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# A Reflection on the Application of Archaeology to the Understanding of the History and Ecology of Holocene Bison in the Greater Yellowstone Ecosystem

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## Introduction

The North American bison (*Bison bison*) has aroused the curiosity of scientists and the public for many years. Steeped in myth and legend, the North American bison, or buffalo, was nearly exterminated in the late nineteenth century (Geist 1996). Its demise occurred before its role as a member of North America's native fauna could be fully understood (Hornaday 2002 [originally published in 1889]). Numerous studies of bison (e.g., McHugh 1972) and compilations of the state of knowledge (e.g., Roe 1972) have been produced throughout the past century. Over thirty years ago, Arthur (1985) published a bibliography of bison studies in which he cited 2,521 scientific publications on topics related to ecology, foraging, and prehistory. The last two decades have witnessed a renewed interest in the study of the North American bison and an assessment of the state of our knowledge (e.g., Franke 2005; Irby and Knight 1997). These studies have ranged from the conservation (Berger and Cunningham 1994; Forgacs et al. 2016) and management on public lands (Gates and Broberg 2011) to bison's role in the economy of post-glacial peoples (Speth 2017), and the indigenous-led movement of restoring bison to tribal lands (Schmidt 2019). A major impetus for this renewed interest is the scientific, political, and management challenges large mammal populations present (Berger et al. 2006; Cawley 1993; NPS 1999; Sellars 1997).

The cultural and ecological role of bison in the pre-Euro-American settlement of the Greater Yellowstone Ecosystem (GYE) has been debated for decades by biologists, historians, and archaeologists. However, we do know that bison have been members of the regional ecosystem for more than 10,000 years. Despite this long-term presence, knowledge of their ecology has largely been gained through the study of modern herds who have been subjected to various management practices for over a century. In this chapter we will discuss how the archaeological record can be an important tool in filling in the gaps of our knowledge of bison in the GYE and its potential application to a more informed management of this iconic species.

At a fundamental level, this research follows Gleason's (1926) hypothesis that individual species react to environmental perturbations based upon their individual tolerances and behavior, a hypothesis that has been supported by Quaternary mammalian patterns (FAUNMAP Working Group 1996). More recently, Grayson (2008) has emphasized the importance of "Gleasonian individualism" by arguing that in order to build explicit models of past ecosystems, we must first build detailed life history models of individual species, particularly those that have either been extirpated from their former ranges or those that have become extinct. In the broadest sense, this is the traditional goal of biogeography, to study the distribution of species, both past and present (Brown and Gibson 1983). However, the research focus of biogeographers has expanded to include all aspects of an individual's life history within the context of contemporary issues, wildland management, and climate change (e.g., Grayson 2005).

A number of contemporary social, economic, and ecological factors also have focused attention on public herds in the United States (e.g., Gogan et al. 2001) and in the Canadian Provinces (e.g., Gates et al. 2001). Specifically, increased herd size on public lands has caused range expansion, potentially placing bison into close proximity with cattle. While bison and cattle interaction may not seem problematic, the potential for the transmission of the bacterium *Brucella abortus* (often referred to in the literature more generically as brucellosis), an infectious microorganism that can cause abortions in ruminants (Baskin 1998), could have widespread economic consequences for the cattle industry (Newby et al. 2003). Human exposure to the bacterium can cause various symptoms of "undulant fever" (Corbel 2006). The disease was initially detected in Yellowstone National Park (YNP) bison in 1917 and has been present ever since (NRC 1998). Management and eradication of the disease in the YNP herd has been a concern since the 1930s (Franke 2005), and the efforts have cost billions of dollars (McMillion 2006). A consequence of this disease has been the annual winter vigilance of the YNP boundaries for bison migration into Montana. Once they cross the invisible border they are met by an array of well-intentioned individuals, with a series of sometimes conflicting solutions that range from chasing bison back into YNP to controlled hunting and roundup for butchering (Franke 2005).

When the harsh winter of 1996–1997 forced bison to leave the park in record numbers in search of forage, national attention was focused on the fate and management of Yellowstone's bison (Peacock 1997). In response to the public discussion, then Secretary of Interior Bruce Babbitt asked the National Academy of Sciences to undertake a 6-month study of brucellosis in the GYE (NRC 1998:1). It was about this same time (fall of 1995) that the Yellowstone Center for Resources contacted the National Biological Service to discuss information needs relative to the ecology of Yellowstone bison (Gogan et al. 2001). Two initial studies were implemented in 1996 (Dawes 1998; Ferrari 1999), the study area was expanded to include the Jackson Hole bison, and several research topics, including bison demography, habitat use, migration, and ecological impacts, were identified (Gates et al. 2005; Gogan et al. 2001:68–69).

Despite this seemingly comprehensive list of research needs, understanding the ecology of bison prior to the establishment of YNP in 1872 was not considered (Cannon 2001a). This is striking in light of management documents, such as the Greater Yellowstone Ecosystem Vision Statement (Greater Yellowstone Coordinating Committee 1990) and statements by the National Research Council such as this: "Yellowstone is a dynamic landscape, and we cannot determine whether management actions have forced components of the system beyond their historical range of variability unless we place recent dynamics in a longer time frame. Knowledge of prehistoric and historical environments is essential for creating a context for this evaluation" [NRC 2002:32]. Earlier studies by the FAUNMAP Working Group (1996) preceded these recommendations by the National Research Council (NRC 2002) by looking at ecosystem development within longer time frames and coming to the realization that the community-based approach is no longer tenable. Individual species respond in their own particular way to environmental perturbations, and it is only through the study of individual species that we will be able to understand how these larger ecological systems have evolved (e.g., Grayson 2006).

One of the fundamental goals of the Greater Yellowstone Area Vision Statement (Greater Yellowstone Coordinating Committee 1990) is the maintenance of the ecosystem's integrity based on sound scientific research. To reach such a goal, the study of the ecosystem must be grounded in the fact that it is a dynamic system, continually undergoing change, whether this be by forest fire, the shifting weather patterns, or plant competition—processes that have been affecting the system for thousands of years. The ecosystem today is a result of its history. By utilizing evidence of past variability, it only follows that this information can be used to inform future decisions. To accomplish this, a management context must be devised that integrates modern ecological studies and prehistoric data. Bison, while they may represent a keystone species, are an excellent species to study in the context of changing climatic and environmental conditions at an ecosystem level, because they will reflect these larger-scale patterns. Prehistoric data can be an essential tool for providing a baseline of pre-Euro-American conditions against which the modern situation can be assessed (NRC 2005).

In the case of bison, knowledge is largely based on non-systematically collected historic records (Bamforth 1987) and modern studies of small, isolated populations (Berger and Cunningham 1994). The prehistoric record, however, can provide a millennia-long account, providing a baseline of pre-Euro-American conditions against which the modern situation can be assessed, and future management decisions can be made (Cannon 2001a). While ecologists, conservation biologists, and resource planners and managers have typically been trained to view ecosystem function in synchronic terms, (although this situation seems to be changing as indicated by recent applied zooarchaeology publications [e.g., Lauwerier and Plug 2004; Wolverton and Lyman 2012]), paleoscientists have been trained to think in terms of diachronic processes and long temporal spans (Lyman and Cannon 2004). By the very nature of the data, archaeologists can provide the long-term view of ecosystem change. Bringing the geologically historic record to bear on this issue is a goal emphasized not only for the GYE (NRC 2002), but for other public lands as well (NRC 2005).

Understanding bison ecology and migration patterns through the study of post-Pleistocene bison is one of the few methods for the reconstruction of past conditions. Bison today are confined to small, isolated herds that are not allowed to range freely within their historic ranges which were well beyond YNP borders. If the few surviving undisturbed areas are to be managed in a meaningful way, there must be an effort made to study how ecosystems have developed through time. Today, ungulate management is a very politically charged issue, and much of the information used to make the management decisions is based on modern studies of herds under confined situations (e.g., Berger and Cunningham 1994). Few, if any, studies incorporate long-term data, such as that available from paleostudies. New methodologies, such as applied stable isotope analysis, provide a means to decipher paleoenvironmental conditions in order to model future changes and the restoration of habitats, while long-term historic records provide an original perspective for examining bison populations. By analyzing the skeletal remains of bison within an interdisciplinary framework, it is possible to reconstruct a record that has a continuous temporal span of not just a few decades, but many centuries. This is the type of resolution that is necessary for examining long-term ecological processes.

### *Study Objectives*

The primary goal of this study is to provide an ecological and historical context for pre-Euro-American contact bison recovered from several archaeological contexts within the GYE. Several techniques and methods are applied in this case study. First, we examine the archaeological record of bison in the GYE and how taphonomic processes may be influencing this record and interpretations drawn from it. Second, we discuss the application of light stable isotope analyses to prehistoric and modern bison remains to reconstruct the biogeography of prehistoric bison in order to make reasoned recommendations for contemporary management of the GYE. The research is focused on Holocene specimens recovered from the GYE (Figure 8.1). GYE boundaries were first proposed in the 1970s and 1980s based on the range of the local grizzly bear (*Ursus arctos*) (Schullery 1997). The study area was chosen because it represents a largely intact system with a wealth of published ecological research.

The broader purpose of this study is to develop a more comprehensive historical perspective on the mammalian community of the GYE, as identified in National Research Council (NRC 2002, 2005) reports, with bison as the initial focus. The lack of historical knowledge of the local mammalian community is notable given the glacial (Pierce 1979), climatic (Whitlock and Bartlein 1993), and vegetative (Whitlock 1993) histories that have received extensive scientific study.

