CHAPTER XI

WHY ARE ELK SO RARE IN THE ARCHAEOLOGICAL RECORD?

INTRODUCTION

At least six possible explanations can be advanced to account for the scarcity of elk in the archaeological record (Chapter 10). These include (1) Native Americans could not kill elk; (2) Native Americans chose not to kill elk; (3) elk were killed but their bones were not brought back to human habitation sites -- this can be posed as a transportation problem; (4) elk were killed and their bones transported to areas of human use (i.e., today's archaeological sites), but they did not survive the ravages of time -- this would be a differential preservation or taphonomic problem; (5) special elk processing sites exist, but have not been excavated by archaeologists, thus skewing the available archaeological record; or (6) elk were a plains animals and, hence, were not present in the mountains for Native Americans to hunt or kill. In this Chapter, I will discuss each of these hypotheses in turn.

NATIVE AMERICANS COULD NOT KILL ELK

Though often not explicitly stated, the idea that prehistoric humans lived a brutish existence underlies most out-of-hand dismissals of Native Americans as important ecological factors. Native Americans are invariably characterized as possessing a "primitive" technology which made killing large ungulates extremely difficult. Native Americans have been delegated to the role of poor, starving savages who had to spend most of their time just looking for something to eat (McCabe 1982:65, 87; McCabe and McCabe 1984:37, 39).

Unbeknown to most ecologists, anthropologists generally abandoned this stereotype of "primitive" people over 20 years ago with the publication of Lee's (1968) research on the !Kung and the subsequent Man the Hunter Conference (Lee and DeVore 1968). Lee demonstrated that the !Kung spent relatively little time in the quest for food despite living in one of the most inhospitable environments on earth. Lee showed that those "primitive" people had more leisure time than the average person living in today's "most advanced" western civilizations. Sahlins (1972) even went so far as to call hunter-gatherers "the original affluent society." While more recent studies have shown that Lee's original estimates for !Kung work effort were too low, nevertheless the !Kung and most other present-day hunter-gatherers who have been studied usually spend relatively less time provisioning themselves than modern man, though periods of scarcity may occur (Hawkes and O'Connell 1981, Hawkes et al. 1985, Hawkes 1987).

Unlike carnivorous predators which must physically encounter their prey and thereby risk injury at each predation event (Mech and Nelson 1990), humans kill at a distance. The short-range spear was superseded by the atlatl or spearthrower which had an effective range of about 23m (Grant 1980:20). The atlatl was replaced by the more efficient bow and arrow between 1,000 and 2,000 years ago (Grant 1980:22, Blitz 1988). This new weapon was an improvement over the atlatl for it killed at a longer range, was more accurate, achieved higher projectile velocities, and had superior penetrating power. In addition, arrows could be launched while the hunter remained crouched in his blind, whereas the atlatl had to be hurled from the standing position (Grant 1980).

The Shoshone who inhabited a large portion of the Intermountain West, including Yellowstone (Trenholm and Carley 1964, Hultkrantz 1974, Janetski 1987), made their bows out of wood, elk antler, or bighorn sheep horn (Catlin 1844a:32, Lewis and Clark 1893:560, Steward 1943:313). The most highly prized bows were made of bighorn sheep horn backed with sinew and took 2 months for a skilled specialist to produce (Dominick 1964:155). Those bows were so highly prized that a well made one could be traded for five or ten good horses (Dominick 1964:156).

In 1835, trapper Osborne Russell (1965:26-27) met a group of Shoshone in what is today Yellowstone Park. He observed that they were "well armed with bows and arrows pointed with obsidian. The bows were beautifully wrought from Sheep, Buffalo and Elk horns secured with Deer and Elk sinews and ornamented with porcupine quills and generally 3 feet long."

These bows were extremely powerful and could drive arrows completely through mature bison at ranges under 10m (Catlin 1844a:33, 212-213; Replogle 1956:72; Trenholm and Carley 1964:80; McHugh 1972:79-80; Pattie 1984:36). In 1834, Townsend (1978:55) observed a Native American shoot an arrow entirely through an antelope at a distance of 13m with so much force that the arrow "skimmed to a great distance over the plain" after passing out of the antelope.

Native Americans were highly skilled in the use of the bow and arrow (Kroeber 1961) and they could shoot 15 to 20 arrows a minute with great accuracy (Catlin 1844a:33). In many instances, even after Native Americans obtained firearms, they still used the bow and arrow for hunting (Ewers 1958:77, 84, 122, 141-142; Skimkin 1947:266; Russell 1965:36; McCabe 1982:75), reserving their guns for warfare (Lewis and Clark 1893:560).

Pope (1923:368-369) compared the penetration of arrowheads by shooting identical arrows with steel or obsidian points from the same bow at a deer-hide-covered box filled with bovine liver to simulate animal tissue without bone. To his surprise, Pope (1923:369) found that though the arrows were "identical in weight, feathering, and size of head, yet the steelheads, even when sharpened to a keen cutting edge, do not approach the penetration of obsidian by twenty-five percent." Pope (1923) also compared various bows for draw weight, arrow speed, and flight distance. He concluded that in general Native American bows were inferior to the English long-bow. However, Laubin and Laubin (1980) did not consider Pope's test of Native American bows to be fair, thorough, nor complete. Laubin and Laubin (1980) pointed out that Pope used bows from museum collections which were inferior because of their advanced age and improper storage.

Laubin and Laubin (1980) constructed bows using techniques and materials which were once common throughout North America. They found that the relatively short, 1-1.2m, sinew-backed bows of the Plains and Intermountain tribes were far superior to any bows developed in the history of world archery except for Turkish compound bows of 1450 to 1570 A.D. Laubin and Laubin (1980) concluded that the sinew glued to the back of the bow was the key to these bows' marvelous elasticity and limb speed which imparted high velocity to the arrows and enhanced the arrows' penetration power. A Native American equipped with such a bow and arrows could kill the largest of North American ungulates at distances approaching 50m or more. Native Americans certainly possessed the technology to kill all species, age classes, and condition classes of ungulates at will.

