric Native Americans hunted leporids (cottontails and hares) for food, clothing, and to obtain raw material for the manufacture of bone tools such as awls. Leporids are also favorite prey of various carnivores and raptors, hence many archaeological sites may contain leporid bones that were deposited by both human and nonhuman activities. This paper provides data to distinguish specific agents and processes that affected leporid bones in archaeological sites. Human behavior tends to create hare tibia diaphysis cylinders, cut-marked bones, unidentifiable burned bone fragments, and assemblages with predominantly adult leporid bone specimens. In contrast, raptor behavior creates more cottontail tibia diaphysis cylinders, bones with beak and talon punctures on only one side, shearing damage principally to innominate and femora, and high frequencies of forelimb and juvenile bones when leporid bones are deposited mainly in raptor pellets.

Los aborígenes Norteamericanos prehistóricos cazaban leporinos (conejos americanos y liebres) para obtener alimento, vestimenta, y materia prima para fabricar instrumentos de hueso, tales como punzones. Los leporinos también constituyen presa favorita de varios carnívoros y aves rapaces; por consiguiente, muchos sitios arqueológicos pueden contener huesos de leporinos que han sido depositados debido a actividades tanto culturales como no culturales. El presente artículo proporciona datos para diferenciar agentes y procesos específicos que afectaron los huesos de estos animales en sitios arqueológicos. El comportamiento humano tiende a crear cilindros con las diáfisis de tibias de liebres, huesos con marcas de corte, fragmentos de huesos quemados no identificables, y conjuntos con predominio de leporinos adultos. Por el contrario, el comportamiento de las aves rapaces produce cilindros con las diáfisis de tibias de conejos americanos, huesos con perforaciones producidas por pico y garras, con cortes principalmente en la pelvis y el femur, y altas frecuencias de extremidades anteriores y huesos de individuos juveniles cuando los huesos son depositados principalmente en los residuos vomitados por aves rapaces.

Leporids (cottontails [*Sylvilagus*] and hares [*Lepus*]) are ubiquitous medium-sized mammals inhabiting different environments ranging from valley floors to high mountains throughout North America. A large body of literature documents the important role these animals played in Native American diets (Beals 1933; Du Bois 1935; Ebeling 1986; Forde 1931; Heizer and Elsasser 1980; Kelly 1932; Stevenson 1894; Steward 1933; Wheat 1967). Other leporid predators such as coyotes (*Canis latrans*), bobcats (*Lynx rufus*), and many species of raptors have been sympatric with humans in North America for at least 12,000 years (Haynes 1987), and, thus, it seems probable that non-cultural processes may have deposited leporid bones in the same sites that also contain archaeological bones. It would be a mistake for archaeologists to assume a priori that leporid bones were deposited solely by human activity at any particular site, yet taphonomic studies of small and particularly medium-sized mammal-bone assemblages lag behind actualistic studies on large faunal remains. Recent research on small to medium-sized mammals has nevertheless been closing the gap (Andrews 1990; Andrews and Nesbit Evans 1983; Brain 1981; Bramwell et al. 1987; Briuer 1977; Dansie 1984; Dodson and Wexlar 1979; Duke et al. 1975; Emslie 1988; Hockett 1989a; Hoffman 1988; Hoffman and Hays 1987; James 1986; Jones 1984a, 1984b; Korth 1979; Kusmer 1986, 1990; Livingston 1988; Maas 1985; Miller 1979; Payne 1983; Plug 1978; Pratt 1989; Raczynski and Ruprecht 1974; Schmitt 1988, 1990; Schmitt and Sharp 1990; Shaffer 1990; Yellen 1991).

This paper discusses some of the taphonomic traces that humans and raptors leave on leporid bones. These data are based on a review and synthesis of published data about the ways that leporid bones are modified and deposited in North American archaeological sites by raptors and humans, and are also derived from analysis of bones in raptor pellets from southern California and from

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Two Ledges, an active raptor roost in northwestern Nevada that contains over two thousand leporid bones. Integrating these data with studies on large faunal remains may lead to more reliable reconstructions of prehistoric human subsistence patterns and changes in those patterns over time (Stahl 1982).

