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Author(s): Douglas B. Bamforth
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HISTORICAL DOCUMENTS AND BISON ECOLOGY ON THE GREAT PLAINS

by

Douglas B. Bamforth

ABSTRACT

Although many anthropologists have studied the Plains bison using historical documents, such studies often do not consider the information needed to make ecological sense out of the data these documents contain. Arguments about the "predictability" of herd movements are particularly weakened by this problem. Modern ecological research indicates that there are two critical factors which need to be addressed in reconstructing bison ecology on the Plains: the pattern of forage and other conditions which structure bison adaptations to a given local environment, and the effect of white expansion and predation upon these adaptations. This paper discusses several important aspects of the relationship between environmental conditions and bison ecology and presents information suggesting that historical records document a period during which bison adaptations were being seriously disrupted. Direct extrapolations from historic to prehistoric times which rely on these records are therefore uncertain.

INTRODUCTION

As the role of bison procurement in aboriginal High Plains society has become increasingly apparent to anthropologists, so too has the importance of understanding bison herding and migration patterns. Because bison no longer exist under natural conditions on the Plains and, thus, cannot be studied directly, many of the recent arguments over these aspects of bison ecology (Arthur 1975; Hanson 1984; Morgan 1980) have relied heavily on historic records which indicated the size and location of bison herds seen in the past at various times of the year. Roe (1970: 334-366; cf. Eltringham 1979:75-76) noted some of the problems in interpreting the information contained in these records. However, there has been little explicit consideration either of what data, in addition to notes on herd sizes and locations, are needed to make ecological sense out of relatively unsystematic historical observations, or of how bison adaptations in Historic times may have differed from bison adaptations in earlier periods.

Two important factors are rarely considered in attempts to reconstruct bison ecology from historical records. First, despite a great emphasis on reconstructing migration patterns, these attempts often do not explicitly address either the factors which lead ungulates to migrate or the effects on migration

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patterns of variation in these factors. Second, despite voluminous documentation of changes in the ways humans exploited the Great Plains in general and the bison in particular over the course of the eighteenth and nineteenth centuries, reconstructions of bison ecology have only occasionally discussed, and in some cases have explicitly denied, the possibility that these changes might have disrupted bison adaptations in the region. My purpose here is to discuss ecological data on modern ungulate adaptations which bear on these two topics and to consider the implications of these data for studies of bison ecology on the Great Plains which rely on historical documents.

Much of the debate over bison ecology has centered on the degree of predictability in bison movements. Because human hunters were not physically capable of literally following herds of migrating bison (cf. Burch 1972), Plains societies had to know where the herds would be at different times of the year. Using this knowledge, hunters could position themselves in places where they could successfully make a kill. The notion of "predictability" in this context has essentially been taken to refer to the regularity with which bison herds returned to the same points on the landscape at the same time of the year. Debate over this issue to date has tended to present only two alternative positions; the bison are said either to have moved in extremely repetitive seasonal migrations within a large region (i.e., Morgan 1980; Syms 1977, 1979) or to have been utterly unpredictable and found in any part of their range at any time of the year (Hanson 1984; McHugh 1972; Roe 1970).

As in most cases where incompatible positions can be supported by different sets of data, the actual situation was probably somewhere on the middle ground. As is discussed below, animal distributions can be "predictable" in a sense which allows hunters to exploit their prey with great success without those distributions being precisely the same from year to year. Although occasional starvation among the Plains tribes leaves no doubt that bison movements were "unpredictable" to a degree, there is good reason to expect that the bison had reasonably repetitive responses to variation in local forage and weather conditions. The careful observation of animal species typical of hunter-gatherers would almost certainly have led Plains Indians to recognize these conditions and bison responses to them. This knowledge would then have allowed Plains tribes to predict hunting conditions successfully despite variation in the herds' locations and sizes.

SOME RELEVANT UNGULATE ECOLOGY

Although the North American bison can no longer be studied in its natural habitat on the open Plains, general ecological principles derived from modern studies of species with similar habits can often explain or predict selected aspects of its adaptation. It is important to note, however, that reliance on such principles is not simply a matter of transplanting specific patterns of behavior from one species to another. Generalizing ecological relationships between species depends on two factors. First, it is necessary to identify the conditions to which a given species is adapted and its responses to variation in those conditions. Second, it is necessary to demonstrate that essentially the same conditions obtain for the second species and that this species has adapted to them in essentially the same way. When similar environments are exploited in similar ways by different species, it is reasonable to expect those species to respond to variation in those environments in similar ways.