Under certain conditions, snow has been shown to enhance wolf predation (Mech et al. 1971, Peterson 1977, Gasaway et al. 1983, Mech 1984), but it has seldom been recognized that snow in general and in mountainous areas in particular also facilitated aboriginal predation. Snow restricts ungulate movements and makes them and their sign more visible. Throughout the Intermountain West and the Greater Yellowstone Ecosystem, snow forces ungulates to utilize restricted lower elevation winter ranges where they are more vulnerable to Native Americans especially those wearing snowshoes (Lewis and Clark 1893:623). Native Americans used snowshoes to hunt all ungulate species in winter (Murphy and Murphy 1960:310, Dominick 1964:152).

Native Americans on snowshoes killed white-tailed deer with clubs and hatchets or simply ran them to exhaustion in deep snow (McCabe and McCabe 1984:40, 48). Elk were easily killed in a similar manner (McCabe 1982:69, 76, 84, 85), as were bison (Catlin 1844a:253, plate 109; Catlin

1844b:139, plates 240, 243; Butler 1971a:10, 1978:111; McHugh 1972:62, 81; Miller 1972:74) and bighorn sheep (Skimkin 1947:268; Hultkrantz 1961:27, 1974:235). The Intermountain West experiences a differential accumulation of snow in that snow depth increases as one progresses from the valley floors up the adjacent mountains. Therefore, during winter, ungulates like elk could be chased or driven upslope into deeper and deeper snow where they could be easily caught and killed (Doane 1876:11) often with no more than a knife (Haines 1977:308) or club (Norris 1877:842). Snow also made it easier to trap large numbers of ungulates (Schroedl 1973:61; see below).

The olfactory capabilities of wolves and other animals are superior to those of humans and would seem to confer an advantage on carnivorous predators. However, Native Americans minimized this difference by utilizing dogs. Native Americans had domesticated dogs (Canis familiaris) for at least the last 11,000 years (Wright and Miller 1976:300, Wright et al. 1980). The remains of two dogs were unearthed at a 3,100-year-old archaeological site in Yellowstone Park (Wright et al. 1982). At Mummy Cave, 19 km east of the park, remains of dogs dated to 7000 BP (Harris 1978).

Native Americans used dogs to hunt game (Frison et al. 1986), for transportation, and in some instances for food (Lewis and Clark 1893). Even after they obtained the horse, most Native Americans still kept large numbers of dogs. For example, Catlin (1844a:40, 201) observed that each family or lodge had "at least 5 dogs." Native Americans trained their dogs to hunt all ungulate species including elk (McCabe 1982:76, 79, 80, 81). Dogs were also used in conjunction with snow to hunt game in winter (Dominick 1964).

The Shoshone used dogs to hunt bighorn sheep (Murphy and Murphy 1960:310). The dogs chased the bighorns over the cliffs and drove the sheep past hunters hidden in blinds (Barry 1932; Steward 1938:37, 1943:269; Hultkrantz 1970:249, 254, 1974:235) or into traps and corrals

(Dominick 1964:158-159). In 1835, Osborne Russell (1965:26) met a group of Shoshone in Yellowstone Park which consisted of 6 men, 7 women, 8-10 children, and about 30 dogs. In the Kalahari, one aboriginal hunter with a trained pack of dogs brought in 75% of the total meat obtained by one camp. Six other resident hunters who lacked hunting dogs accounted for the remaining 25% (Washburn and Lancaster 1968:294-295).

Carnivores are often depicted as having physical traits which are superior to humans, yet humans are remarkably versatile and durable and have a strong physical constitution. Only man can swim a mile, walk 20 miles, and then climb a tree (Laughlin 1968). The full list of man's physical superiorities must also include his ability to run long distances. Native Americans participated in races which covered up to 160 km in 24 hours. They ran down horses and deer by pacing the animal, keeping it moving, and taking advantage of the tendency of many ungulates to move in an arc by traversing the chord (Laughlin 1968). The tracking skills of Native Americans were highly refined (Lewis and Clark 1893, Townsend 1978). Kalahari Bushmen often track ungulates for days before they sight their prey (Lee 1968).

Humans can also carry very heavy loads for long distances. Man's sight is acute and includes detailed color vision which is not shared by his ungulate prey or other predators. The external integument of humans is remarkably tough (Laughlin 1968) and man has greater plasticity than any other species. No other animal lives at high and low altitudes, in extremely hot and extremely cold climates, and in all the combinations of humidity, light, and darkness that compose the panel of human habitats (Laughlin 1968). Of course, humans utilize a great array of cultural devices which enable them to persist in this wide latitude of ecological situations. Human culture, in all its many facets coupled with its great transferability, is an advantage which other predators cannot match with their physical skills.

The assets of speech and language combined with superior mental planning abilities enable human predators to realize a higher degree of communal hunting than is achieved by wolves or any other carnivores. Humans' superior coordination in both time and space is exemplified by their extensive use of communal drives, surrounds, traps, and jumps (Steward 1938, Forbis 1978). Game drives and traps require detailed knowledge of animal behavior and suitable topography for implementing the desired strategy. Once a driveway or trap was constructed, it could be used repeatedly over a period of years with only minor repair. As mentioned in Chapter 10 (above), Native Americans in the Greater Yellowstone Ecosystem also used large nets to capture ungulates for at least the last 9,000 years (Frison et al. 1986).