HUMANS AFFECTING LEPORID BONES

Ethnographic studies clearly document the hunting and trapping of hares and cottontails by historic Native Americans (Chamberlin 1911; Osgood 1937; Radin 1916; Stevenson 1894; Steward 1938). Leporid bones may have been cut by stone tools during hide removal and/or stripping meat from the bones (Grayson 1988; James 1987a, 1987b), although small mammal bones are much less likely to be cut than large mammal bones during carcass processing (Jones 1983). Bone marrow was available by removing epiphyses of long bones and either sucking out the contents, or pushing marrow out of the diaphysis with a slender object such as a stick (Jones 1983, 1984a; Schmitt 1988, 1990). This behavior produces open-ended diaphysis cylinders with jagged or spirally fractured ends (Jones 1983; Schmitt 1988) (Figure 1a). Comparisons of tibia diaphysis cylinders from the Vista Site near Reno, Nevada, and those recently uncovered from cultural features in Warner Valley, Oregon (Hockett 1990a) reveal striking similarities. All of the leporid cylinders from these two sites are *Lepus* tibia diaphysis cylinders. Jones (1983) notes that as long bone cavity size increases, so does the likelihood of bones being broken open for marrow. In a leporid carcass, tibiae are larger than femora. Additionally, hare tibiae are much larger than cottontail tibiae. Thus, hare tibiae contain the greatest amounts of leporid bone marrow, which may account for the preponderance of hare tibia diaphysis cylinders in some archaeological sites in the Great Basin. In addition, hare tibia diaphysis cylinders are sometimes charred on proximal and/or distal ends, probably from cooking jackrabbits on hot coals prior to marrow extraction. Of the 14 hare tibia diaphysis cylinders recovered from cultural features in Warner Valley, four are charred on the proximal and distal ends of the bones, but they are not charred on the central diaphysis. Roasting leporid carcasses (Beaglehole 1937; Spier 1933; Stevenson 1894; Steward 1938) may therefore burn bones, and further processing behavior such as pounding or mashing meat and bones together with milling stones (after which bones may be discarded into the fire pit, [Jones 1983]), produces small, often unidentifiable burned bone fragments (Dansie 1984; Michelsen 1967). Finally, leporid tibia diaphysis cylinders may be further modified into beads or tubes, which also produces waste tubes with cut or sawed ends opposite jagged ends (Schmitt 1990).

Human hunters may kill predominantly adult leporids seasonally. Smith (1975) states that the harvesting of mainly adult leporids results from the low availability of juveniles during specific seasons of the year. Leporids have long breeding seasons but high juvenile mortality rates (Rue 1965; Sowls 1957), thus fewer young are available in the late fall and winter months because breeding diminishes and many young have fallen to predators. "Rabbit drives" conducted during the late fall and winter months (Lowie 1939; Steward 1938) probably resulted in the capture of many adult hares (interestingly, leporid drives also may have been conducted to fulfill social functions such as matchmaking in addition to satisfying subsistence requirements [Du Bois 1935; Steward 1933]). Hunting cottontails in the winter would also procure more adults than juveniles (James 1983), though rabbits were generally hunted individually rather than by organized drives (Ebeling 1986). Leporids also forage for longer periods of time during the long winter nights (Costa and Shoemaker 1976; Shoemaker et al. 1976), making them more susceptible to capture in traps and snares. Leporid hunting could have taken place in any season (Beaglehole 1936; Goddard 1916; Smith 1975), however, so caution must be exercised when determining seasonality of site occupation based on the presence of leporid bones. Nevertheless, a high percentage of adult leporid bones (particularly cottontail bones) probably suggests that a site may have been occupied during the fall and/or winter months (see James 1983).

Native Americans may have accumulated leporid bones more frequently in open-air sites than in caves and rockshelters. Larger, well-ventilated rockshelters and caves sometimes served as base or field camps (Aikens et al. 1977 [Dirty Shame Rockshelter, Oregon]; Thomas 1983b [Gatecliff