By far the best modern ecological research on large, gregarious grazers such as the bison has been conducted in the Serengeti and other regions of East Africa. The incredible diversity of fauna in this area has provided ecologists with an array of responses to similar environmental conditions, and these responses illuminate the basic nature of ungulate adaptations.

The basic determinant of these adaptations shown in the Serengeti data is the pattern of spatial and temporal variation in forage conditions. The Serengeti grasslands show a clear seasonal progression in forage abundance and nutritional quality as a direct response to rainfall: grass growth and quality are systematically highest in the wet season and lowest in the dry season. The amount of forage produced determines the size of the herbivore populations in the region (Sinclair 1975, 1977). Different parts of the region receive different amounts of rain dur-

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ing the wet season and experience different degrees of aridity during the dry season, and the distribution of rainfall at any one time, even within one of these regions, is extremely patchy (McNaughton 1979; Norton-Griffiths et al. 1975; Sinclair 1977). Differences in the ways in which particular species of ungulates are adapted to this environment are determined principally by interspecific competition (Sinclair 1974, 1979:14-15, 20-21; Sinclair and Norton-Griffiths 1982).

Speth (1983) points out that the grasslands of the Great Plains show an extremely similar pattern of seasonal growth and forage quality to that seen in the Serengeti, with production and quality highest during the late spring and summer, when most rain falls, and lowest during the winter. Low winter temperatures also inhibit grass growth during much of the year, particularly on the Northern Plains. As in the Serengeti, the distribution of rainfall at any one time on the Plains is very patchy (see, for instance, Haragan 1976). The North American bison, therefore, exploited an environment whose basic structure was quite similar to that now being exploited by the East African herbivores. It is highly likely that many of the general ecological relationships (although not necessarily the specific adaptations) found among African species should be relevant to the bison.

The remainder of this section discusses a variety of ecological data, drawn largely, but not entirely, from East Africa, which bear on two topics: the role of forage distributions in the movements of large, gregarious ungulates and the effects of hunting and human settlement on ungulate adaptations.

Why Do Large, Gregarious Ungulates Move Around?

As was noted above, understanding bison migration patterns is particularly important to anthropologists working on the Plains. There are at least three major reasons why large herbivores migrate from place to place: to search for food and water, to search for other members of their species, and, like other sensible creatures, to escape dangerous or uncomfortable circumstances. The first of these is by far the most important and is the only one I will discuss here. Human hunting as a source of danger is addressed in a later section.

As part of an exhaustive analysis of animal migrations, Baker (1978:546-551) discussed the effects of the distribution and abundance of food and water on group dispersion and aggregation. Most of the time, water is available in relative abundance at a few restricted locations such as rivers or lakes, and animals (such as bison), which cannot obtain sufficient water from the plants they eat, often form relatively large groups at these locations. These aggregations, however, cannot remain permanently near water because they exhaust local forage as they feed; most ungulates, therefore, commute between feeding and watering areas (cf. Pennycuick 1979).

Seasonal changes in forage conditions affect these movements. During the growing season, grassland herbivores are presented with a superabundance of highly nutritious food which can support high densities of animals in relatively small areas; the aggregations of many grazing animals for the annual rut are clearly coordinated with the period of greatest forage production. During the dry season in tropical regions or the winter in temperature regions, though, forage is of poor quality and is dispersed at low densities across the landscape. No small area can support many animals under these conditions, and dispersion during these periods is common.

As Baker (1978:551) has pointed out, this basic pattern is often modified by winter conditions. Snowfall can enhance the dispersive effects of poor winter forage by satisfying an animal's water needs; animals which get their water from snow do not regularly have to seek out a fixed and limited number of watering areas. When the snow is too deep to dig through, however, grazing animals are forced to search out windswept, sheltered, or otherwise scantily-snowclad areas where patches of food can be found. Relatively large aggregations may then form in these areas.

On average, then, we can expect a basic pattern of winter dispersion and summer aggregation for gregarious ungulates in temperate regions, but this pattern is likely to break down in direct response to increases in snowfall. The increasingly severe winters which are generally associated with greater amounts of snow also tend to bring high

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winds and low temperatures which can also drive animals out of open areas and into more sheltered and, usually, more restricted regions. Both of these factors will tend to inhibit the degree of winter dispersion. The varying seasonal distributions of food and water and different climates in different regions should thus lead to predictable variations in the seasonal patterns of herbivore migration and aggregation. Overall, a herd of a given size will have to move less frequently and over shorter distances when forage and water are abundant and widely distributed than when they are sparsely and patchily distributed (also see McHugh 1958:12).