Native Americans used driveways and corrals to trap bighorn sheep (Steward 1938, 1943; Dominick 1964:157-158; Wright and Miller 1976:300; Grant 1980:9-10; see also Chapter 10) antelope (Steward 1938, 1943), mule deer (Steward 1938:360, Schroedl 1973:61, Keyser 1974), elk (Schroedl 1973:61; McCabe 1982:80, 82), and white-tailed deer (McCabe and McCabe 1984:48-49). Norris (1880b:605-606) reported that when he first visited Yellowstone Park there were extensive networks of brush driveways, traps, and corrals throughout the park. Norris (1880b:606) noted that one driveway on Yellowstone's winter range was "nearly two miles distant [long]."

Thus, a review of the available evidence suggests that Native Americans could kill elk. Aboriginal technology was more than sufficient to kill all ungulate species for the last 10,000 or so years (Frison 1978, 1987, 1989a, 1989b). As noted in Chapter 10 (above), bison remains occur two to three times more frequently in archaeological sites than those of elk. Since Native Americans could kill bison, there is no logical reason to assume that aboriginal peoples were physically unable to kill elk. Based on an analysis of elk behavior and Native American hunting techniques, Frison (1978:274) concluded that elk were "not difficult to hunt." In fact, he believes elk were one of the easiest ungulates for Native Americans to hunt and kill (G. Frison, pers. commun. 1989). There can be little doubt that prior to European contact, Native Americans possessed the physical, cultural, and social attributes to be effective predators of all ungulate species.

NATIVE AMERICANS CHOSE NOT TO KILL ELK

Optimal-foraging theory represents an attempt to develop a set of models general enough to apply to a broad range of animal species yet rigorous and precise enough to explain details of the behavior of each individual forager (Stephens and Krebs 1986). The theory assumes that foraging behavior evolved by natural selection to respond to changing conditions in a way which maximizes each forager's individual survival and reproductive success (Stephens and Krebs 1986). Optimal-foraging theory represents an attempt to specify a general set of decision rules for predators based on cost-benefit considerations which are in turn deducible from first principles of adaptation via natural selection (Stephens and Krebs 1986).

Originally developed and used by biologists to study non-human animals (Pyke et al. 1977, Stephens and Krebs 1986), optimal-foraging models have been applied by anthropologists to explain human foraging (Winterhalder 1981a, Smith 1983). Optimal-foraging models have been used to study a variety of hunter-gatherer societies (Smith 1979a, 1983), as well as to better understand the archaeological record (Yesner 1981, Simms 1984, Bettinger 1987).

Most foraging models assume that natural selection will select foragers which act to maximize their net rate of energy return per unit foraging time (Smith 1983). Moreover, Winterhalder (1987) demonstrated that an energy-maximization strategy can also minimize risk. Though anthropologists have applied optimal-foraging models of diet-breadth or prey-choice, patch-choice, time allocation, foraging-group size, and settlement patterns (Smith 1983), the diet breadth and patch choice models are most applicable to questions of ungulate exploitation. As noted by Smith (1983:628)

> The fine-grained diet-breadth model assumes, first, that a forager encounters available prey types "at random" -- that is, in the same relative proportions throughout the foraging area. . . . Second, total foraging time is partitioned into two mutually exclusive and exhaustive categories: search time (generalized over all prey types, in accordance with the random-encounter assumption), and handling times (the average time spent pursuing, capturing, processing, and consuming one item of each prey type once encountered). Thus, it is assumed that foragers search for all prey items simultaneously and that once a prey item has been encountered and the decision to pursue has been made the time spent handling it is unavailable for searching. Third, the forager is assumed to rank prey types along a single dimension of profitability, measured as net energy or food value obtained per unit handling time. . . . This fundamental trade-off between search costs and handling costs defines a unique and optimal set of prey types for any foraging system fitting the assumptions of the fine-grained diet-breadth model. For any particular situation, then, the optimal diet is achieved by "adding" prey types in descending rank order until the expected return (e.g., in calories) per unit foraging time is maximized.

A prey item will be in the optimal diet set if and only if its net energy return per unit handling time is greater than the average return (including search time) for all prey types of higher rank.

The prey-choice model generates the following testable predictions:

> First, as the availability of high-ranked prey types fluctuates, the optimal diet breadth shrinks or expands: increased availability should result in more specialized diets, while scarcity of high-ranked items favor a more generalized diet. . . . Second, prey types should be added to or dropped from the diet in rank order of handling efficiency, with low-ranked types moving in and out of the forager's "consumption mix" while the higher-ranked types are invariably pursued when encountered. Third, and least obvious, the inclusion of a prey type in the diet should depend only on the availability of higher-ranked prey types, not on its own availability. . . . high ranked types should be harvested even if they are rarely encountered, as long as the expected return from handling them is higher than the expected return if they are passed by in favor of different prey [Smith 1983:628]

Thus, the rank of a prey type predicts not how common it will be in a forager's diet but only whether or not it will be taken when encountered. To predict the number of prey harvested, the encounter rates of all prey types, as well as their rank orders must be known (Smith 1983). Moreover, the prey types with the highest handling efficiencies are the most susceptible to over-exploitation since they will always be taken when encountered, even at low densities. To the optimizing hunter, the decision to pursue a prey item will rest only on a consideration of the cost, benefits, and alternatives, not the long-term health of the prey population (Webster and Webster 1984:282).