## The Regional Prehistoric Bison Record

The prehistoric record of bison in the GYE extends back 10,000 years (Cannon 1992), although the record is fragmentary with most data from the later part of the Holocene (Figure 8.2). Nineteenth-century observations suggest


**FIG. 8.1.** Map of the Greater Yellowstone Area.

that bison ranged throughout the lower-elevation meadows, with probable summer migrations into the high alpine meadows (Fryxell 1926; Meagher 1973:Appendix II). Today, bison are restricted to public lands in YNP and Jackson Hole. Although culling within YNP was halted in 1969 (Fuller et al. 2009:248), bison migrations beyond the national park boundaries result in

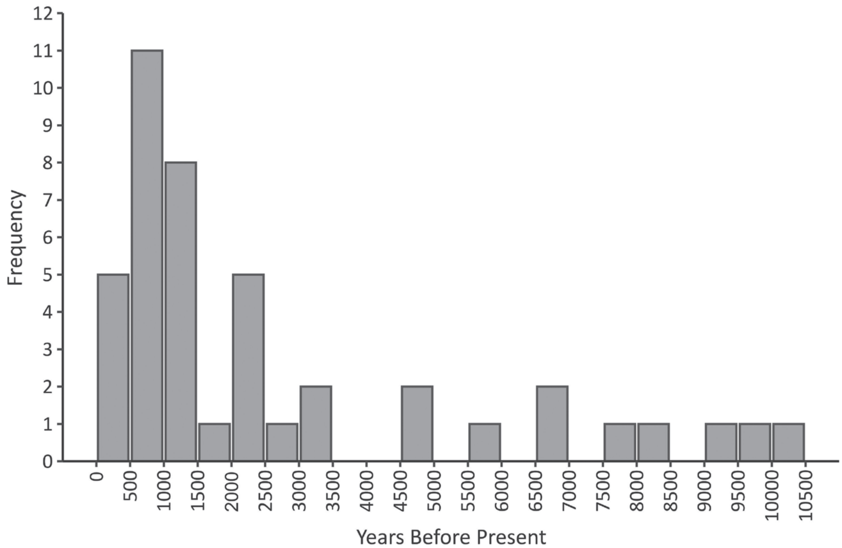



**FIG. 8.2.** Bar chart of directly dated components with bison remains.

either hazing or culling (Peacock 1997). A general paucity of bison in the archaeological record, as well as low and fluctuating numbers of modern bison in Yellowstone and Jackson Hole, led Wright (1984:28) to conclude that "bison were always relatively rare in northwestern Wyoming, and that they would have been too unpredictable in numbers to provide a stable food source." Wright continues, "since populations were small, one successful kill of adults would have reduced the reproductive potential of the herd to a level where it would no longer have been a significant part of the ecosystem." Mary Meagher (1973:14), on the other hand, suggests that "substantial numbers of bison inhabited the Yellowstone Plateau at all seasons, and long before the killing of the northern herd of Great Plains bison in the early 1880s." While these two perspectives illustrate extreme views, it is clear there is still much to learn about the details.

Since the time when both Wright (1984) and Meagher (1973) presented their views, new information has become available concerning both modern and prehistoric populations. Part of Wright's argument for low numbers of bison in the prehistoric record came from the extrapolation of population dynamics of modern bison in both YNP and Jackson Hole. While bison in both areas received protection from the Department of Interior, Wright failed


**FIG. 8.3.** Bison counts for Yellowstone National Park (1901-2014). Breaks in lines indicate years when counts are not available.

to mention that bison were often removed from the herds based upon various management decisions. If we look at winter counts for bison in Jackson Hole, we see that since the mid-1960s, when the National Park Service (NPS) implemented a noninterventionist approach to natural resource management, bison numbers have increased to a high in 2016 of approximately 5,000 (Figure 8.3). In 1969, the Jackson Hole herd was established with 16 founders and subsequently high fecundity rates caused exponential population growth rates of 16–19 percent a year (Cain et al. 1998).

However, the debate continues both in opinion articles that question the management practices of large ungulates in YNP (Hanscom 1997) and the lack of evidence to support the current number of bison in the Park (Keigley 2015), and in research articles in the journal *Rangelands* by Keigley (2019) and Beschta and Ripple (2019). The two most recent articles argue that (1) bison were absent from YNP before 1840, (2) only bulls were present on the Yellowstone Plateau with mixed herds only present on the lower elevation plains, and (3) bison played no significant role in the ecological processes that shaped the YNP prehistoric landscape.

Despite the characterization of the contemporary YNP herd as free ranging, much of its history during the twentieth century has been based upon management decisions to restrict the movement of the population. Following a period of management practices that allowed the herd to grow in the early twentieth century, during the mid-twentieth century the herd was intensively managed, with culling a common practice (Meagher 1973; Schullery 1986; Schullery et al. 1998). Shortly after the Leopold Report (Leopold et al. 1963) was issued, the NPS took a less interventionist approach to natural resource management, relying on natural processes (e.g., winter deaths, reduction in culling, and reintroduction of wolves) to effect change and to control wildlife numbers (Keiter 1997). Bison responded by increasing their numbers from 397 in 1967 to a high of over 5,000 individuals in 2006 (http://www.ibmp.info/bisonopsupdates.php). Bison numbers in 2020 lie just below this high at 4,680 (https://www.nps.gov/yell/learn/nature/bison.htm).

The Jackson Hole bison herd was initially established in 1948 when 20 bison from YNP were introduced to the 1,500-acre Jackson Hole Wildlife Park near Moran, Wyoming. The population was maintained at 15–30 bison in the large enclosure until 1963 when brucellosis was discovered in the herd. All the adult animals were euthanized. Four vaccinated yearlings and five vaccinated calves were retained. Twelve certified brucellosis-free bison were added to the herd. In 1968 the herd (11 individuals) escaped the wildlife park and the following year a decision to allow the herd to range freely was made. In 1975, the expanded 18-member herd began wintering on the National Elk Refuge. Bison fed on standing forage as their natural behavior, but also fed on supplemental feed provided for elk, leading to a decline in winter mortality and an increase in population growth (U.S. Fish and Wildlife Service and National Park Service 2007).

Since 1990, the bison herd has averaged an increase between 10 percent and 14 percent despite harvesting and culling outside the refuge and Grand Teton National Park by the Wyoming Game & Fish Department since 1997. The rapidly increasing bison population has raised concerns about habitat damage, competition with elk, increased risk of disease transmission, and the rising cost of supplemental feeding. In 2007, a bison hunt was initiated as a management tool to control population growth (U.S. Fish and Wildlife Service and National Park Service 2007). Today the population of bison in Jackson Hole is about 1,000 animals.

While it is problematic to draw comparisons in bison population dynamics between prehistoric populations and modern managed herds, it is apparent that the region can support a fairly sizable population, although there are arguments that the current large numbers are having an impact on native vegetation (Beschta et al. 2020). Based upon new information, it may be time to reevaluate the role of bison in the regional ecosystem and in the precontact indigenous economy.

Through the Wyoming Cultural Resource Information System, we obtained site data for the Wyoming portion of the GYE (data was obtained in March 2019). This dataset documents 6,336 recorded Native American precontact sites. Of these, less than 4 percent (n=228) have been tested through archaeological recovery methods, including small scale test excavations to larger data recovery excavations. Of the few archaeological sites that have subsurface testing, 126 have preserved bone or organic materials of which 49 have bison bone identified (Figure 8.4). Admittedly limited, the extant record indicates bison were in the GYE for over 10,000 years.

A closer review of the prehistoric record of the GYE provides a minimum of 66 components from 30 archaeological and three paleontological sites that produced bison remains (Cannon et al. 2015:Table 1). These components represent 29 open archaeological sites, one archaeological cave site (Mummy Cave), and three paleontological sites (Dot Island, Lamar Cave, and Astoria Hot Springs) but do not include the various drive/jump sites in Paradise Valley north of YNP (Cannon 2001a). George Arthur (1966:45–56) estimated that at least 10 bison kill sites are present in Paradise Valley, including a large complex of drive lines and rock cairns for herding known as the Emigrant Buffalo Jump (24PA308). Ice patch research in the GYE by Craig Lee (Lee and Puseman 2017), Rebecca Sgouros (email 28 September 2016), and Marcia Peterson (email 7 July 2016) have also produced bison remains from high altitude settings east and north of YNP. Ages for these bison range from about 110 ± 20 BP to 3,368 ± 20 BP.

The earliest evidence of bison in the region was reported from south of Jackson Hole on the Snake River at Johnny Flats Count near Hoback. Because the association of cultural material with the bison remains has not been demonstrated, these deposits are considered paleontological. During excavation for the development of Astoria Hot Springs (48TE342), "a layer of mixed bison bone and shell was exposed. . . . Several bison skulls were retrieved from this layer . . . [and] . . . were not of any bison larger than modern populations" (Love 1972:50). Mollusk shell was collected for radiocarbon dating from a "trench intersecting 2-ft shell bed at depth of 3 ft" by J.D. Love in 1959 and submitted to the U.S. Geological Survey, which produced an age of 11,940