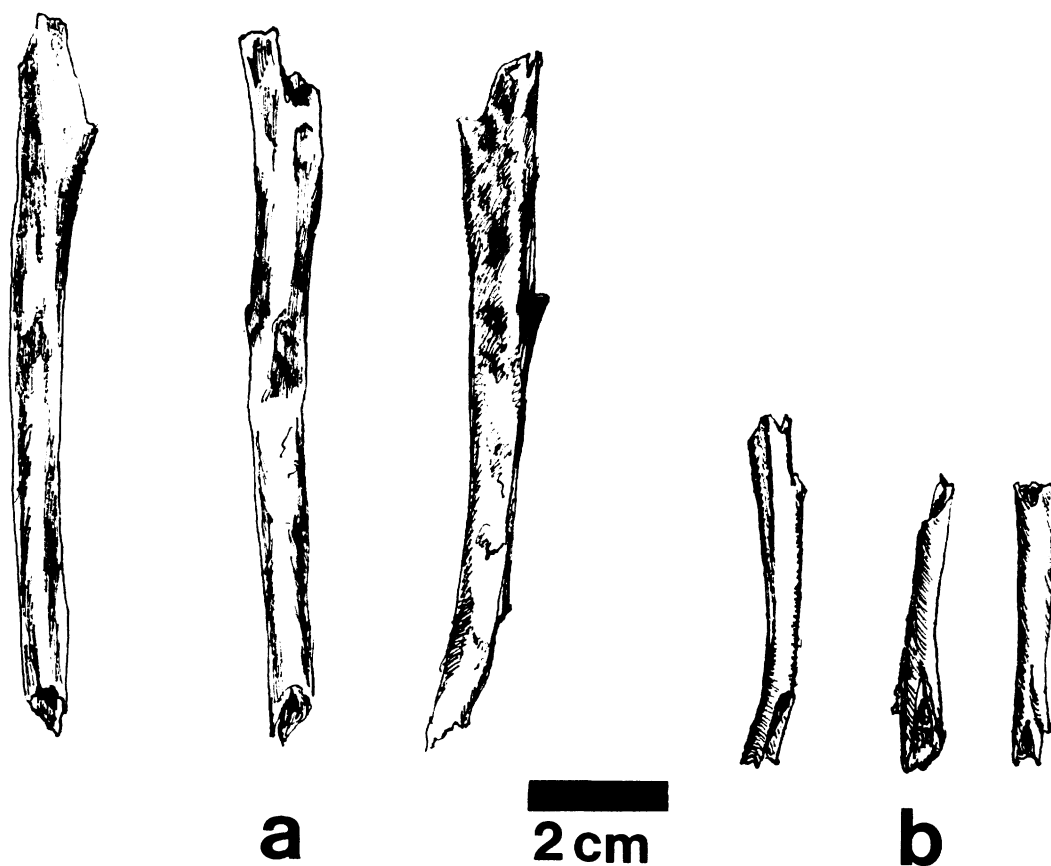


Figure 1. Tibia diaphysis cylinders from (a) the Vista site and (b) Two Ledges, Nevada.

Shelter, Nevada]; Thomas 1988 [Butler Ranch Cave and Triple T Shelter, Nevada]), but many North American cave sites were dusty, dirty, dark, and damp places that did not encourage the cooking and eating of animal resources (Heizer and Krieger 1956 [Humboldt Cave, Nevada]; Livingston 1988; Loud and Harrington 1929 [Lovelock Cave, Nevada]; Thomas 1985 [Hidden Cave, Nevada]). These latter sites were utilized as artifact caches, burial chambers, or short-term, temporary or diurnal stopovers (terminology from Thomas [1983a, 1988]).

RAPTORS AFFECTING LEPORID BONES

Raptors may break, "shear," and puncture leporid bones while dismembering and eating leporid carcasses (Anderson 1968; Guilday and Parmalee 1965; Hockett 1989a). Bones may be swallowed during feeding and later deposited in regurgitated pellets (Errington 1930, 1932; Errington and Breckenridge 1936). Pellet matter (dried hair, etc.) may adhere to bones long after deposition by raptors (James 1986; Parmalee 1970). Raptors' gastric juices may pit, scour, or polish bones (Mayhew 1977), but owls have weaker gastric fluids than do hawks or eagles, so bones in owl pellets are often less corroded than bones in pellets of other raptor families (Clarke 1972; Dodson and Wexlar 1979; Duke et al. 1975; Errington 1930; Fitch et al. 1946; Hoffman 1988). Leporid bones from owl pellets may however show corrosive damage, and they may be extremely polished as well. Polished and corroded leporid bones from owl pellets may be indistinguishable from similar bones often found in coyote scats (also see Hockett 1991).