In the patch-choice model or marginal-value theorem, food resources occur only in discreet patches and the foraging process gradually depletes the patch's resource level as a monotonic declining function (Smith 1983). Thus, the critical variable to be optimized is the point on the diminishing-returns curve at which the forager should depart for another patch (Smith 1983). Several predictions follow from this model:

> First, the optimal forager should leave any patch when it is depleted to the point where foraging elsewhere will yield higher returns per unit time (taking travel costs into account). Second, since optimal time allocation to any patch is a function of average yields for all utilized patches, as the overall productivity of a habitat (set of patches) rises less time should be spent in any one patch and conversely (declining productivity increases optimal patch-stay times). A similar prediction holds with changes in higher productivity and conversely. Finally, any patch not yet in the utilized set should not be added unless it can yield a marginal rate of return equal to or greater than the average rate for the utilized set [Smith 1983:631]

In both the prey-choice and patch-choice models, a calorie of any diet item is assumed to be equivalent to a calorie of any other diet item. Thus, to a hunter-gatherer, a calorie of ungulate flesh presumably has the same value as a calorie of vegetal foods. If a calorie of ungulate is worth more than a calorie of other diet items, this would effectively increase the ungulate's handling efficiency (Hill et al. 1987, Hill 1988). Similarly, if ungulates have additional non-food (Yesner 1981:165) or social value (Kaplan and Hill 1985b; Hawkes 1990, in press), that will also act to raise their handling efficiencies.

With the exceptions noted below, anthropologists who have employed optimal-foraging models to study hunter-gatherer societies have all concluded that in general those peoples foraged optimally (Bayham 1979; Perlman 1980; Hawkes and O'Connell 1981; O'Connell and Hawkes 1981, 1984; Winterhalder 1981b; Hawkes et al. 1982; Beckerman 1983; Hill and Hawkes 1983; Hill et al. 1984, 1987; Simms 1984; Kaplan and Hill 1985a, 1985b; Madsen 1986; Webster 1986). While some anthropologists still doubt the utility of applying optimal-foraging theory to humans, the evidence does not support that contention (Smith 1983). For the most part, hunter-gatherers appear to maximize their net rate of energy acquisition especially if the sexual division of labor is considered (Hill et al. 1987, Jochim 1988). Women gather mainly vegetal foods and small animals while men hunt larger animals (Hill et al. 1987). Except for certain types of communal hunts, the pursuit and capture of ungulates is almost exclusively a male-dominated activity.

In all studies conducted to date, large mammals or ungulates had the highest handling efficiencies of all diet items (Feit 1978, 1987; Perlman 1980:280; Winterhalder 1981b; Hawkes et al. 1982; Hill and Hawkes 1983; Smith 1983; Hill et al. 1984, 1987; Simms 1984; Webster and Webster 1984; Hawkes and O'Connell 1985:402; Madsen 1986:36; Webster 1983, 1985, 1986). Hawkes et al. (1982:389) reported handling efficiencies of 65,000 kcal/hr for collared peccary (<u>Pecari tajacu</u>) and 27,300 kcal/hr for white-tailed deer based on a small sample of Ache foraging. Using a larger data set, Hill et al. (1987:20) found that although earlier reported handling efficiencies were too high, only honey was higher ranked than deer among the Ache.

Winterhalder (1981b) reported handling efficiencies as high as 95,600 kcal/hr for Cree moose hunters. Working with Waswanipi Cree, Feit (1987) found that moose hunting was three times more efficient than beaver harvesting, six times more efficient than fishing, 10 times more efficient than waterfowling, and 15 times more efficient than small game hunting. Feit (1978:737) also noted that on an output/input ratio, moose hunting returned between 24 and 40 kcal for every kcal invested. Simms (1984:90-94) calculated that mule deer and bighorn sheep had handling efficiencies varying from 15,800 to 31,450 kcal/hr while most vegetal diet items only had handling efficiencies of 1,500 kcal/hr or less. Since all studies reported net acquisition rates ranging from 1,500 to 3,500 kcal/hr, it is clear that whenever an ungulate was encountered, it should have been pursued if the hunter were to maximize his net rate of energy capture.

Accounts of running down ungulates or the long distance pursuit of ungulates are common in the ethnohistoric literature (Anell 1969). There are numerous reports that Native Americans tracked individual ungulates for days (Spier 1938:29, Anell 1969). At first glance, this would appear to be a very inefficient subsistence strategy. Yet upon closer examination, the long-distance pursuit of ungulates most likely resulted in not only a positive energy balance but may also have been an optimal-foraging strategy.

Data on the approximate weights and energy yields of various Yellowstone ungulates are presented in Table 61. If the energy available per animal is divided by 2,000 or 3,000 kcal/hr, an estimate of how long an ungulate can be pursued before it is killed and still have a net acquisition rate greater than 2,000 or 3,000 kcal per hour is obtained (Table 62). Though the inclusion of butchering and transportation costs would lower these figures; nevertheless, Native Americans who chased individual ungulates for days still could have had higher net return rates than if they had chosen to pursue other possible diet items.

Ray (1932:82) noted that when Salish encountered an elk track while deer hunting, they would stop hunting for deer and follow the elk. Since on average, an elk is four times the size of a deer (Table 61), it could be followed for 70 to 110 hours and still yield a net return

Table 61. Approximate weights and caloric yields of various ungulate species.

Species	Live weight (kgs)[1]	Approximate food yield (kgs)	Percent edible weight	Energy per animal	
				1258 kcal/kg[2]	1800 kcal/kg[3]
Bison	627	425	68%	534,650	765,000
Deer[4]	75	52	70%	65,416	93,600
Elk	272	185	68%	232,730	333,000
Moose	502	345	69%	434,010	621,000
Antelope	48	31	65%	38,998	55,800
Bighorn	60	39	65%	49,062	70,200

1. Average for adults of both sexes $\geq$ 3 years of age adapted from McCabe 1982:89.
2. Simms (1984:89).
3. Christenson (1981:75)
4. Mule and white-tailed deer.

Table 62. Number of hours an individual animal could be pursued and still yield a net acquisition rate of 2,000 or 3,000 kcal per hour if killed at the end of that time period.