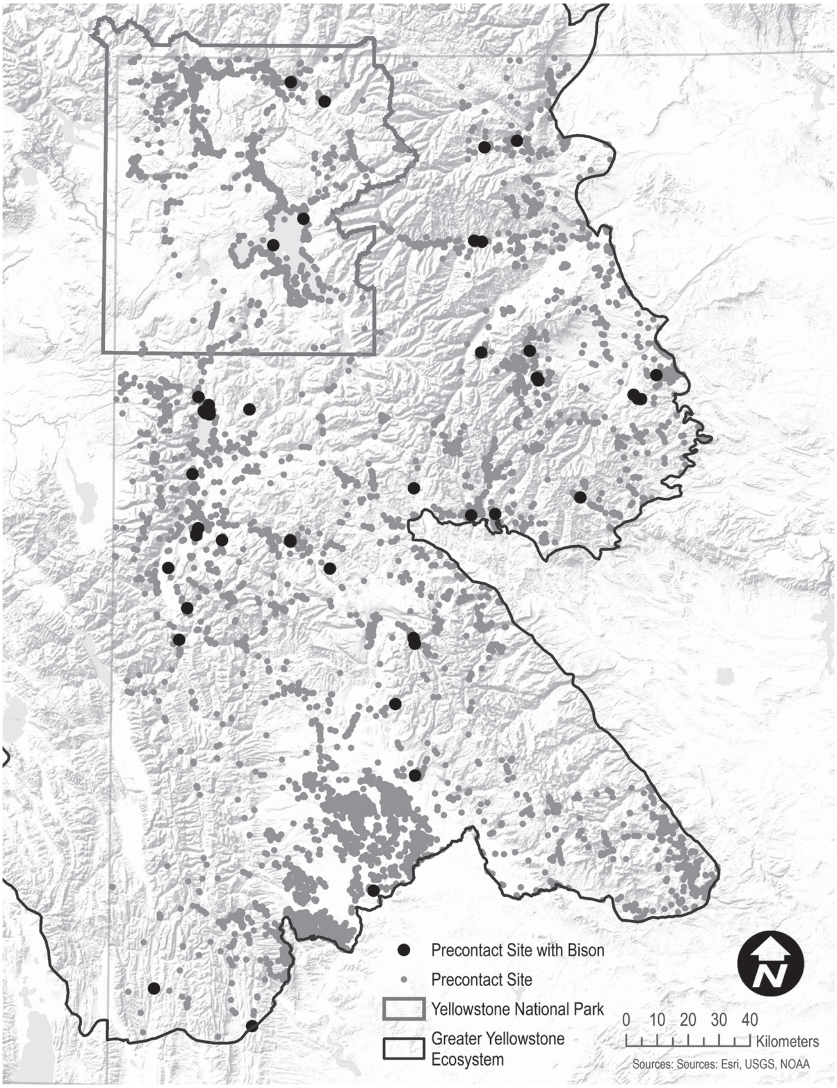



**FIG. 8.4.** Wyoming portion of the GYE illustrating the number of precontact archaeological sites and those with identified bison bone (derived from Wyoming State Historic Preservation records March 2019).

± 500 BP (W-1070; Ives et al. 1964:60). With the current understanding of the process of radiocarbon dating (e.g., Goslar and Pazdur 1985), especially given its proximity to geothermal features, this age might be problematic. For example, Preece et al. (1983:253) explain that a theoretical maximum of 50 percent of dead carbon could be incorporated into freshwater shell by ingestion, "introducing an apparent error for such shells with respect to contemporaneous terrestrial vegetation of up to one $^{14}$C half-life (5730 ± 40 years)." The implications of this work should be reviewed with these issues in mind.

The Goetz site, (48TE455), located on the National Elk Refuge in Jackson, was initially investigated by Dr. George Frison and his student at the time, Charlie Love. The investigations were in response to dragline excavations to draw water from a spring for elk and other wildlife. Love (1972:69–71), in his master's thesis, provides the following narrative of the investigations:

> A dragline operation to open up the spring brought up quantities of butchered bison bone and flake materials. An incomplete bear mandible was recovered from this site in an earlier test hole. A 5 by 10 foot test pit into an undisturbed portion revealed the scattered remains of three separate butchered bison as well as numerous flakes, choppers, bifacial fragments, and projectile point pieces. Over twenty pounds of flakes, core pieces, scrapers, and chopper or knife-like bifaces were obtained from the single test pit. . . . A thin layer of carbon at a depth of approximately 9 inches was collected and subsequently dated at A.D. 1560 ± 115. At this level and below were found a reworked obsidian edgeground lanceolate point, a thin straight-edged, square-based, unnotched brown chert point, a piece of obsidian corner notched point, and what appears to be a McKean-like stem base of an obsidian point. . . . A great deal of fire-cracked rock was distributed throughout the test pit as well as other undiagnostic tools. . . . Possibly two layers of bone and materials are present, though a specific dividing line between them could not be drawn [Love 1972:69–71].

According to Frison, the excavation was salvage in nature (personal communication, October 1999). The relationship of the bone and the cultural material is difficult to assess, and Love's radiocarbon age should be considered minimum. Bone from the site was reanalyzed by Cannon et al. (2015). The results indicate that a minimum of four bison, two of which are males, are represented in the assemblage.

Two elements from the 1972 assemblage were subjected to radiocarbon assays. A right metatarsal (FS455.1.49) produced an age of 800 ± 40 BP or 1216–1268 cal A.D. (Beta-133690; $\delta^{13}$C = −21.0‰). The second age, 370 ± 40

BP or 1453–1521 cal A.D. (Beta-241894; $\delta^{13}C = -18.8‰$) obtained from the roots of an isolated bison lower third molar, suggests multiple depositional events. These dates support Love's (1972:71) observation at the time of excavation that "[p]ossibly two layers of bone and materials are present, though a specific dividing line between them could not be drawn." Both dates are earlier than the minimum age (1560 A.D.) presented by Love (1972) and suggest periodic encounter hunting of bison. A test of significance (Calib 6.1.1) of the two dated bison specimens indicates that they are statistically different ($T = 57.78$; $\chi^2_{.05} = 3.84$). The two radiocarbon ages indicate that at least two episodes of hunting are represented in this assemblage.

Four sites, including the Goetz site, are within the current bison habitat. The sites, at the southern end of Blacktail Butte, were investigated by Wright and his students in the 1970s and produced bison remains. Blacktail Butte 6 (48TE352) produced "two cranial fragments of a large mammal, apparently a bison" in Test Pit 1 (Wright and Marceau 1981:5). It appears that remains from a minimum of two bison were recovered during the test excavations. Wright and Marceau (1981:6) indicate the "midden included parts of a butchered bison . . . while a second section of the site [Area 2] . . . produced a bison ulna at a depth of 40 cm." They also report two obsidian-hydration dates on artifacts recovered from the midden—AD 92 and AD 172; however, those dates may be problematic due to uncertainties in obsidian age calculations (Cannon 2001b:VIII-2–VIII-5).

At the extreme southwestern end of Blacktail Butte is Blacktail Butte 12 (48TE391), which was documented in 1974 and tested in 1975. Faunal remains were recovered from at least two contexts. While the majority (>95 percent) were unidentifiable fragments, at least three elements were attributed to "at least two butchered bison" (Wright and Marceau 1981:4). "Level 1 [Test Pits 2 and 2A] . . . produced . . . a fragment of tooth enamel from a large mammal, possibly bison. . . . [In] Level 4 we found . . . at a depth of 32–35 cm . . . the proximal end of a bison radius" (Wright and Marceau 1981:3). Thirty-five bone fragments were recovered from Level 1 of Test Pits 3 and 3A, one of which "is part of a long bone, probably bison" (Wright and Marceau 1981:4).

Late Prehistoric/Protohistoric hunting of bison at high elevation sites has been discovered east and northeast of YNP. Sites in the Boulder Ridge area indicated warm seasonal use during the Little Ice Age (Eakin 2005). Winter occupation has been identified at the Bugas-Holding site within overbank alluvial deposits of Sunlight Creek in the Sunlight Basin at an elevation of 2178 m. The area is a well-sheltered winter range for bison and sheep as indicated by the faunal remains from eight hearth and dump area locales that were radiocarbon dated to median cal AD 1540. At least 15 bison are represented in the assemblage along with 14 bighorn sheep (*Ovis canadensis*), two elk (*Cervus canadensis*), and one pronghorn (*Antilocapra americana*). Bison fetal bones at this site indicate the presence of a breeding herd occupying the areas from November through May (Rapson and Todd 1999).

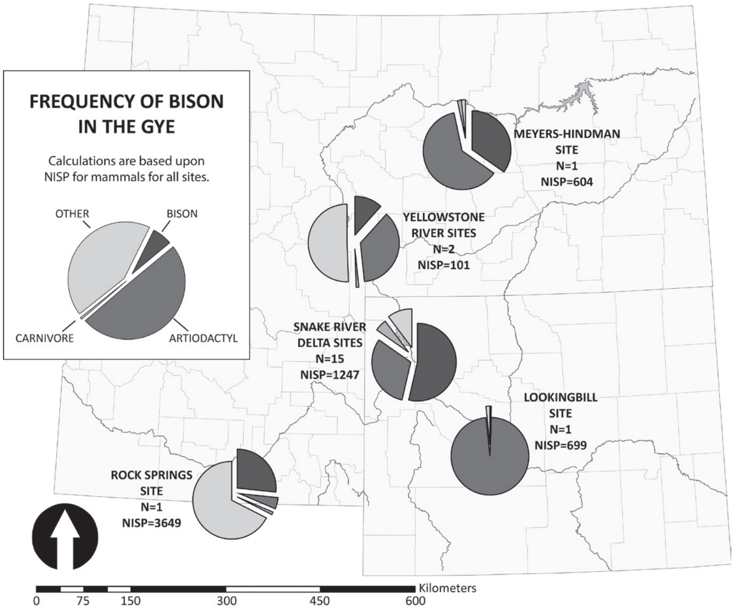
Additional high elevation sites recorded in the Absaroka Mountains as part of the Greybull Rivers Sustainable Landscape Ecology (GRSLE) research project have produced bison remains from at least six different contexts ranging in age from 420 to 80 BP. The sites have an elevational range from 2494 m to 2792 m (Todd 2019:Table 11.2).

To date, the largest assemblage of bison from YNP and Jackson Hole comes from late Holocene contexts on the former Snake River delta, now inundated by Jackson Lake. Archaeological investigations by the Midwest Archeological Center in 1987 and 1988 under the direction of Dr. Melissa Connor (1998) produced the remains of at least 39 bison (Cannon 1991). While it is unclear whether humans were responsible for the entire assemblage, the association of the bone with artifacts and the limited evidence of butchering suggest some of the animals were the result of human predation. Finally, the Game Creek site (48TE1573) south of Jackson has recently produced a well-stratified assemblage of bison and other prey species. A minimum of 12 bison have been identified, including fetal and a late term/infant, dating from the Late Paleoindian through Late Prehistoric Period (Page 2017).