Almost no region in the world, however, has a climate which produces identical conditions from year to year, and these deviations from average conditions affect the availability of food and water and thereby alter animal herding and migration patterns. As was just discussed, the quality and amount of forage in a region is a critical determinant of these patterns. In the grassland environments, which are most important here, forage production and climate are intimately linked. Not only is total annual forage production in these environments largely a function of the amount of precipitation they receive (Coe et al. 1976; Sims and Singh 1978; Sinclair 1975), but the nutritional quality of the forage produced, particularly its protein content, drops dramatically under conditions of insufficient moisture (Lyttleton 1973). Thus, forage production and palatability from year to year vary in direct response to fluctuations in precipitation.

In addition, local patterns of forage production within a given year vary with local precipitation patterns. Native range grasses grow in spurts in direct response to even tiny amounts of local precipitation and remain largely dormant between rainfall events (Sala and Lauenroth 1982). Therefore, the distribution of relatively high quality forage in a region at any given moment forms a mosaic of patches of varying forage quality, with the distribution of high quality patches largely controlled by the spatial distribution of available moisture. This mosaic is determined largely by the location of permanent water sources and areas where rain has recently fallen.

Grazing animals quite clearly have evolved the ability to respond to the specific structure of such a mosaic, both through their feeding habits and through their migration patterns. All wild ungulates which have been studied, including North American bison, African buffalo, topi, impala, zebra, Thomsen's gazelle, and wildebeest (see Bell 1971; Jarman and Sinclair 1979; Peden 1972; Sinclair 1977), select food with a higher nutritional content than that of the average forage available to them.

Because the nutritional content of plants is highest in their early stages of growth (Sinclair 1975, 1977; Speth 1983), this tendency frequently leads large ungulates to systematically seek out new growth within a grazing area and to seek out areas where plants are actively growing; that is, to move to the higher quality patches in the regional mosaic. Both the highly migratory wildebeest (Maddock 1979; Talbot and Talbot 1963) and, occasionally, the much less migratory buffalo (Sinclair 1977:98) actually migrate towards areas where they can see rain falling, apparently in anticipation of good forage conditions. For the buffalo, though, the more common pattern is for the herds to move into a previously dry environmental zone two months after rain has fallen there and the grasses have had time to grow (Sinclair 1977:66-67). Despite the overall spatial unpredictability of precipitation and, hence, of forage quality at any given moment in the Sergeneti, the more migratory species of herbivores there are almost always found near fresh green forage. McNaughton (1979: 71), in fact, states that "the fundamental paradox of the grassland-herbivore dynamics in the Serengeti ecosystem is the extent to which coevolution of grasses and ungulates has superimposed a deterministic functional system on an inherently stochastic environment."

To summarize, the distribution and quality of forage in a region are major determinants of ungulate migrations. Aggregations tend to occur during seasons when forage productivity is highest, while dispersion is most common during seasons when it is low, although factors such as excessive snowfall can modify these basic patterns. Natural selection has led grazing animals to develop both the ability to select the highest quality forage available to them at any one place and to seek out those places within a larger region

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where high quality forage can be found. Migrations tend to be closely associated with the locations of permanent water and recent precipitation because these factors are the major determinants of forage quantity and quality.

Hunting, Human Settlement, and Ungulate Ecology

Although less research has been conducted on the specific effects of human activities on large ungulates, certain basic patterns related to the effects of hunting and of the appearance of new permanent settlements in a region seem to be clear.

One obvious effect of an increase in hunting pressure is to increase the overall mobility of the prey species. As the individuals or herds escaping their hunters flee, they often cause nearby individuals and herds to flee with them. The degree of wariness of a prey species increases through experience with hunters (Mloszewski 1983:38, 139; Moen 1973:236) and one result of increased wariness is clearly to increase the likelihood of a herd fleeing from any disturbing stimulus. Mloszewski (1983:67), studying African buffalo, also states that "heavy and irregular predation, particularly by man, . . . often leads to erratic movements and even to herd disintegration." In addition, unsystematic removal of portions of a herd rather than complete cropping of entire social units not only frequently stampedes the surviving animals but also appears to create larger aggregations of animals in the vicinity of the hunting area. This is probably at least partly a response to the disruption of the existing social structure of the herds (Laws et al. 1975:105; Laws 1981:227).

Establishing permanent human settlements in a region also appears to increase herd size in neighboring areas, as the animals who previously inhabited the settled areas are driven into the ranges of neighboring herds. This increases local animal densities and requires that the new migrants be integrated into the existing social structure. Such a pattern is clearly present among elephants in Uganda, where herd sizes on the margins of their range adjacent to recent settlements are much larger than elsewhere (Laws et al. 1975:104-105). It is important to note that this process can also operate without intensive human occupation throughout an entire area if settlements systematically monopolize a critical resource which has a restricted distribution. Exclusion of wild animals from water sources is the most obvious example of such a situation.