Species	Hours (Net = 2,000 kcal/hr)	Hours (Net = 3,000 kcal/hr)
Bison	267 - 382[1]	178 - 255
Moose	217 - 310	145 - 207
Elk	116 - 166	78 - 111
Deer	33 - 47	22 - 31
Bighorn	25 - 35	16 - 23
Antelope	20 - 28	13 - 19

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[1] Values correspond to the 1,258 kcal/kg and 1,800 kcal/kg columns respectively in Table 61.

rate of 3,000 kcal/hr if killed at the end of that period (Table 62). When moose were very rare, Koyukon hunters who encountered a moose track would follow it for days until they managed to overtake and kill the animal (Nelson 1983:165).

Hill et al. (1987:4) cautioned that optimal-foraging studies have not demonstrated that some other alternative foraging pattern would not produce higher net acquisition rates than those observed. For example, if some potentially high-return resources were ignored by the foragers, then their actual return rates would be lower than if they were trying to maximize their net rate of energy capture. Hill et al. (1987) reported that male Ache foragers, who always hunted and who seldom gathered vegetal foods, could have increased their net rate of energy acquisition by harvesting only vegetal resources which were freely available to them.

Hill (1988) found a similar pattern in Cuiva foragers of the Venezuelan savanna and in Yora foragers from Peru. Gould (1982), working with Australian Aborigines, noted that men devoted large amounts of time to hunting with very poor returns. Gould (1982:77) reported that women gathering mainly vegetative foods provided 95% of the band's total diet 90% of the time. The men spent as much or more time hunting as the women did in gathering edible plants, yet men provided less than 9% of the total diet.

Though these studies appear to invalidate the application of optimal-foraging models to hunter-gatherers, a closer examination reveals that the currency assumptions are in error. In maximizing the net rate of energy return, optimal-foraging models assume that a calorie of meat is equivalent to a calorie of plant foods. However, if a calorie of meat is worth more to foragers than a calorie of vegetal foods, then this apparent conflict is easily resolved (Hill 1988). Hill et al. (1987:16) postulated that a calorie of meat (protein and fat) is worth approximately three to four times more to Ache foragers than a calorie of plant foods (mainly carbohydrates).

Not only is meat an ideal source of protein (Abrams 1980, 1987) but animal fats may be of critical importance (Speth 1983, 1987; Speth and Spielmann 1983). Anecdotal support for the importance of lipids can be found in statements about the desirability of fat animals which have universally been expressed by hunter-gatherers (Jochim 1976:19-24; Hayden 1981:394-398; Hawkes et al. 1982; Werner 1983:233-234; Hill et al. 1984, 1987; Abrams 1987; Good 1987; Johnson and Baksh 1987). There also appear to be valid physiological reasons why animal fats are universally preferred by hunter-gatherers and other humans (Hayden 1981:395, Speth and Spielmann 1983, Abrams 1987, Lieberman 1987). Meat is so highly desired by some societies that its low availability often intensifies social disharmony (Baksh 1985, Good 1987).

Adding this nutrient constraint to optimal-foraging models (Smith 1983) improves their predictive power (Hill et al. 1987, Hill 1988). Speth (1983:146-159) noted that people select fat animals because of nutritional considerations. Humans cannot survive on a diet which consists solely of lean meat. A diet of lean meat which is not supplemented with carbohydrates or fat will lead to nutritional disorders and eventually death. This would predispose Native Americans to select for the fattest ungulates. Under certain circumstances, aboriginal hunters abandoned animals which were found to lack fat after being killed. Speth (1983:147) reported that the Australian Pitjandjara

> . . . immediately (upon killing an animal) feel the body for evidence of the presence of caul fat. If the animal is _njuka_ or fatless, it is usually left, unless they are themselves starving.

Obtaining prime hides was also an important consideration to Native Americans since their clothing was fashioned almost entirely from skins (Gramly 1977, 1979; Turner and Santley 1979; Webster 1979; McCabe and McCabe 1984:27). Gramly (1977) argued that deer skins were more valuable to the Huron than deer meat. Turner and Santley (1979) supported Gramly's contention while Webster (1979) concluded that Hurons hunted white-tailed deer despite a "considerable energetic loss" solely for their hides. (But see Trigger 1981 and Webster's 1981 reply.) Keene (1981:186) noted that deer hides were a critical resource to Native Americans living in Michigan. Webster (1983:154, 356) postulated that Iroquoian hunters were subsidized by agricultural provisions in their quest for deer hides.

Yesner (1981:165) was not the first to report that successful hunters were accorded special social status. He noted that "social value" is often offered as the reason why peoples placed emphasis on hunting of ungulates even when those species were at low densities. Kaplan and Hill (1985b) translated this unmeasurable "social value" into reproductive fitness when they demonstrated that among Ache the most successful hunters had greater reproductive success than men with lower hunting abilities. Hawkes (1990) used game theory to show that as long as hunters obtained some paternity through extra-marital consorts, high variance in daily income from hunting was important enough to make it the best strategy for men (at least part of the time) even if their mean rates of return were lower than the alternative low-risk option of gathering vegetal foods. Hawkes (in press) expanded upon this idea and concluded that "under some circumstances, men may choose risky endeavors [hunting large mammals], not in spite of, but partly because of the gamble gives them the chance to claim favors they can win by showing off."

Thus, not only do ungulates have higher-ranked, energy-based handling efficiencies than most other diet items, but they are also valued because of their high fat content, hides, and for other social considerations. These additional currencies and any reproductive advantages which superior hunters may enjoy have the effect of increasing ungulate handling efficiencies. This makes ungulates even more profitable to pursue and puts additional harvest pressure on them even at low populations.

Native American's pursuit of ungulates apparently followed a prey-choice not a patch-choice optimal-foraging model. Most aboriginal campsites were located primarily near vegetal foods (Jochim 1976:53-54, 1981:153; Wright 1984a), but even when species are more or less isolated in distinct habitat patches, a hunter radiating out from a base camp would have to pass through an array of habitats to reach the one he intended to hunt. In the Intermountain West, many ungulate species share the same habitat with smaller prey items. Thus, if a hunter set out to hunt small mammals, in all likelihood he would have to pass through the habitat of some ungulate species. If by chance he then encountered an ungulate, he could forego his intended small mammal hunt and pursue the ungulate, depending on the circumstances.