While the results of this review are not conclusive, they do suggest that bison may have been more prevalent in the region than previously thought. In a review of bison and other large mammals, Cannon (1992) and Cannon et al. (2015) found bison to be the second most ubiquitous large mammal occurring at 21 of 31 sites (67.74 percent), second only to elk (24 of 31 sites). If bison were a more common member of the precontact Jackson Hole faunal community, they may have provided a significant resource to aboriginal groups in the valley, especially prior to the early nineteenth century. It may be time to dust off the model of the local prehistoric economy of GYE and reassess the role of bison (Figure 8.5).

## Taphonomic Effects on Preservation of Bone

The GYE, and the Yellowstone Plateau specifically, is a particularly challenging place for the preservation of bone and other organic materials (see Figure 8.4; Cannon et al. 2020). When we look at sites with preserved bone, they tend to be in soils with moderately acidic to neutral pH, which are substantially



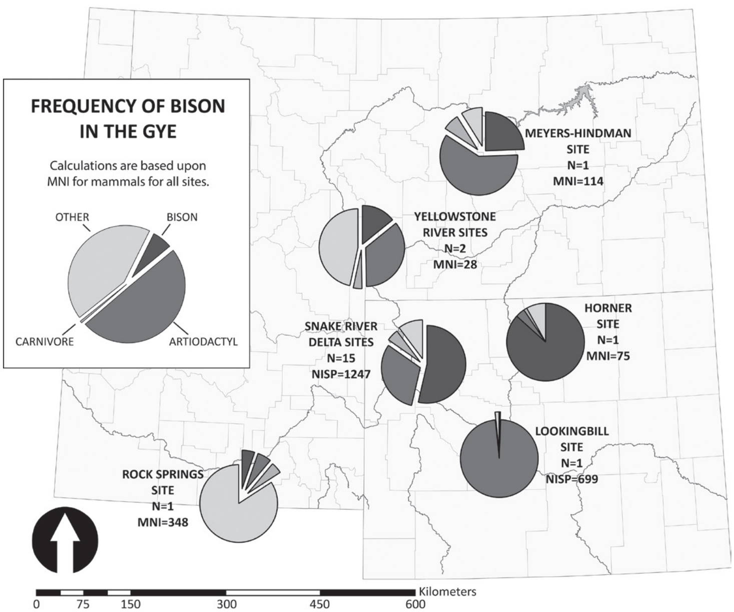
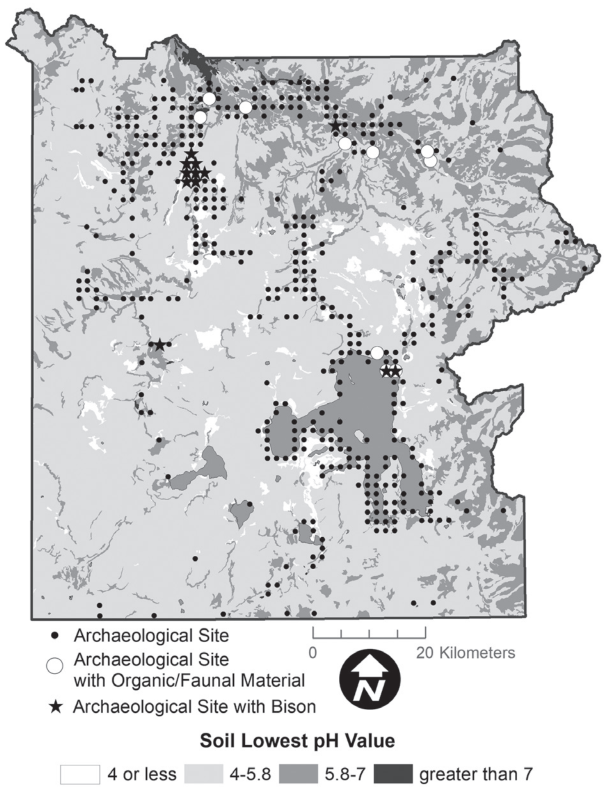




**FIG. 8.5.** Frequency of bison bones based upon MNI (top) and NISP (bottom) at key archaeological sites in the GYE in comparison to other mammals.

limited on the Yellowstone Plateau (Figure 8.6; Rodman et al. 1996; and see Chapter 4, this volume). Another important taphonomic issue in forested areas (Figure 8.7), which today and during much of the Holocene (Whitlock 1993) predominate the Yellowstone Plateau, is tree-throw or floralturbation disturbance of the archaeological matrix (Bonnichsen and Will 1999; Waters 1992:306–309). Repeated tree tip-outs or tree-throws (i.e., as trees fall over during catastrophic events surficial sediments and soils adhere to the roots leaving behind a depression which is later filled by younger sediments) keep the archaeological record and organic materials higher stratigraphically in the biomantle where they continue to be degraded as opposed to allowing them to be incrementally buried where they might be preserved (Connor et al. 1989; Norman 2013).

Late eighteenth and early nineteenth century Native American sites are few largely due to these poor preservation conditions, such as the acidic grass-

FIG. 8.6. Soil pH map and sites with preserved bone in Yellowstone National Park. Bone preserved in moderately acidic to neutral pH (5.4-6.6).



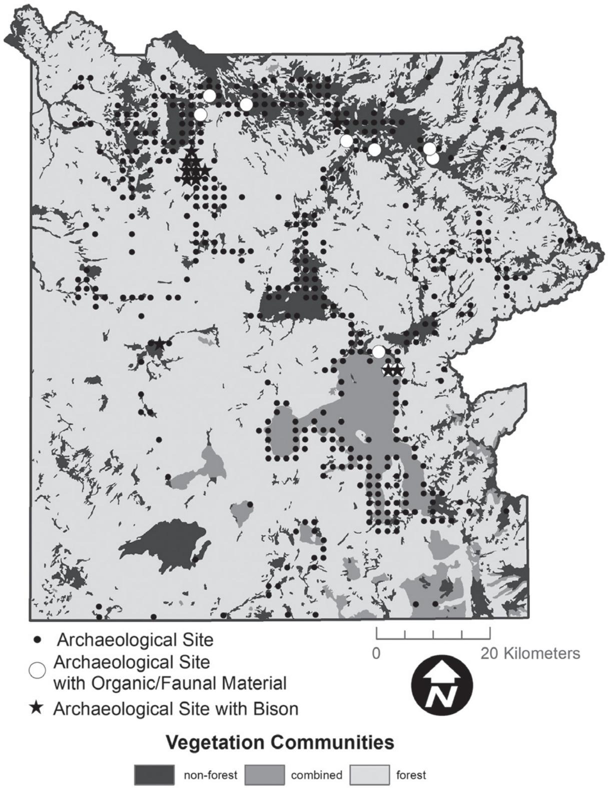



**FIG. 8.7.** Vegetation map of YNP illustrating location of sites with preserved bone and organic materials. Sites with bone preservation are typically preserved in open grassland settings.

roots zone and forest floor duff (O horizon), or within the churned floor of caves and rock shelters (Finley 2016). The limited number of preserved sites from this time period has led to a false impression that the high country of the GYE was abandoned during this time period which coincides with the Little Ice Age (Cannon et al. 2020). Increasing forest fires, and the general lack of post-fire cultural resource investigations have also resulted in loss of information related to the use of high-elevation environments. When an area is burned, and the duff consumed, there is typically an extensive faunal assemblage that is present for the first year after the fire. This freshly burned bone is highly weathered, and once the duff is removed, is unprotected, and quickly disintegrates (Figure 8.8). In YNP alone 771 sites have been subjected to recent fires (Figure 8.9). Additionally, exposed surface deposits become vulnerable to information lost through looting and trampling by grazing livestock (Eakin 2005:82; Todd 2015:370).

A final factor to consider is glaciation (Pierce 1979). Extensive glaciation of the Yellowstone Plateau and surrounding high country scoured the landscape. The combination of till, with its tight, compact nature, along with tree cover has yielded little sediment from slopes and thus little sediment flux in the fluvial and slope systems. Areas of glacial scoured bedrock add to this low sediment flux issue. In the northern Yellowstone region, there are essentially no footslope deposits and not much in the way of Holocene-aged fans, which typically preserve long records (Figure 8.10). This contrasts with the southern portion of the GYE (southern Jackson Hole), where loess accumulated on slopes after the Pinedale retreat, and reworked loess deposits have provided deeply buried soils with good faunal preservation. These types of landscapes include stratified sites such as the Game Creek site (Page and Peterson 2017), the Goetz site (Cannon et al. 2015), the Crescent H Ranch site (Cannon and Cannon 2004), and the Stinking Springs Rockshelter (Cannon and Cannon 2011).