As a part of research in Borderfield State Park, southern California (Hockett 1989a), I collected

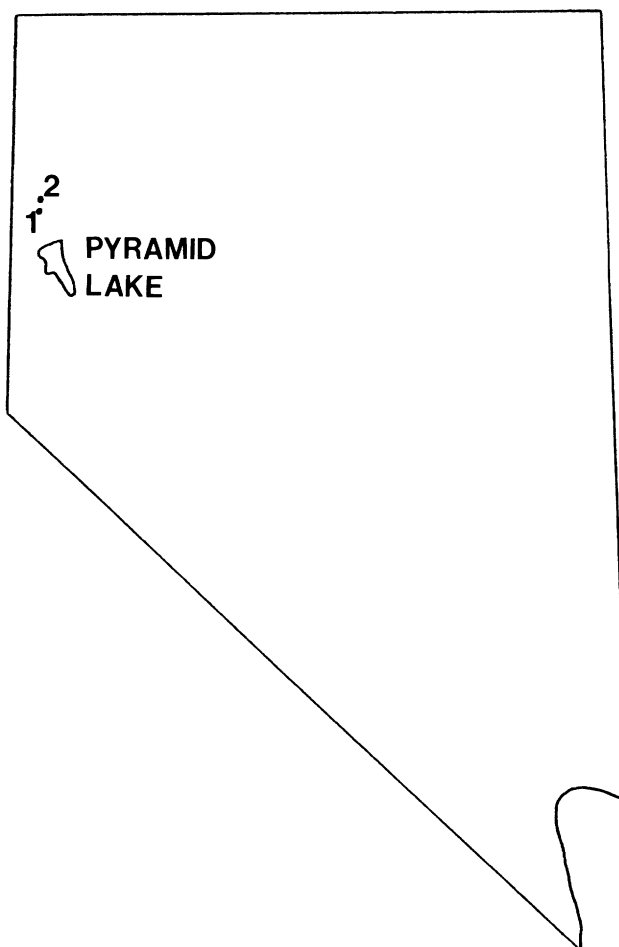


Figure 2. Location of (1) Two Ledges and (2) Whit Hugh Cave.

approximately 50 Northern harrier (*Circus cyaneus*) pellets, 10 of which contained leporid bones. The park is situated along the Pacific coast and consists of mixed marsh-flood plain-estuary habitats dominated by succulents and grasses. Blacktail jackrabbit (*Lepus californicus*) and brush rabbit (*Sylvilagus bachmani*) currently inhabit the park. Harrier pellets were found in open-air localities and under trees and fence posts. Leporid bones were extracted by pulling each dry pellet apart carefully by hand.

Pellets also were collected from an active raptor roost (Two Ledges) located in the Smoke Creek Desert, northwestern Nevada (Figure 2). Two Ledges is approximately 100 m north of Dryden Cave, a small rockshelter that contained numerous prehistoric artifacts and two human burials (Basin Research Associates 1986), and approximately 4 km south of Whit Hugh Cave. Vegetation in the area is typical of cattle-grazed Great Basin flora with greasewood (*Sarcobatus vermiculatus*) and sagebrush (*Artemisia tridentata*) dominating the landscape. Blacktail jackrabbit and Nuttall's cottontail (*Sylvilagus nuttalli*) currently live in the area (James 1986). The majority of leporid bones from Two Ledges had pellet matter in their notches and cavities, indicating that they were originally deposited in raptor pellets. Two Ledges contained 30 intact Barn Owl (*Tyto alba*) pellets, and 19,443 identifiable bones and teeth from weathered raptor pellets, including 2,401 leporid bones and teeth (Table 1). The majority of nonleporid bones belong to kangaroo rats (*Dipodomys* sp.) and various

Table 1. Leporid Bones in Raptor Pellets from Borderfield State Park, California, and Two Ledges, Nevada.

Element	Borderfield				Two Ledges			
	NISP ^a	MNE ^b	MAU ^c	Relative Frequency ^d	NISP	MNE	MAU	Relative Frequency
Humerus	13	13	6.5	100.0	184	90	45.0	100.0
Mandible	13	13	6.5	100.0	112	77	38.5	85.6
Scapula	11	11	5.5	84.6	79	75	37.5	83.3
Ulna	13	13	6.5	100.0	88	73	36.5	81.1
Radius	12	11	5.5	84.6	94	55	27.5	61.1
Calcaneus	0	0	0	0	55	55	27.5	61.1
Tibia	1	1	.5	7.7	148	46	23.0	51.1
Astragalus	0	0	0	0	44	44	22.0	48.9
Femur	1	1	.5	7.7	123	42	21.0	46.7
Innominate	1	1	.5	7.7	44	34	17.0	37.8
Sacrum	0	0	0	0	13	13	13.0	28.9
Maxilla	0	0	0	0	14	14	7.0	15.5
Vertebra	0	—	—	—	570	—	—	—
Phalange	0	—	—	—	233	—	—	—
Metapodial	0	—	—	—	206	—	—	—
Teeth	0	—	—	—	194	—	—	—
Unidentified	0	—	—	—	200	—	—	—
Totals ^e	65	64	6.5	—	2,401	618	45.0	—

^a NISP: number of identified specimens.