Ray (1932:82) noted that among the Sanpoil and Nespelem,

> . . . it is doubtful that expeditions for the specific purpose of hunting elk were often organized [because the elk population was so low, but] Deer hunters took full advantage of any opportunity to secure elk; the quest for deer was forsaken when these larger animals were sighted.

Winterhalder (1981b:91) reported that during winter when moose were usually confined to patches of preferred habitat, Cree hunters searched interstices for moose tracks. This strategy not only reduced search costs but also changed a patch-choice problem into more of a prey-choice situation. Yesner (1981:162) found that Aleut utilized a "coharvesting" exploitation strategy whereby hunters who set out after one species would take other species if they were encountered and if those "alternative" prey items were highly ranked, again depending on the circumstances of the encounter.

Contrary to the notion that Native American diets were primarily red meat (McCabe and McCabe 1984:28), anthropologists have long noted that those peoples should more appropriately be called gatherer-hunters since, except for the Arctic Eskimos and perhaps the Plains tribes, vegetal foods or fish made up to 60 to 90% of their diets (Lee 1968, 1979, 1984). However, Native Americans preferred to eat meat when it was available (Webster 1985:44). Vegetal foods were a poor second choice even though they may be highly nutritious (Woodburn 1968:52, Cohen 1977, Gould 1982:77, Nelson 1982b:213).

Native Americans in the Greater Yellowstone Ecosystem utilized fish, berries, small game, roots (Dominick 1964:161; Hultkrantz 1974:223, 234; Janetski 1987), and camas (Wright 1984a). As discussed in Chapter 10 (above), Wright (1984a) concluded that the aboriginal people who inhabited Jackson Hole for the last 10,000 or so years subsisted mainly on vegetal foods. The Nez Perce were heavily dependent on salmon fishing and on local, seasonally available plant resources (Lewis and Clark 1893, Schroedl 1973:63). All the tribes along the Columbia River in Washington and Oregon made extensive use of salmon and roots (Lewis and Clark 1893, Townsend 1978, Hunn and French 1981). Even Paleo-Indians 9000 BP in Wyoming's Bighorn Basin made wide use of small mammals (Frison 1978:298). By prey-switching to a diet of fish or vegetal foods, Native American populations could be maintained or continue to grow despite the increasing scarcity of their preferred ungulate foods (Woodburn 1968:52, Smith 1975) and the diminishing returns of the hunt.

Since vegetal foods and small mammals are lower-ranked diet items than ungulates, the high relative abundance of those foods in prehistoric diets would strongly indicate that few ungulates were available to those people (Bayham 1979, Smith 1983, Simms 1984). Based on optimal-foraging models and the data discussed above, it is difficult to believe that aboriginal peoples in Yellowstone and Jackson Hole chose to subsist on roots and other low-ranked vegetal foods at the same time 15-20,000 elk supposedly roamed each of those areas. Furthermore, as discussed in Chapter 10 (above), most of the bone recovered from Intermountain archaeological sites is highly fragmented which is indicative of bone grease processing and nutritive stress in the aboriginal population. In such situations, it is difficult to imagine that those peoples chose not to kill elk.

On Yellowstone's northern winter range, elk presently occur at densities of 20 to 40 animals per km^2. If, as assumed by the Park Service, similar densities were common in prehistoric times, optimal-foraging models would predict that those peoples' diet should have been nearly 100% elk. Since that was not the case (see above and Chapter 10 herein), it can only mean that few elk were actually available to the aboriginal peoples who inhabited the Greater Yellowstone Ecosystem.

Moreover, in order to obtain the ungulate species ratios which exist in Yellowstone's archaeological sites (Table 57-59) from the relative abundances of ungulates found in the Greater Yellowstone Ecosystem today (Tables 55 and 56), deer would have had to be selected over elk by a factor of 136, while for bighorn sheep the selection factor would have had to be 533. On the Clarks Fork of the Yellowstone (Table 59), the selection factors for deer and bighorn sheep over elk would have had to be 482 and 133, respectively, while on the North Fork of the Shoshone the selection factors would have had to be 47 for deer and 390 for bighorn sheep. Clearly, there is no evidence to support the notion that elk bones are rare in Yellowstone and Intermountain archaeological sites because Native Americans chose not to kill elk. In fact, elk were a highly preferred diet item wherever they occurred. For instance, Lewis and Clark (1893:725-794) reported that elk were highly prized by Native Americans as a supplement to their regular diets of fish and vegetal foods.

A TRANSPORTATION PROBLEM

This hypothesis assumes that Native Americans killed elk, but did not bring bones from those animals back to human habitation sites (i.e., today's archaeological sites). White (1952, 1953a, 1953b, 1954) was one of the first archaeologists to note that the bones of any one ungulate species found in archaeological sites did not match the proportion of bones in the live animal. That is to say, certain bones appeared in archaeological sites less frequently than would be expected if the entire ungulate had been brought to the site. White (1952, 1953a, 1953b, 1954) noted that, in general, "anatomical parts with comparatively large amounts of meat (e.g. femurs) are more likely to be transported than those with comparatively small amounts of meat (e.g. feet)" (Metcalfe and Jones 1988). "This phenomenon was later formalized as the 'Schlepp Effect,' defined as 'the larger the animal killed and the farther from the point of consumption it is killed, the fewer of its bones will be schlepped back to camp, village or other area'" (Lyman 1987a:255).

