Quaternary Research 73 (2010) 449–463

Contents lists available at ScienceDirect

Quaternary Research

journal homepage: www.elsevier.com/locate/yqres

Middle Holocene *Bison* diet and mobility in the eastern Great Plains (USA) based on $\delta^{13}C$, $\delta^{18}O$, and $^{87}Sr/^{86}Sr$ analyses of tooth enamel carbonate

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ARTICLE INFO

Article history:
Received 14 March 2008
Available online 6 March 2010

Keywords:
Bison
Isoscapes
Stable Isotopes
Teeth
Strontium
Carbon
Oxygen
Migration
Middle Holocene
Eastern Great Plains

ABSTRACT

During the Holocene, bison (*Bison bison)* were key components of the Great Plains landscape. This study utilizes serial stable isotope analyses (tooth enamel carbonate) of 29 individuals from five middle Holocene (~7–8.5 ka) archaeological sites to address seasonal variability in movement patterns and grazing behavior of bison populations in the eastern Great Plains. Stable carbon isotopes ($\delta^{13}C$) indicate a bison diet that is similar to the C3/C4 composition of modern tallgrass prairies, while $^{87}Sr/^{86}Sr$ values generally indicate very little seasonal movement (<50 km) and relatively limited inter-annual movement (<500 km) over the course of 4–5 yr. Analyses of variability in serial stable oxygen isotope samples ($\delta^{18}O$) further substantiate a model of localized bison herds that adhered to upland areas of the eastern Plains and prairie–forest border.

Introduction

Bison are ubiquitous in the late Quaternary record of the North American Great Plains. The behavioral ecology of these large herbivores is sensitive to spatial and temporal variability in animal habitat. Therefore, bison behavior is visible in the isotopic ecology of individuals represented in the fossil record. This study examines bison diet and landscape-use in the eastern Great Plains through multiple stable isotope ($\delta^{13}C$, $\delta^{18}O$, $^{87}Sr/^{86}Sr$) analyses during the middle Holocene (7–8.5 ka), a period usually known for increasing aridity and drought. Specifically, we are interested in understanding bison responses to aridity, which requires careful consideration of diet ($\delta^{13}C$), water-use ($\delta^{18}O$), and animal mobility ($^{87}Sr/^{86}Sr$) at the sub-annual resolution that is possible through the incremental study of bison dentitions.

The Great Plains record of bison is unique. It is one of those rare instances where significant numbers of large animals from a single biological population routinely entered the fossil record at the same time. These remains can provide herd-scale biological data on a species that has since been extirpated across the region. The expansive historic range of bison masks significant differences between different local bison populations. Diet, movement patterns, and seasonal herd dynamics could be strongly affected by variability in regional resource structure (Van Vuren and Bray, 1986; Widga 2006a). Through consideration of penecontemporary, population-level trends in bison dietary niche and movement patterns, the degree of variability in middle Holocene bison landscape-use can be assessed.

Although overall landscape responses to middle Holocene aridity in the North American Great Plains have been investigated (Grimm, 2001; papers in Bettis, 1995), it is unclear how these conditions affected bison populations (Bamforth, 1988; Meltzer, 1999). Increasingly severe and frequent drought cycles would have changed the quality and quantity of bison forage, as well as the seasonality of preferred grazing resources. Given the patterns in modern bison grazing behavior, we would expect these animals to respond to drought conditions in terms of increased mobility (Fortin et al., 2003), an overall decrease in population size or even morphological change (Craine et al., 2009; Hill et al., 2008). Furthermore, because bison require fresh drinking water, the temporal and spatial distribution of water sources is important (Bamforth, 1997; Sheehan, 1994). Quantitative measures of the bison response to landscape changes are rare in the literature, with most studies forced to rely on models based in behavioral ecology (e.g., Bamforth, 1988) or historical documents (e.g., Bamforth, 1987; Reher, 1978; Tatum, 1980) which are of dubious utility when investigating middle Holocene bison.

This study investigates the isotopic ecology of four bison-dominated, middle Holocene archaeological assemblages from the western tallgrass prairie and one assemblage from the prairie–forest border (Table 1, Fig. 1). Down-tooth stable isotope analyses from these assemblages present relatively high-resolution and seasonally

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0033-5894/$ – see front matter
doi:10.1016/j.yqres.2009.12.001

Table 1
Description of bison assemblages used in the current study.

Name	State	Site type	Age (cal yr BP)[a]	Bison NISP (MNI)	Series Length (yr)	# Individuals (# teeth)	# Light isotope samples	# Sr samples	Reference[b]
Simonsen (lvl. 7)	IA	Bison Kill	7610–7800	1172 (21)	4+	10 (7)	53	13	Agogino and Frankforter, 1960
Cherokee Sewer (IIb)	IA	Camp/Processing site	8170–8930	205 (13)	5+	3 (4)	9	29	Anderson and Semken, 1980
Hill	IA	Camp/Processing site	7420–7570	56 (2)	2+	1 (2)	10	10	Frankforter, 1959
Itasca	MN	Bison Kill	7790[c]–7970	2969 (16)[d]	4+	11 (12)	90	31	Shay, 1971
Logan Creek (Zone B)	NE	Camp/Processing site	6980–7480	901 (17)	4+	4 (4)	27	27	Widga, 2003