Given that a major effect of these types of human interference with large ungulates is an increase in herd size, and bearing in mind the previous discussion of the reasons for ungulate migration, these processes have other inevitable effects (Laws et al. 1975:147). First, larger herds tend to be more widely spaced across the landscape. Second, they exhaust local forage faster than herds with fewer members and, hence, are forced to move more frequently and over longer distances. The formation of larger herds as a result of human activites should thus be accompanied by an increase in the proportion of a region which is essentially devoid of animals and by a greater degree of herd mobility.

HISTORICAL DATA ON BISON HERDS IN ECOLOGICAL CONTEXT

As was discussed above, the timing, direction, and distance of ungulate movements is largely controlled by external environmental conditions, particularly the distribution of forage. This clearly implies that variation in these conditions can lead directly to variation in ungulate movements and that, in order to understand overall migration and herding patterns, this variation must be taken into account. Variation can exist both in the average conditions found in different regions and within a region from year to year.

A recent debate over bison aggregation and dispersion patterns exemplifies the problems which result from ignoring the first of these kinds of variability. The traditional view of this issue (Frison 1971; Oliver 1962) holds that the bison formed large herds in summer and dispersed into much smaller groups during the winter. In contrast, Arthur's (1975) more recent analysis of historical data from the Canadian Plains seemed to indicate that relatively large herds were found there year-round. Although Arthur (1975:120) briefly mentioned the possibility of regional variation in bison adaptations, the clear emphasis of

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his argument was on refuting the traditional view.

The apparent difference between winter herd sizes on the Canadian Plains and elsewhere can be explained as the adaptation of the bison to different environmental conditions in different areas. Snow is deeper and lasts longer and temperatures are lower on the Plains as one moves north (compare Court 1974 with Hare and Hay 1974). This implies, then, that winter herds in Canada should have been larger than in other regions as animals sought out restricted areas where forage and shelter could be found. The data appear to indicate that this was the case. The apparent conflict between Arthur's data for this region and the accepted reconstruction for the rest of the Plains is clear evidence that no single pattern of migration and aggregation characterized all bison in all parts of their range. We can expect similar and substantial variation in bison migration and herding patterns throughout the Plains in response to the substantial environmental variation in the region (Bamforth [1986] discusses the probable basic pattern of variation in bison adaptations on the Plains in more detail.)

Moodie and Ray (1976) are essentially the only writers who have discussed the second source of variation in bison herding and migration patterns: year to year variation in environmental conditions. In particular, they showed how factors such as weather conditions, fires, and human conflict apparently disrupted what would otherwise have been fairly regular bison migrations. The well known wide range of climatic variability on the Plains (Borchert 1951; Thornthwaite 1941) must have led to a comparably wide range of forage and weather conditions with which the bison had to cope over the course of their lives, and on this basis alone there is no good reason to expect that the herds would have acted in exactly the same way every year. Because the range of climatic variability on the Plains is roughly known and its effects on the grasslands can be specified (see, for instance, Coupland 1958), however, the responses of the bison to it should also have been, at least in part, predictable.

This possibility, however, is rarely considered in the majority of anthropological investigations of historic observations of bison herds, with almost all such studies neglecting the local conditions which probably had powerful effects on the locations and sizes of the herds the observers recorded. A particularly clear example of the potential problems this approach to the historical record can create is in Hanson's (1984) recent paper criticizing several earlier reconstructions of bison herding and migration patterns on the northern Plains.

Hanson made two important points. First, his careful reanalysis of modern data on seasonal changes in bison herd size showed clearly that the assertion by Morgan (1980) and Arthur (1975) that herds were larger during the winter than during the rest of the year had no empirical basis. Second, and more important for this discussion, he rejected the reconstructions of bison migration patterns offered by Morgan (1980) and Syms (1977, 1979) by tabulating records of large herds throughout North Dakota during all seasons of the year.

In so doing, Hanson particularly ignored Morgan's (1980:147, 150) specific and repeated qualification that her reconstruction referred to bison behavior "under average climatic conditions as defined by Coupland (1961);" Morgan clearly noted (1980:147) that climatic variability on the northern Plains causes substantial variability in the forage conditions to which she related bison movements. Despite this, Hanson (1984:100) enumerated the recorded locations of large herds at different seasons of the year with no reference to the conditions which might have affected the herd's behavior.