^b MNE: minimum number of elements.

^c MAU: minimum animal units (MNE/number of body parts for that particular element in a complete animal).

^d Relative frequencies give percentages of each element recovered from the number expected (if entire individual animals were deposited at the site) based on MAU counts. Relative frequency is calculated as follows: MAU for each element/MAU of all elements × 100.

^e MNE/NISP ratio for Borderfield: 98.5 percent; MNE/NISP ratio for Two Ledges (epiphyses taken out of NISP counts): 72.5 percent.

other small rodents such as mice. Interestingly, 1,635 scorpion parts are also present in the Two Ledges assemblage (Hockett 1990b).

Raptors other than barn owls (such as great-horned owls [*Bubo virginianus*] or red-tailed hawks [*Buteo jamaicensis*] [Alcorn 1942; Fitch 1940, 1947]) may also be responsible for accumulating leporid bones at Two Ledges. Raptor diet studies indicate that barn owls only occasionally hunt leporids, but their diet varies considerably between habitats, and includes young cottontails when these animals are available (Bond 1940; Bonnot 1928; Brain 1981; Cunningham 1960; Foster 1927; Hawbecker 1945; Herron et al. 1985; Marti 1974; Voous 1989; Wolfe and de la Torre 1990).

Two Ledges is significant because scant information is available regarding leporid bone patterning in raptor pellets (but see Brain 1981:Figure 129; also see Stiner 1990:Figure 35). Research suggests that raptors may swallow mice-sized carcasses whole (Dodson and Wexlar 1979; Duke et al. 1975; Hoffman 1988; Kusmer 1990), but leporids are simply too large for raptors to swallow whole. Leporid carcasses are systematically dismembered by raptors, and long bones must often be broken before being swallowed (young carcasses with small bones are an exception) (Brooks 1929; Errington 1932; Hockett 1989a). As a result, studies of mice-raptor interactions have little applicability to the taphonomic study of leporid bones in raptor pellets.

Borderfield and Two Ledges corroborate these data. All Borderfield leporid bones are derived from very young cottontails and consequently are mostly complete specimens (Table 2). Two Ledges leporid bones are principally juvenile *Sylvilagus* specimens (Table 3), and are fractured more ex-

Table 2. Leporid Long Bone Portions (NISP) from Borderfield State Park, California, and Two Ledges, Nevada.

Element Portion	Femur		Tibia		Humerus		Radius		Ulna	
	BF	TL	BF	TL	BF	TL	BF	TL	BF	TL
Complete	1	2	1	4	10	15	9	15	8	9
Proximal	0	40	0	42	0	50	2	40	5	64
Distal	0	35	0	32	3	75	0	32	0	3
Diaphysis	0	1	0	12	0	2	1	7	0	12
Proximal epiphysis	0	8	0	44	0	35	0	0	0	0
Distal epiphysis	0	37	0	14	0	7	0	0	0	0

Note: BF: Borderfield; TL: Two Ledges.

tensively than the bones from Borderfield (Table 2). The degree of bone fracturing can be quantified by comparing minimum number of elements (MNE) to number of identified specimens (NISP), and at Two Ledges this ratio is only 72.5 percent (Table 1). Two Ledges leporid bones range in size from 55 mm in length (including juvenile *Sylvilagus* long bones and adult *Lepus* innominates) to small fragments of bone measuring only 5 mm in length. Approximately 200 unidentifiable leporid-sized bones are present at Two Ledges and are similar in size to bones produced by humans pounding leporid carcasses with milling stones. No bones from Two Ledges are burned, but raptor pellets containing small leporid bones may nevertheless burn by natural fires igniting dry debris in caves, rockshelters, and open-air sites (Connor and Cannon 1990; Connor et al. 1989; Grayson 1988; James 1989).