[a] Combined age range, calibrated in OxCal 3.1 (Bronk Ramsey, 2005) using IntCal04 (Reimer et al., 2004); see Supplementary Table 1 for complete listing of ^{14}C age-estimates.
[b] All assemblages re-analyzed in Widga, 2006b.
[c] An earlier component is also present at this locality (8520-8180 cal yr BP).
[d] Quantification of bison remains from Shay, 1971.

calibrated records of middle Holocene environmental conditions and offer insight into the response of large mammal communities to middle Holocene paleoenvironmental change. Stable isotope studies have the potential to track, or at least constrain, bison movement patterns in the Great Plains. Early work (Chisholm et al., 1985) examined δ^{13}C patterns in late Holocene bison bone collagen to understand animal migratory behavior. These researchers suggested that bison migrated between shortgrass plains and bordering parklands because bone collagen δ^{13}C values, a material that represents a multi-year average of the diet, were intermediate between C3 and C4 diets suggesting that these bison periodically inhabited both areas.

Since that time, researchers have continued to utilize stable isotope tracers in bison migration studies. Koch et al., (2004) examined tooth enamel δ^{18}O and δ^{13}C values to infer bison movement patterns suggesting that bulk samples from herbivore teeth, representing ~1 yr of growth, should exhibit a predictable amount of

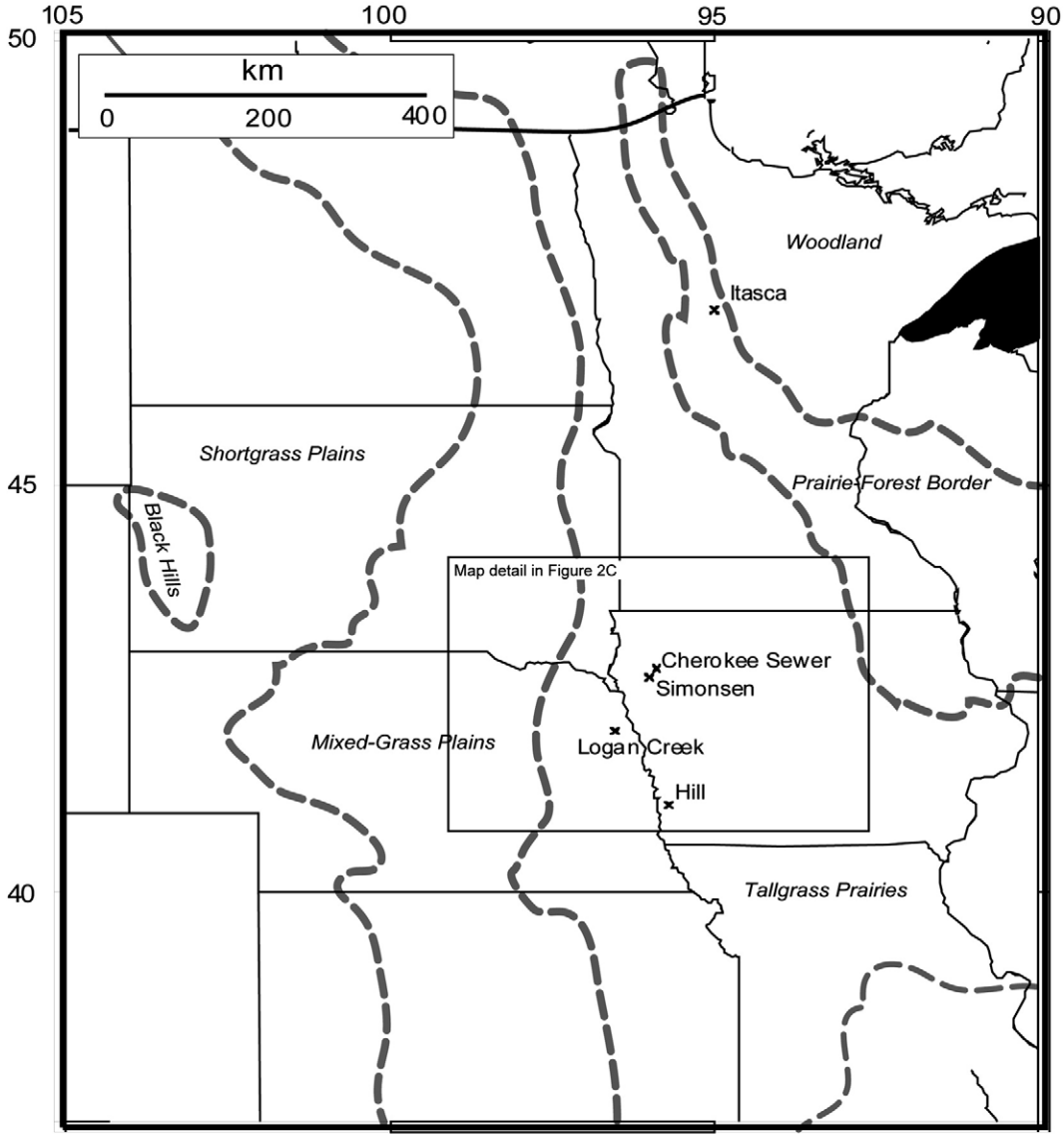

Figure 1. Map of localities discussed in this study. Great Plains ecological divisions are based on Omernik (1987).