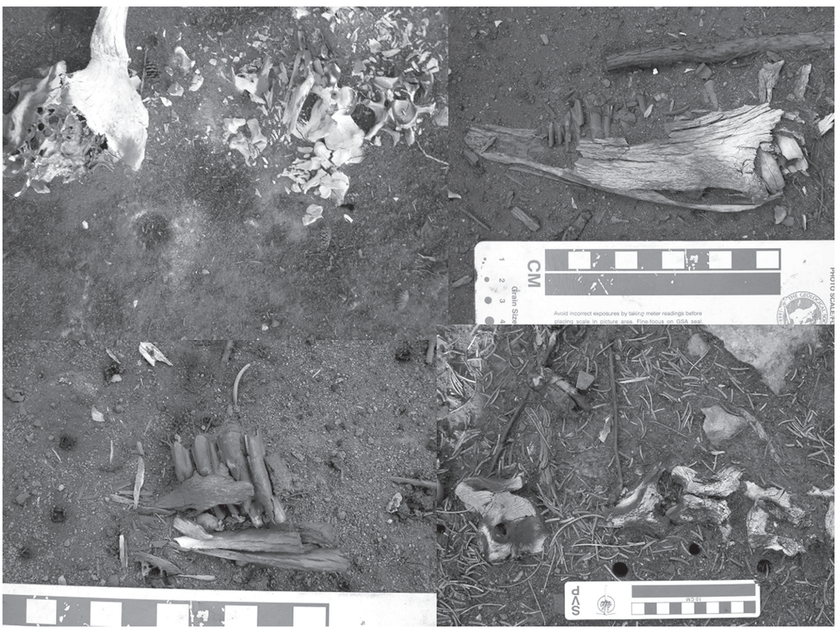



**FIG. 8.8.** Protohistoric/Historic archaeological bone after recent fire (photos courtesy of Larry Todd).

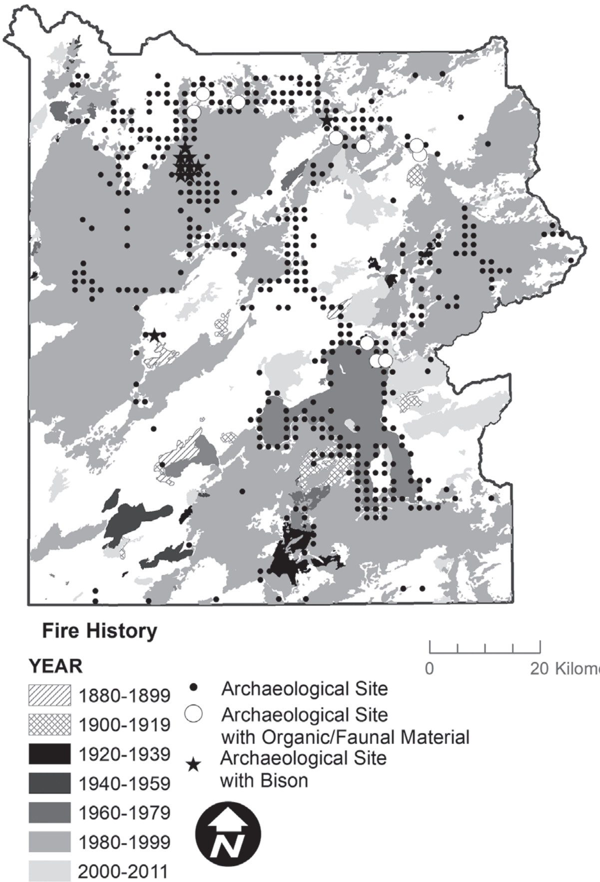



**FIG. 8.9.** Map of YNP fire history and relationship of sites with preserved organic material.

## Stable Isotope Studies

Analysis of stable isotopes in bone collagen has been widely used to determine diet in humans and other vertebrates, and isotopic methods are well established in theory and practice (Koch et al. 1994; Tieszen 1994). Teeth were chosen for this study because they tend to preserve well due to their "high degree of elasticity and strength" (Carlson 1990:534), but most significantly because they preserve a detailed record of an individual's foraging history through incremental growth of the tooth enamel (Kohn et al. 1996). By sampling the third molar, which mineralizes from the 9th to the 24th month of life and is not affected by isotopic offsets caused by nursing (Bryant and Froelich 1995), a geochemical


**FIG. 8.10.** Map of GYE and Late Pleistocene (Pinedale age) glacial maximum and relationship of bone preservation and deeply stratified archaeological sites.

record reflecting the individual's foraging history can be extracted at a seasonal or subannual resolution (Gadbury et al. 2000; Widga 2006). For this study, we used carbon (C), oxygen (O), and strontium (Sr) to investigate bison ecology and migration during the Holocene in comparison with modern bison.

In terrestrial environments (and for our purposes), two main categories of plants are recognized based upon their carbon-fixation pathways and are clearly distinguished by the stable carbon isotope signatures. The cool season, or $C_3$ plants, represent about 90 percent of all plants and include all trees and herbaceous plants from cold and temperate climates. The warm season, or $C_4$ plants, include warm weather and tropical plants. These plants are more competitive under periods of stress. Both relative and absolute abundance of $C_4$ plants in the western United States correlates with mean annual temperature and mean annual precipitation (Teeri and Stowe 1976). $C_3$ plants, which do most of their growing in the spring and early summer are most productive under conditions of cool temperature and adequate winter precipitation. In general, the abundance of $C_3$ plants increases with latitude and elevation (Körner et al. 1988; Körner et al. 1991). Because bison are non-selective grazers, their carbon isotope signatures should reflect the relative abundances of $C_3$ and $C_4$ plants within the ecosystems that they graze (Kohn and Cerling 2002; Peden 1976).

Oxygen isotope analysis of bone and teeth is another important tool for understanding bison ecology, migration, and paleoenvironmental conditions. Experimental studies have shown a strong linear relationship between stable isotope values and temperature proving valuable for paleoenvironmental reconstruction. Tooth enamel is one of the best reservoirs of oxygen isotope signatures (Fricke and O'Neil 1996; Fricke et al. 1998; Schoeninger et al. 2000). As moisture off the ocean evaporates, the lighter isotope ($^{16}O$) is preferentially released into the atmosphere where it forms within clouds. These moisture-laden clouds move inland with the heavier isotope ($^{18}O$) being precipitated more rapidly. Therefore, as these storm clouds move inland, they become more depleted in $\delta^{18}O$. Studies have shown that fractionation of the $^{16}O$ and $^{18}O$ isotopes are temperature dependent, with greater fractionation occurring at lower temperatures (Burk and Stuiver 1981; Gat 1980). This fractionation contributes to further depletion of $^{18}O$ at higher latitudes and elevations (-0.5‰ per degree of latitude and -0.15 to -0.5‰ per 100 meters in elevation), with precipitation as snow being the most isotopically depleted. Therefore, waters in the GYE, which are largely derived from cold, isotopically light winter precipitation (Kharaka et al. 2002), should exhibit limited seasonal variability. Hughes' (personal communication, 2005) analysis of water and snow samples from the North Fork of the Shoshone River (east of YNP) show highly depleted values (-19 to -20‰) that reflect the great distance clouds travel before they precipitate over the region. Obligate-drinking herbivores, such as bison, display stable oxygen isotope values that closely correlate with local water values. For example, bison drinking from wetlands and lakes that experience evaporation will have isotopically enriched signatures, while bison drinking exclusively from streams and rivers filled by snow runoff should reflect less seasonal variability with signatures that are isotopically depleted.

The third isotope examined, Sr, may provide the most direct evidence for tracking bison on the landscape (Hoppe et al. 1999; Koch et al. 1995). Strontium isotopic signatures, expressed as the ratio $^{87}Sr/^{86}Sr$, is reflective of the geologic substrate and the living organisms that live upon it. In studies of migration and mobility, strontium isotopes are used to determine if the

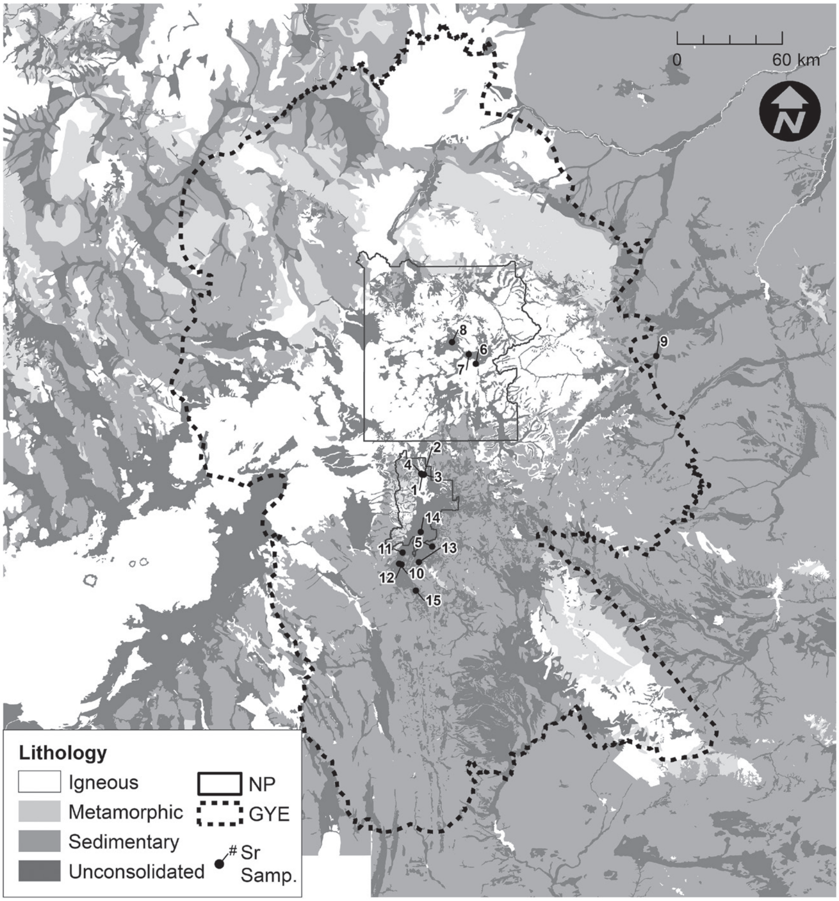



**FIG. 8.11.** Generalized map of the Greater Yellowstone Ecosystem lithology illustrating the location of bison and plant samples: 1. 48TE1090; 2. 48TE1101; 3. 48TE1102; 4. 48TE1114; 5. 48TE455 (Goetz Site); 6. 48YE697 (Windy Bison Site); 7. YNP/94KC1 (modern); 8. 2000.HV.002 (Hayden Valley modern); 9. 48PA29 (Horner Site); 10. 17SR001 (modern grass); 11. 17SR002 (modern grass); 12. 17SR003 (modern grass); 13. 17SR004 (modern grass); 14. 17SR005 (modern grass); 15. 17SR006 (modern grass). Map data is from Horton (2017).

individual is 'local' to a particular area by comparing the isotopic values from bone and dental enamel of the specimen with local isotopic values that must be established for that specific geographic location. The "local" values of a specific place are determined by studying the underlying geology of a particular place, in the case of strontium; and through the analysis of local groundwater resources and precipitation (rainfall and snow), in the case of oxygen. Under this assumption it is taken that if an individual displays isotopic values that are the same or within the range for the region in which they were discovered (or buried) then it may be possible to suggest that they were from the area originally (Bentley 2006).