Beak or talon punctures are present on only 11 bones from Two Ledges, including five innominates and four vertebrae. Four of the five punctures on innominates, however, are located behind the acetabular fossa (Figure 3), and occur on only one side of the bones (carnivore chewing often leaves marks on ventral and dorsal sides of bones). Iliia sometimes display shearing or scissoring-like damage (after Guilday and Parmalee 1965), and the greater trochanter of three femora are damaged (Hockett 1989a).

Ends of long bone fragments are generally undamaged at Two Ledges, but tibia diaphysis cylinders are present (Table 2, Figure 1b). All diaphysis cylinders from Two Ledges are *Sylvilagus tibiae*, and they all measure under 5.5 cm in length. In contrast, *Lepus* tibia diaphysis cylinders created by humans often average 9.5–10.5 cm in length (Figure 1a). *Sylvilagus* tibia diaphysis cylinders from

Table 3. *Sylvilagus* and *Lepus* Bones (NISP) from Two Ledges, Nevada.

Element	<i>Sylvilagus</i>	<i>Lepus</i>
Mandible	109	3
Maxilla	13	1
Innominate	33	11
Femur	107	16
Tibia	123	25
Sacrum	12	1
Humerus	164	20
Radius	86	8
Ulna	86	2
Scapula	73	6
Calcaneus	46	9
Astragalus	36	8
Totals	888	110
Percent of totals	90.2	9.8

Note: All Borderfield leporid bones are *Sylvilagus*.

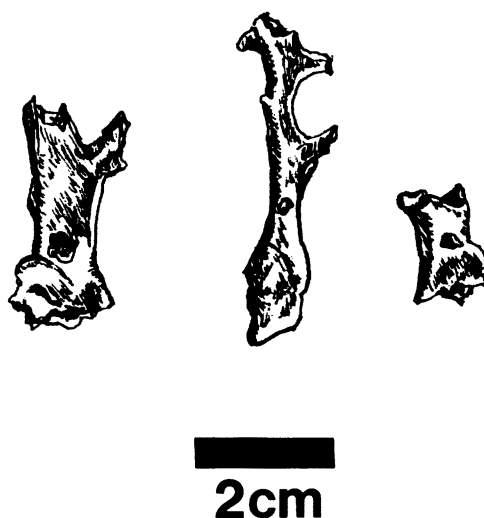


Figure 3. Raptor-damaged innominates from Two Ledges.

Two Ledges resemble unscored beads or tubes used by Native Americans in constructing necklaces more than they resemble human food waste. Although many Native American bone beads were constructed by the groove-and-snap technique, some necklace items were constructed by simply breaking the ends off of long bones, leaving jagged proximal and distal ends (see Hattori 1982). Further research presently being conducted on leporid bones from raptor nests will focus on whether or not raptors produce *Lepus* tibia diaphysis cylinders that resemble those from strong cultural contexts (such as those diagrammed in Figure 1a).

Leporid mandibles are common at Two Ledges and forelimb bones are more common than hindlimb bones (Table 1). High frequencies of leporid forelimb bones may be due to the greater size and robustness of the tibia and femur, which makes hindlimb bones harder to break and more difficult to swallow. Extensive fracturing may obscure the presence of hindlimb bones (Lyman and O'Brien 1987), but since ends of long bones are generally undamaged, this suggests fracturing occurred at the diaphysis (and occasionally bones were swallowed whole). Leporid forelimb bones also outnumber hindlimb bones in harrier pellets (Table 1), and the two recovered hindlimb bones are from a single pellet. Nine out of 10 harrier pellets therefore contained front limb bones only. Hindlimb bones may sometimes be regurgitated separately from forelimb bones, so further actualistic studies are necessary to corroborate this pattern as characteristic of raptor pellet accumulations.

Interestingly, *Sylvilagus* hindlimb bones outnumbered forelimb bones in six prehistoric sites in New Mexico (Driver 1985). Driver (1985) suggests that postdepositional processes may differentially destroy smaller cottontail forelimb bones, or perhaps they are easily missed during recovery of faunal material. Raptors may also cause this patterning by differentially swallowing forelimb bones, leaving high frequencies of hindlimb bones at kill or feeding sites.