Based on his work with Nunamiut hunters, Binford (1978) proposed a series of utility indices based on the amount of meat attached to various bones, as well as their marrow content. From his field work and experimental studies, Binford (1978:44, 459) noted:

> . . . [1] The greater the distance over which meat is to be transported, per unit of time, the more radical will be the culling of low-utility anatomical parts along the transport route. . . .
>
> [2] The greater the bulk of material to be transported, per unit of time, the more radical will be the culling of low-utility anatomical parts along the logistical route . . .
>
> [3] Under conditions of game scarcity when search and pursuit time would necessarily be high, we would expect maximizing to take the form of maximum utilization of available food regardless of labor costs in transport and processing. . . .
>
> [4] Under conditions of game abundance or increased subsistence security, with accompanying decreases in search and pursuit time, we would expect maximizing to shift increasingly to labor considerations with an increasing convergence between utilization frequencies and anatomical scales of utility as presented.

When faced with carrying portions of a large ungulate back to a distant campsite, aboriginal hunters would tend to leave behind the lower-quality bones in favor of transporting meat (Binford 1978, 1981). Others have used Binford's utility indices to study bone frequencies in archaeological sites (Speth 1983; Thomas 1983, 1985; Grayson 1984, 1988, 1989a; Lyman 1984, 1987b; Galm and Matsen 1985; Frison and Todd 1987;

Borrero 1988; Galm and Lyman 1988). Recently, Metcalfe and Jones (1988) and Jones and Metcalfe (1988) demonstrated that Binford's utility indices are "needlessly complex" and proposed a simplified food-utility index which scaled the amount of meat, marrow, and bone grease associated with different body parts.

More importantly, Jones and Metcalfe (1988) reported that the use of high-ranked and low-ranked body parts followed predictions derived from optimal-foraging models. They (pp. 420-421) concluded:

> An important prediction of the diet model is that when the availability of high ranking food items (i.e. those with higher kcal/h values) decreases (as in food shortages), the diet will expand, including lower ranking items in order of their rank. For the Nunamiut, this would mean that when "food is short" the next part added to those processed for marrow would be the mandible, followed by the pelvis, scapula and then the phalanges. Conversely, when times were good, the list would contract in reverse order: the metacarpal would be the first dropped from the present diet.
>
> The relative nutritional value of phalanges and other distal marrow bones is expected to increase as the nutritional state of the animal worsens (Turner, 1979). Thus, when "food is short" and the animals available are in good nutritional condition, the mandible, pelvis and scapula are likely to be processed before the phalanges. If, however, the animals are in a poor nutritional state, phalanges may contain the last reserves of the animal's marrow and hence may be more nutritionally valuable than other parts.

O'Connell et al. (1988:113) studied Hadza "patterns of medium/large mammal [ungulates] carcass dismemberment and transport from kill sites to base camps." They (p. 113) concluded that "body part transport patterns are highly variable, but they probably are understandable in terms of the goal of maximizing net nutritional benefit relative to the costs of field processing and transport." Jones and Madsen (1989) demonstrated that including transportation costs improved the predictive power of optimal-foraging models and predicted how far human foragers would have transported various resources.

Notwithstanding these considerations, it is unlikely that transportation costs excluded elk from archaeological deposits in the Greater Yellowstone Ecosystem and throughout the Intermountain West for at least three reasons. First, many archaeological sites are found in close proximity to known ungulate wintering areas such that the "ditching" of bones would probably not have been an overriding consideration. Second, as discussed in Chapter 10 (above), bison bones outnumber elk bones in archaeological sites. Since bison are nearly twice as large as elk, aboriginal hunters would probably not have "ditched" elk bones but brought bones back from bison kills. Finally, studies of modern hunter-gatherers (O'Connell et al. 1988, 1990) have shown that only the largest bull elk are within the size class of animals from which aboriginal hunters commonly fail to transport bones to habitation sites.

Native Americans used specific bones for tools. Those bones may be overrepresented at archaeological sites since aboriginal peoples not only actively selected those bones but also transported them long distances (Read 1971). As discussed in Chapter 10 (above), many occurrences of elk in Intermountain archaeological sites are represented by elk antler fragments or tools. For instance, 134 elk antler tines were recovered from Idaho's Bobcat Cave, yet not a single other elk bone was discovered. Similarly in Utah, the Old Woman site contained elk antler fragments but an absence of other elk bones, suggesting that the occupants found the antlers elsewhere and transported them to the site because of their tool value.

DIFFERENTIAL PRESERVATION OR A TAPHONOMIC PROBLEM

This hypothesis assumes that Native Americans killed elk and brought their bones back to human habitation sites, but for some reason, elk bones were more susceptible to the ravages of time than the same bones from other ungulates. The study of the formation of the fossil record is called taphonomy (Brain 1981). "Taphonomy is a geobiological historical method of study of the transition, in all details, of animal organics from the biosphere into the lithosphere; it's the science of the laws of burial" (Lyman 1982a). Taphonomy is also an important consideration in understanding archaeological bone deposits (Frison 1978, Brain 1981). Loss of material occurs between the butchering or consumption of the animal and the incorporation of residual bone debris into the archaeological deposit.

Factors affecting the incorporation of bones into archeological sites include (1) consumption of fresh meat beyond the limits of the site, and "ditching" of low-quality bones (see above); (2) the use of bone as raw materials to manufacture tools (see above); (3) the consumption and removal of bones by dogs or other scavengers (Lyon 1970, Payne 1972, Kent 1981, Haynes 1982, D'andrea and Gotthardt 1984, McCabe and McCabe 1984:29, Garvin 1988); (4) trampling damage (Olsen and Shipman 1988); and (5) weathering of exposed bone (Lyman and Fox 1989). Once covered by sediment, little selective alteration of bone deposits normally occurs (Uerpmann 1973).