The GYE provides a unique research laboratory due to the number of distinct geologic substrates it contains (USGS 1972a, 1972b). The measured ratio is derived from $^{87}Sr$, which is a radioactive decay product of $^{87}Rb$, and $^{86}Sr$, which is stable. Therefore, the $^{87}Sr/^{86}Sr$ in any given rock is dependent on the amount of rubidium (Rb) it contains, the mineral composition, and its age (Bataille and Bowen 2012). We should expect high resolution $^{87}Sr/^{86}Sr$ variation in this mountainous area due to the complex juxtaposition of lithologies. For example, younger volcanic substates should have lower ratios than older sedimentary rocks (Porder et al. 2003:Table 1) which in turn will be reflected in the bison $^{87}Sr/^{86}Sr$ ratios (Figure 8.11). The geologic Sr samples were analyzed by Dr. Douglas Walker at the University of Kansas Isotope Geochemistry Laboratory following methods discussed in Widga et al. (2010).

Sequential sampling from the third molar followed the protocol established by Balasse (2002) and was conducted by Susan Hughes. Dr. Hughes removed each of the enamel sections with a dremel tool. The sampling consisted of sequential tooth samples for intra-individual variability and a vertical sample that can be used to compare between individuals. The number of samples per tooth was dictated by the condition of the tooth and the maximum length (Figure 8.12). For example, younger animals have more of their tooth remaining so more samples can be removed. Data sheets for each of the teeth are presented in Appendix C. After processing, approximately 10 grams of powdered tooth enamel per sample were submitted to Dr. David Dettman in the Department of Geosciences at the University of Arizona for analysis. $\delta^{18}O$ and $\delta^{13}C$ of tooth enamel carbonate were measured using an automated carbonate preparation device (KIEL-III) coupled to a gas-ratio mass spectrometer (Finnigan MAT 252). Powdered samples were reacted with dehydrated phosphoric acid under vacuum at 70°C in the presence of silver foil. The isotope ratio measurement is calibrated based on repeated

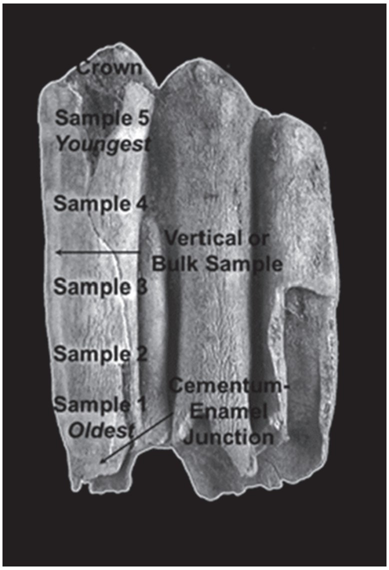



**FIG. 8.12.** Buccal side of left M3 (Specimen 48PA29/133H) from the Horner site illustrating location of intra-individual samples removed for isotopic analysis. A vertical or bulk sample was also removed from the metaconid. Distance from the maximum length (crown of tooth) represents an age proxy with the oldest portion of the tooth at the bottom (Sample 1).

measurements of NBS-19 and NBS-18 and precision is ± 0.1 ‰ for $^{18}O$ and ±0.06‰ for $^{13}C$ (1σ). The carbonate – CO2 fractionation for the acid extraction is assumed to be identical to calcite.

Three samples from the Horner site were selected, plus an 800-yr old YNP bison and three modern YNP bison, aged 2.6 (1233H), 3.6 (2548H), 4.6 (1181H) years. The number of samples per tooth was dictated by the condition of the tooth and the maximum length. This method offers a high-resolution record of changing body values driven by seasonal changes in vegetation and water intake (Gadbury et al. 2000). Values are reported in permil (‰) units relative to VPDB standards. Standard deviation in $\delta^{13}O$ and $\delta\,^{18}O$ values associated with triplicate measurements on a single sample is also presented (Table 8.1).

The detailed intra-tooth variability of the modern YNP bison provides evidence of seasonal variability in water resources but limited variability in vegetation which is expected of the modern $C_3$ dominated ecosystem of the Yellowstone Plateau (Figure 8.13). Comparing modern bison with an 800-year-old archaeological specimen illustrates more variability implying historically larger range sizes than the restricted range of modern bison, which are currently restricted to the boundaries of YNP (Figure 8.14). Specifically, we wanted to see if prehistoric bison were migrating seasonally

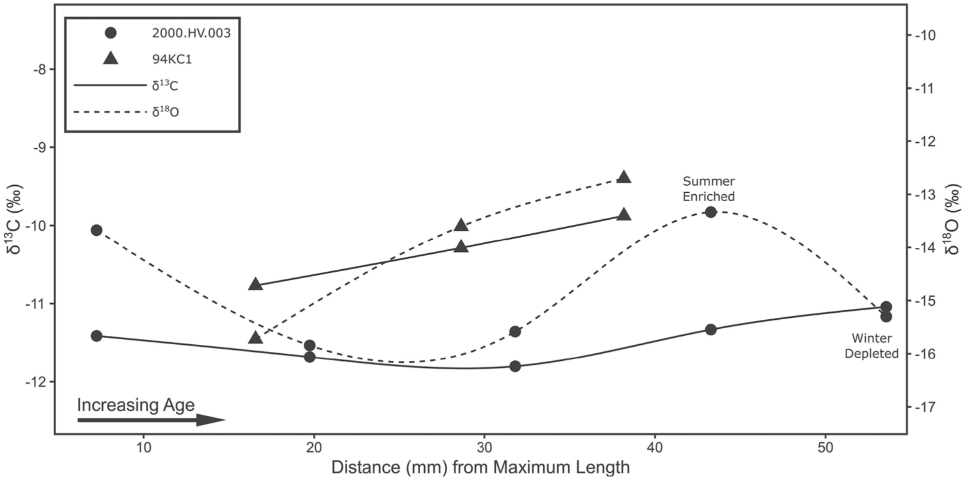



**FIG. 8.13.** Plot of intra-tooth sample from modern YNP bison. The oldest portion of the tooth would be on the right side of the graph moving left and younger. The $\delta^{13}C$ values show little variability reflecting the $C_3$-dominated ecosystem of the Yellowstone Plateau.

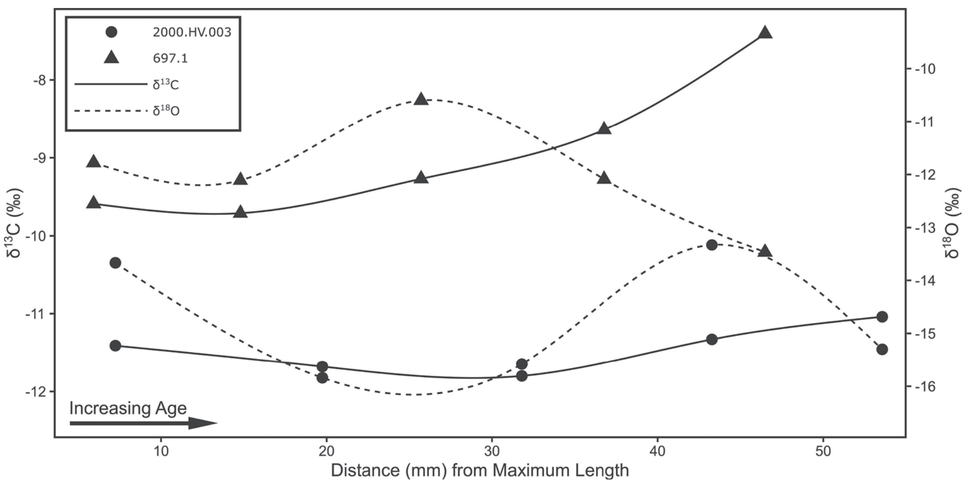



**FIG. 8.14.** Plot of intra-tooth samples of modern YNP (2000.HV.003) and archaeological (697.1) specimens. The archaeological specimen is a bull and illustrates a much greater variability in the use of vegetation (Δ23.38‰) implying a larger range than the modern YNP bison which is restricted to the $C_3$-dominated Yellowstone Plateau.