Epiphyseal fusion of the proximal humeri and tibiae provides estimates of the number of year-old or older leporids (Driver 1985; Hale 1949; Sowls 1957). At Two Ledges, of the proximal humeri and tibiae, only 12.3 and 8.7 percent have closed epiphyses, respectively, corroborating previous age-structure studies of owl pellets (Burton 1973; Hammerstrom 1986; Herron et al. 1985; Kusmer 1986; Marti 1974). The size and strength of most owls limit the size and age of prey these raptors can capture (Hall 1927; Marti 1974), although great-horned owls and other raptors, such as ferruginous hawks (*Buteo regalis*) and golden eagles (*Aquila chrysaetos*), can kill adult leporids (Atkinson 1899; Eakle and Grubb 1986; McGahan 1968; Smith et al. 1981).

Raptors may sleep or rear young in caves and rockshelters (Bond 1940; Emmslie 1988; Leach 1929; Work and Wool 1942), and leave regurgitated pellets and leporid carcasses beneath roosts. Northern

harriers nest in bushes or in tall grasses on the ground, and harriers inhabiting marshes (which prehistorically also attracted humans) may feed on leporid carcasses in abandoned, open-air human-built structures (Hockett 1989a). Because many raptors utilize a perch-and-wait hunting technique (Ballam 1984; James 1984), any human structure built above-ground may be used as a perch and a place for raptors to eat their prey. Sugden (1928) notes that a Pueblo cliff dwelling in Utah contained a great-horned owl nest, and a woodrat (*Neotoma* sp.) midden containing bones.

SUMMARY AND DISCUSSION

Humans and raptors leave different traces on leporid bones. Specifically, humans may have deposited leporid bones in archaeological sites if (a) *Lepus* tibia diaphysis cylinders are present, some of which may possess cut, sawed, or charred ends; (b) many small, burned bone fragments are present; (c) cut marks made by stone tools are present; (d) high frequencies of adult specimens are present; and (e) artifacts indicative of a base or field camp (where abundant quantities of food were probably cooked and eaten) are present.

Raptors may have deposited leporid bones in archaeological sites if (a) there are low numbers of *Lepus* tibia diaphysis cylinders, and perhaps higher numbers of *Sylvilagus* tibia diaphysis cylinders, none of which have cut or sawed ends; (b) single or multiple beak or talon punctures are found on only one side of bones (and the innominates are often punctured directly behind the acetabular fossa), (c) shearing damage and damage to the greater trochanter of femora are present; (d) pellet matter adhering to bones is present; (e) a high frequency of juvenile leporids is found; (f) there is a relatively higher frequency of forelimb bones over hindlimb bones; and (g) artifacts indicative of a cache or very short-term stopover site are present.

Because each of the above traces can probably be produced by more than one agent or process, it is the *collective pattern* that points to human or raptor deposition of leporid bones. Many archaeological sites undoubtedly contain leporid bones affected by human and nonhuman activity, partly because raptors and humans both utilized similar areas to fulfill subsistence requirements, and partly because relatively slow rates of deposition of sediments can mix the remains of chronologically separate events (Payne 1983). These problems do not suggest that medium-sized fauna be ignored in favor of analysis of only large faunal remains, as has too often been done in the past. Remains of large fauna have similar problems, as the plethora of studies conducted on the Zinj floor fauna from Olduvai Gorge attests (Binford et al. 1988 and references therein). More importantly, small-to-medium-sized faunal remains conservatively constitute greater than 60 percent of the total number of bones recovered from many North American archaeological sites. This may mean that smaller fauna such as leporids and rodents were more important to the aboriginal diet on a day-to-day basis than were larger fauna such as deer. For example, Pertulla and Bruseth (1983) recently analyzed faunal remains recovered from trash middens at the Taddlock and Spoonbill sites in eastern Texas. Of the 63,463 bones recovered from the Taddlock site trash middens, over 80 percent of the total MNI for mammals was accounted for by small-to-medium-sized mammals such as cottontails, hares, and squirrels (Pertulla and Bruseth 1983).

Finally, in this paper I have focused on a specific aspect of a more general problem—distinguishing human and nonhuman patterning on leporid bones. Woodrats, carnivores (especially bobcats and coyotes), and natural deaths are other noncultural agents or processes that damage and accumulate leporid bones in archaeological sites. For example, carnivores may feed on, or defecate leporid remains in archaeological sites (Schmitt 1988). Woodrats collect scats, raptor pellets, and even raptor and carnivore-damaged bones (Heizer and Brooks 1965; Hockett 1989b, 1989c). Clearly, much additional research must be completed before we understand the range of variability of human, nonhuman, and mixed human–nonhuman leporid bone assemblages. This research may lead to a greater understanding of diachronic changes in prehistoric subsistence practices.

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