Based on extensive experimentation and bone measurements, Miller (1972), Payne (1972), Binford and Bertram (1977), Binford (1981), Brain (1981), Lyman (1982b, 1984, 1985, 1987a, 1987b), and Stahl (1982), reached the following general conclusions regarding bone survivorship. Dense bones survive better than light bones, bones of large animals generally survive better than the same bones of smaller animals, and bones of older animals have a higher probability of survival than the same bones from younger individuals. Lyman (1985) and Grayson (1989b) also found that bone utility indices (see above) and bone density survivorships are similar and suggested that differential destruction was more important than considerations of human transport.

The hypothesis that differential preservation of bones brought to sites may somehow explain the scarcity of elk in archaeological contexts is not supported by the available evidence. Since large, dense bones preserve better than small light bones, differential preservation should favor elk bones over those from mule deer or bighorn sheep, the exact opposite of the species-abundance patterns observed at archaeological sites in the Greater Yellowstone Ecosystem and throughout the Intermountain West. Thus, it is unlikely that elk would be underrepresented in the archaeological record because of this factor.

ELK PROCESSING SITES HAVE BEEN OVERLOOKED

Even though special elk processing sites could exist but have not been excavated or found by archaeologists, the large number of habitation sites which have been excavated in the western U.S. strongly suggests that this cannot account for the observed pattern. Furthermore, since many types of archaeological sites, from temporary camps, to kill sites, to base camps, and permanent villages, have been unearthed (see Chapter 10 above), it is doubtful that there would have been a bias against elk processing sites even if the latter existed. As discussed in Chapter 10, Wright (1984a, 1984b) searched known elk summering and wintering areas in Jackson Hole and either found an absence of archaeological sites or an absence of elk bones in the archaeological sites which were discovered. An identical pattern was also observed for archaeological sites in Oregon and Idaho (see Chapter 10 above).

Only one archaeological site reviewed during the course of this study was identified as an elk processing site by investigators. That was the Joe Miller (48AB19) site in south-central Wyoming situated at the north end of the Medicine Bow Mountains (see Chapter 10 above, Creasman et al. 1982). However, only a small proportion of that site was excavated and only a handful of elk bones were actually uncovered (MNI = 2, NISP = 17, see Tables 68 and 69 in Appendix D). Until more of those deposits are excavated, it is impossible to know if that feature actually contains the remains of a larger number of elk.

Finally, in addition to the 500 or so archaeological sites which I reviewed in Chapter 10, thousands of other sites have been identified throughout the Intermountain West, and of that number, several hundred have been test excavated only to yield no identifiable faunal remains. An even larger number have been ravaged by amateur collectors. Despite this effort, no additional elk processing sites are known or suspected by the archaeologists I interviewed during the course of this study (see Chapter 2 above). Thus, it is extremely unlikely that this factor has biased the available archaeological record to any significant extent.

ELK WERE A PLAINS ANIMAL

Frison (1978) and Wright (1984a, 1984b) believed that elk were originally a plains animal which were driven into the mountains by advancing European civilization. If true, this would violate one of the major assumptions of the Park Service's "natural regulation" paradigm that large numbers of elk always wintered in Yellowstone (see Chapter 1 above). Others maintain that elk were found historically both on the plains and in the mountains and that settlement did not push elk into the mountains, but rather the herds on the plains were exterminated while those in the mountains were better able to survive (Koch 1941, Bryant and Maser 1982:23). Yet this does not explain why elk were rare in the mountains when they appear to be better adapted to that niche than either mule deer or bighorn sheep which dominate archaeological ungulate faunal remains.

Numerous studies conducted throughout the Intermountain West have repeatedly documented that on mountain winter ranges, elk outcompete and dominate mule deer and bighorn sheep (Case 1938; Cliff 1939; Cowan 1947, 1950; Flook 1964; Mackie 1970, 1981; Stelfox 1971, 1976; Compton 1975; Olmsted 1979; Wydeven 1979; Nelson 1982a; Wydeven and Dahleren 1985; Mower and Smith 1989). Elk have a larger diet breadth than mule deer or bighorn sheep (Kufeld 1973, Nelson and Leege 1982, Collins and Urness 1983, Jenkins and Wright 1988) and elk can digest their diets more efficiently than can mule deer (Nelson and Leege 1982, Baker and Hansen

1985). Elk can also digest the diets of mule deer more effectively than can mule deer (Collins and Urness 1983). Because elk have a larger-mass-to-surface area ratio than either mule deer or bighorn sheep, they are better able to withstand cold temperatures and high winds (Moen and Jacobsen 1974, Beall 1976, Grace and Easterbee 1979, Moen 1982).

Furthermore, because of their larger size, elk are better able to cope with deep snow than either mule deer or bighorn sheep (Telfer and Kelsall 1984, Dailey and Hobbs 1989). Elk expend less energy moving through a given depth of snow than mule deer or bighorn sheep (Parker et al. 1984, Dailey and Hobbs 1989). Besides, if elk do so well in the Greater Yellowstone Ecosystem today, why were they not there in the past, especially since elk are superior competitors over either mule deer or bighorn sheep which dominate archaeological faunal remains? Since a few elk were present in the Greater Yellowstone for the last several thousand years, what kept the elk population from expanding? It certainly was not interspecific competition. Thus, Frison's (1978) and Wright's (1984a) hypothesis that elk were not present in the mountains simply because they were a plains animal is not supported by available ecological data.

CONCLUSIONS

If large numbers of elk inhabited the Greater Yellowstone Ecosystem for the last several thousand years as assumed by the Park Service, then those animals should have been killed and transported to habitation sites in equally large numbers by Native Americans. Elk bones should have accumulated in those sites and elk should dominate the archaeological ungulate faunal remains. That this clearly is not the case can only mean that large numbers of resource-limited elk did not inhabit the Greater Yellowstone Ecosystem until the onset of European influences. The Park Service's contention that finding a few prehistoric elk bones in the park implies that thousands of resource-limited elk inhabited Yellowstone for the past several thousand years is not supported by the evidence. That position is simply not defensible.