TABLE 8.1. RESULTS OF CARBON AND OXYGEN STABLE ISOTOPE ANALYSIS. ALL VALUES ARE REPORTED IN PERMIL (‰) UNITS RELATIVE TO VPDB STANDARD. ISOTOPIC ANALYSIS WAS CONDUCTED BY DR. DAVID DETTMAN IN THE DEPARTMENT OF GEOSCIENCES, UNIVERSITY OF ARIZONA. SHADED ROWS REPRESENT MODERN YNP BISON.

| SAMPLE ID | δ13C | C STD DEV | δ18O | O STD DEV | DISTANCE FROM MAX LENGTH (mm) | SITE AND CATALOG NUMBER |
|---|---|---|---|---|---|---|
| KC06.1 | -11.5 | 0.023 | -11.7 | 0.028 | 28.47 | 2000.HV.002 |
| KC06.2 | -11.6 | 0.036 | -11.8 | 0.070 | Vertical | 2000.HV.002 |
| KC07.1 | -11.0 | 0.029 | -15.0 | 0.058 | 53.57 | 2000.HV.003 |
| KC07.1 | -11.0 | 0.012 | -15.3 | 0.050 | 53.57 | 2000.HV.003 |
| KC07.2 | -11.3 | 0.033 | -13.3 | 0.022 | 43.27 | 2000.HV.003 |
| KC07.3 | -11.8 | 0.030 | -15.6 | 0.057 | 31.80 | 2000.HV.003 |
| KC07.4 | -11.7 | 0.023 | -15.8 | 0.079 | 19.74 | 2000.HV.003 |
| KC07.5 | -11.4 | 0.027 | -13.7 | 0.060 | 7.23 | 2000.HV.003 |
| KC07.6 | -11.2 | 0.015 | -15.5 | 0.053 | Vertical | 2000.HV.003 |
| KC03.1 | -6.2 | 0.032 | -10.7 | 0.042 | 59.90 | 48PA29/1181H |
| KC03.2 | -6.6 | 0.023 | -7.6 | 0.076 | 47.87 | 48PA29/1181H |
| KC03.3 | -7.6 | 0.030 | -11.0 | 0.056 | 34.13 | 48PA29/1181H |
| KC03.4 | -8.0 | 0.019 | -10.7 | 0.041 | 22.74 | 48PA29/1181H |
| KC03.5 | -7.8 | 0.034 | -10.8 | 0.060 | 12.58 | 48PA29/1181H |
| KC03.6 | -6.8 | 0.033 | -9.6 | 0.038 | Vertical | 48PA29/1181H |
| KC04.1 | -7.5 | 0.165 | -10.6 | 0.104 | 58.41 | 48PA29/1233H |
| KC04.2 | -7.0 | 0.041 | -7.8 | 0.051 | 49.20 | 48PA29/1233H |
| KC04.3 | -5.0 | 0.027 | -7.5 | 0.016 | 39.02 | 48PA29/1233H |

| SAMPLE ID | δ13C | C STD DEV | δ18O | O STD DEV | DISTANCE FROM MAX LENGTH (mm) | SITE AND CATALOG NUMBER |
|---|---|---|---|---|---|---|
| KC04.4 | 2.8 | 0.028 | -9.6 | 0.081 | 27.73 | 48PA29/1233H |
| KC04.5 | -2.8 | 0.068 | -8.8 | 0.039 | 16.52 | 48PA29/1233H |
| KC04.6 | -4.5 | 0.030 | -8.9 | 0.060 | Vertical | 48PA29/1233H |
| KC08.1 | -7.4 | 0.033 | -12.8 | 0.069 | 55.68 | 48PA29/2548H |
| KC08.2 | -6.9 | 0.017 | -8.4 | 0.051 | 44.48 | 48PA29/2548H |
| KC08.3 | -7.4 | 0.014 | -9.2 | 0.065 | 35.50 | 48PA29/2548H |
| KC08.4 | -7.6 | 0.021 | -9.6 | 0.050 | 23.68 | 48PA29/2548H |
| KC08.5 | -7.8 | 0.029 | -11.0 | 0.031 | 12.83 | 48PA29/2548H |
| KC08.6 | -7.2 | 0.019 | -9.9 | 0.017 | Vertical | 48PA29/2548H |
| KC09.1 | -7.4 | 0.037 | -13.5 | 0.038 | 46.49 | 48YE697/697.1 |
| KC09.2 | -8.6 | 0.029 | -12.1 | 0.025 | 36.77 | 48YE697/697.1 |
| KC09.3 | -9.3 | 0.013 | -10.6 | 0.031 | 25.71 | 48YE697/697.1 |
| KC09.3 | -9.1 | 0.013 | -10.7 | 0.049 | 25.71 | 48YE697/697.1 |
| KC09.4 | -9.7 | 0.044 | -12.1 | 0.059 | 14.79 | 48YE697/697.1 |
| KC09.5 | -10.0 | 0.007 | -11.6 | 0.058 | 5.92 | 48YE697/697.1 |
| KC09.5 | -9.6 | 0.025 | -11.8 | 0.057 | 5.92 | 48YE697/697.1 |
| KC09.6 | -9.3 | 0.027 | -11.8 | 0.091 | Vertical | 48YE697/697.1 |
| KC19.1 | -9.9 | 0.022 | -12.7 | 0.058 | 38.18 | YNP/94KC1 |
| KC19.2 | -10.3 | 0.009 | -13.6 | 0.044 | 28.62 | YNP/94KC1 |
| KC19.3 | -10.8 | 0.023 | -15.7 | 0.030 | 16.57 | YNP/94KC1 |
| KC19.4 | -10.5 | 0.016 | -15.0 | 0.073 | Vertical | YNP/94KC1 |

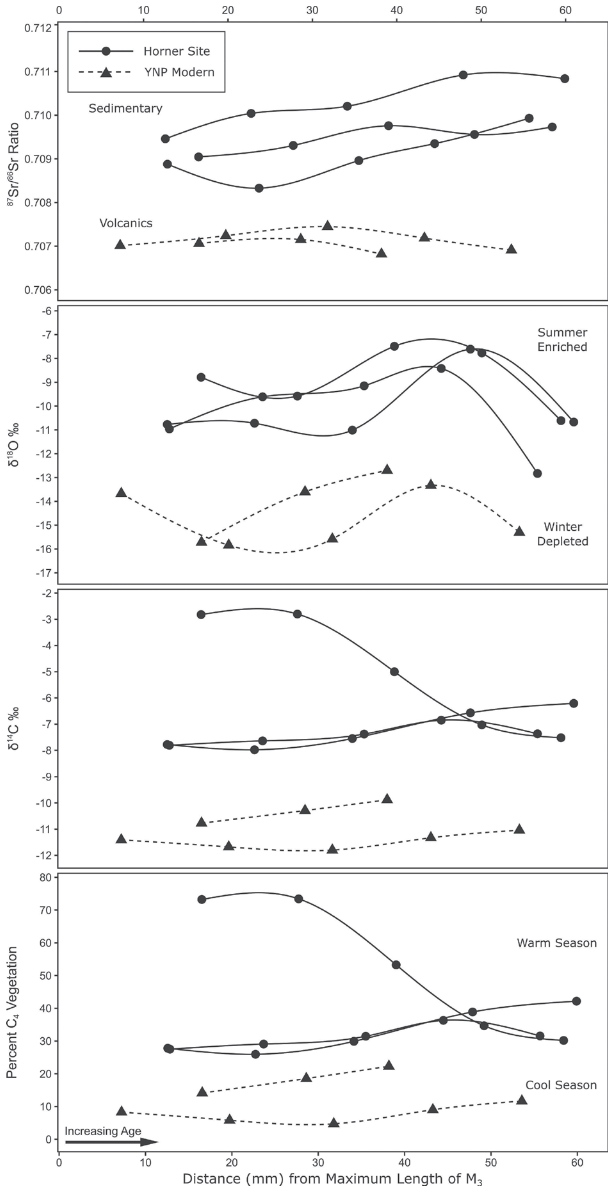



**FIG. 8.15.** The Horner bison ratios (solid triangles) are compared with those from modern Yellowstone National Park (YNP) bison (hollow squares). YNP is characterized by volcanic substrates, higher elevation, cooler temperatures and less $C_4$ (warm season) grasses. Samples were extracted from lower third molars (M3). Values are reported in parts per mil (‰) units relative to VPDB standards.

between the basins and the Yellowstone Plateau, reflected in similar isotopic signatures.

Bison from the early Holocene Horner site were examined in comparison to modern bison, to explore range size and determine if pre-Park bison were migrating seasonally between the lower elevation basin and the high-altitude Yellowstone Plateau (Cannon et al. 2010). The Horner site is a Cody-complex bison kill event (mean age is 9899 ± 79 BP) to the east of the Yellowstone Plateau on the edge of the arid intermountain Big Horn Basin. Excavations at the Horner site carried out by Princeton University and the Smithsonian Institution (Jepsen 1953) and University of Wyoming produced evidence of two distinct bison kills (Frison and Todd 1987). The Wyoming excavations produced a minimum of 65 *Bison* cf. *antiquus* individuals (Walker 1987) from a shallow depression formed by a low-gradient intermittent stream that may have been instrumental in trapping the bison (Reider 1987; see Chapter 3, this volume). Phytolith assemblages reflect a mixed grass environment in a humid and cool climate (Lewis 1987). Wetter conditions are also predicted by Whitlock and Bartlein (1993).

Bison exhibit reproductive synchronicity, and isotopic data from different age cohorts can inform on individual and herd behavior (Berger and Cunningham 1994; Gadbury et al. 2000). The results of the three Horner site bison compared with three modern Yellowstone Plateau bison, which served as controls in this study, show interesting departures between the two samples (Figure 8.15). Strontium values of sedimentary and volcanic substrates are significantly different (e.g., Porder et al. 2003) and indicate the Horner bison range did not extend onto the Yellowstone Plateau but were restricted to the Bighorn Basin. The data reflect seasonal shifts in $\delta^{18}O$ values but are significantly enriched in comparison to modern samples. Enrichment may reflect warmer temperatures and/or greater evaporation during the early Holocene.

The $\delta^{13}C$ values, used as a proxy for diet, display limited variability in two of the samples (1.77 [1181H] and 0.96 [2548H]), with the youngest (1233H) illustrating much greater variability (4.7 ‰). Individuals illustrate significantly different values for both $\delta^{18}O$ ($t = 51.251$, $p = 0.000$) and $\delta^{13}C$ ($t = -14.937$, $p = 0.000$). This pattern suggests greater variability in the landscape from year to year, or less cohesion in herd dietary behavior and water-intake sources. Greater reliance on $C_4$ vegetation in the Horner bison is demonstrated by higher $\delta^{13}C$ values. These individuals also demonstrate greater variability than other early-Holocene bison assemblages (Cannon 2008). Calculated mean annual temperature based on $\delta^{13}C$ values (Hoppe 2006; Hoppe et al. 2006) indicates warmer temperatures during the early Holocene in contrast to phytolith and other proxy data (e.g., Lewis 1987; Reider

1987). This pattern is consistent with bighorn sheep results from the region (Hughes 2003).

As reflected in the Horner sample, these bison appear to have had a range that was restricted to the Bighorn Basin (sedimentary rocks) and were not migrating onto the Yellowstone Plateau (volcanic rocks). This range restriction is also apparent in the comparison of YNP bison and Jackson Hole bison (Figure 8.16). A similar pattern of limited annual migration was also found for middle Holocene bison in the eastern Great Plains (Widga et al. 2010). The patterns suggested by the distinct strontium signatures of the three bison populations may have critical implications for management of contemporary herds and our understanding of how these populations used the landscape (e.g., limited range would have made bison a more predictable prey item for precontact hunters). For example, the Sr data suggest, although a larger sample is necessary to fully support this, that YNP had a prehistoric

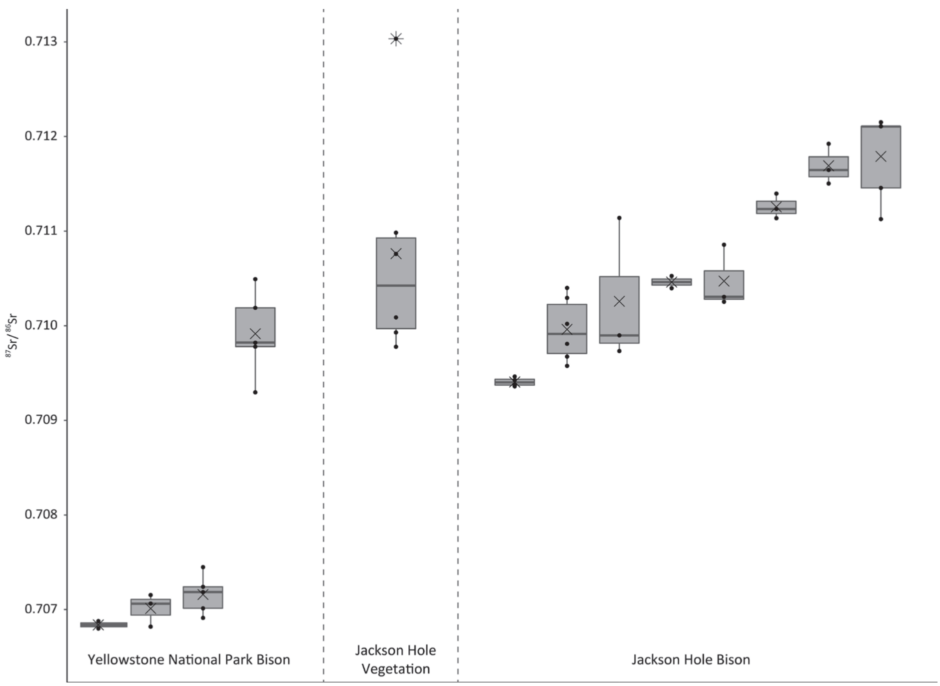



**FIG. 8.16.** Box and whisker plot of $^{86}Sr/^{87}Sr$ signatures for Jackson Hole and Yellowstone National Park bison.

resident herd of bison that appears to have been spatially segregated from other herds in the Bighorn Basin and Jackson Hole. Has the loss of these resident herds had a deleterious effect on bison genetic heterogeneity; was there genetic isolation of these herds? The idea of a resident YNP herd may provide some fuel to revisit the idea of a 'mountain' or 'wood' bison (*Bison bison athabascae*) initially proposed by taxonomist Samuel Rhoads in 1897 (Rhoads 1897) and further explored by Skinner and Kaisen (1947). Cannon (2008:40–55) also addressed this question by conducting discriminant function analysis of prehistoric bison skulls which illustrated a potential genetic isolation of Jackson Hole bison likely due to genetic drift.

## The Bison Genome

Yellowstone National Park bison have been at the center of genomic studies for over two decades. These studies have largely focused on the fidelity of the bison genome and the potential incursion of cattle genes in public herds (Halbert and Derr 2007; Ward et al. 1999), but also how mitochondrial DNA (mtDNA) can be applied to delineate the history of the bison and inform future conservation actions (Forgacs et al. 2016). These studies concluded that, despite a history of intensive management and periods of extreme size reduction, the YNP bison population "appears to be genetically healthy" (Forgacs et al. 2016:10). However, they also warn that prior to the development of new management standards and policies, additional studies of the population's genetic diversity at both the mtDNA level and nuclear genetic level must be conducted (Forgacs et al. 2016:10). This is a significant issue in conservation biology, the management of genetic diversity and integrity of threatened populations (Meffe and Carroll 1997).

A key to this likely lies in understanding the deeper history of the bison genome that involves the study of subfossil bison (Heintzmann et al. 2016). Bison initially colonized North America from Asia across the Bering Land Bridge during the sea level lowstand (MIS 6) between 195 and 135 kya through Alaska, rapidly colonizing the Great Plains ecosystem that was previously dominated by horses and mammoths for more than one million years (Froese et al. 2017). The success and resiliency of this species is evident by their successful dispersal and colonization into North America but also by its vast range from boreal forests to desert steppe and into the alpine (McDonald 1981). Despite this resiliency the effect of potential genetic bottlenecks and modern culling to the behavioral plasticity of the species has not been fully explored and will require study of the full nuclear genome (Shapiro et al. 2004).

Future research of the bison genome will involve well-preserved individuals, some of which are potentially present in the GYE. Archaeological kill sites represent static moments in time, therefore reflecting a cross-section of a population at the time of the event. These assemblages can provide detailed information on herd structure (e.g., age profiles and sex ratios), as well as genetic diversity prior to presumed genetic bottleneck caused by the near extermination of bison in the late nineteenth century. The structure and genetic diversity of these groups can then be compared to modern herds to assess how genetic diversity has changed over time. Such comparisons can potentially alert biologists and/or managers to populations that may be at risk to the various consequences of low genetic diversity, for example the increased prevalence of deleterious alleles and inbreeding depression.

These studies may also help to clarify the confusing taxonomy of the Plains bison and the mountain/wood bison. Currently, two clades are recognized: a northern clade and a southern clade (Shapiro et al. 2004). As was demonstrated by Shapiro and colleagues (2004), almost none of the genetic diversity present in Pleistocene bison survived into Holocene populations. Do modern management practices, including the domestic ranching of bison, have the potential to further degrade the bison genome and seriously impact the long-term survival of this iconic species? Again, management of the genetic diversity and integrity of threatened populations is an important issue in conservation biology (Meffe and Carroll 1997); subfossil bison in the GYE may play a key role in that effort.

## Concluding Statements

In this chapter we have presented a historical record of bison in the GYE based upon the extant archaeological record. The record, although incomplete, extends back nearly 12,000 years and supports the notion that bison have been an integral part of the ecology and economy of the region for the length of the Holocene (Cannon 2008). In recent years, the archaeological record of bison has been queried by non-archaeologists in an effort to critically evaluate management decisions in YNP (e.g., Keigley 2019). However, these studies have typically used the record in a simplistic presence-absence argument without fully understanding how the record came to be visible to archaeologists. This methodology is fraught and can lead to misrepresentations of the true nature of bison during pre-Park times (Cannon et al. 2020). It also minimizes the value of archaeological data to the discussion (Lyman and Cannon 2004).

The archaeological record, through various methods and technologies (e.g., isotopic analysis), can begin to provide a more dynamic story of bison in the GYE that can more thoughtfully inform management of this species on public lands. While we recognize that it is an environment that is challenging for the preservation of faunal remains, particularly on the Yellowstone Plateau where soils tend to be acidic, shallow, and subject to frequent bioturbation, there are unique places where a well-defined record exists and can provide fine-grained data for analysis. The archaeological record can contribute directly to the resolution of various conservation issues, such as: (1) precontact herd demographic structure (e.g., the Horner site), (2) the distribution of precontact populations, (3) information on bison ecology and land-use patterns, (4) herd range predictability for precontact hunting, and (5) a temporal record at an evolutionary scale for the genetic conservation of modern populations.

We present an argument that the archaeological record is an important source of data for addressing long-term development of ecosystems (Cannon and Cannon 2004) but must be understood in the context of the complexity of the archaeological record, because that is how the archaeological record is formed and interpreted by archaeologists. We hope our chapter can be seen as a way forward in developing interdisciplinary research teams of wildlife biologists, rangeland managers, and archaeologists in the investigation of the long-term record of bison, as well as other species, for a more complete understanding of our past and how it can be applied to create a more thoughtful and informed management policy.

## Acknowledgments

The relevance of zooarchaeology to contemporary wildlife management became an interest of mine (lead author, Kenneth Cannon) initially as a master's student under the mentorship of Dr. Klippel. The roots of those ideas were based upon conversations with Walter and the late Dr. Paul Parmalee but grew during my years with the National Park Service. This chapter is derived from my dissertation and other research that is a direct result of Walter's mentorship and his multidisciplinary research. We would like to thank the editors, Meagan Dennison, Jennifer Green, and Samantha Upton, for their persistence and patience in putting this volume of papers together. We would also like to acknowledge the anonymous reviewers who made this a more solid chapter. There have been many who contributed to our understanding of the zooarchaeological record and how it may contribute to our understanding of public land management dating back to my (KPC) graduate days at the University of Tennessee and my (KPC) tenure at the Midwest Archeological Center. Many thanks to Walter Klippel and Paul Parmalee who initially planted the seed. Others who supported me and generously shared their knowledge of bison and the region include Rob Bozell, Cal Calabrese, Molly Cannon, Bill Eckerle, Sheri Fritz, Ralph Hartley, Lee Lyman, Dan MacNulty, Kenneth Pierce, Alan Osborn, Paul Schullery, Larry Todd, Cathy Whitlock, Lee Whittlesey, Chris Widga, and David Wishart.

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