Because his records relate to bison locations during only eight different years, it is quite possible that they do not represent the full range of environmental variation and, hence, of bison responses in the region. Lacking the needed data, there is no way to evaluate whether or not these few years represent the full range of environmental conditions in Hanson's study area. Morgan's hypothesis specifically addressed bison migrations under *average* conditions, and the only data on which it can be tested legitimately are observations of bison under these conditions. The information needed to infer such conditions is clearly difficult to obtain and may often not be available, but Moodie and Ray (1975) have shown that it can be found in at least some cases.

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Environmental analysis in anthropology in general has tended to emphasize average conditions and to ignore the patterns of variation in resource availability to which human beings everywhere have had to adapt (Winterhalder 1980), and the problem addressed here is clearly part of this mainstream approach. This emphasis, though, has a powerfully limiting effect on our understanding, because strictly average conditions almost never actually obtain and restricting our analysis to them restricts the range of human responses we can explain.

The fact that important phenomena vary in space or time does not necessarily mean that they cannot be predicted. A careful analysis of the causes and effects of environmental and resource fluctuations is required before we can claim to understand the conditions under which modern or prehistoric people live or lived. In essence, the point is not that conclusions about the predictability or unpredictability of selected aspects of bison ecology can or cannot be made on the basis of historical records; it is that the observations contained in these records must be studied in an explicit ecological context which considers the effects of both average and deviant conditions.

WHITE EXPANSION AND BISON ECOLOGY

Despite clear changes in the ways in which humans exploited the Plains throughout the Historic Period, only Moodie and Ray (1975) have noted the possible disruptions of bison behavior which these changes might have caused. Roe (1970:385-398), in fact, extensively denies that human predation had any important effects on the predictability of bison movements. Human predation, however, need not simply have pushed the herds back along a continuous front to have seriously affected them.

Moodie and Ray (1976:51; also see Roe 1970:368-370) particularly mentioned that permanent settlement along the Red River in Manitoba by the 1820's prevented the bison in that region from watering along a large portion of the river, thus driving them farther to the west. As was discussed earlier, this is one of the major predictable results of the introduction of human settlements into a region. As was also discussed above, it is likely that one result of such a displacement of game is an increase in herd size and, therefore, herd spacing and mobility in neighboring areas.

Although extensive settlement of the more western Plains occurred mainly after 1840 (McKee 1974:243-265; Webb 1931), it is possible that settlement of the region to the east of the Mississippi River during the eighteenth and early nineteenth centuries caused disruptions of bison migrations and herding patterns which were similar to those along the Red River. Allen (1876) and Roe (1970) have extensively documented the existence of large numbers of bison east of the Mississippi during the early Historic period, particularly on the prairies of Illinois and Indiana and in the Ohio River Valley. McHugh (1972:17) estimates very roughly that there were about two million bison in "the wooded areas bordering the Plains."

These herds had almost completely vanished by the first decade of the nineteenth century (Allen 1876:116). Although the contemporary observers of this disappearance tended to assert that the bison had been driven out of their eastern range, Allen (1876:116-117) rejects this interpretation and argues that the herds were exterminated by wasteful overhunting. The data which Allen cited, though, do not seem to indicate the level of human predation such a mass slaughter should require, and there is some reason to suggest that the pattern of westward expansion across the Appalachian mountains into the eastern bison range was likely to force the herds to move elsewhere.

This could have resulted from the concentration of human transport and settlement near permanent water and along major bison trails to and from such water. The main routes of human migration into the eastern bison range were along the rivers, as the distribution of early settlements in the region clearly shows. Riegel (1930:71) described the preferred characteristics for a homestead site as "fertile soil, the existence of a spring or clear brook for drinking water, and nearness to a navigable stream." The specific confrontation between settlers and bison which Allen (1876: 109-110) cited as the most detailed evidence for wasteful overhunting in the region occurred because a house was built at a salt lick which the bison used. The settlers in this

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house killed several hundred bison for their skins and left the carcasses to rot, thereby permanently driving other herds away. In Kentucky Jakle (1968) has shown that areas away from navigable streams were made accessible to settlers by well-developed "buffalo traces" between feeding and watering areas used by the bison. These traces were used extensively for transport of goods throughout the region and their locations helped to determine the locations of permanent settlements.

It is thus possible that a pattern of American expansion and/or settlement along the major waterways, other permanent water sources, bison trails, and adjacent to resources such as salt licks could have created conditions capable of driving the bison out of their eastern range. The combination of an undoubted increase in hunting pressure in the region with these conditions may thus account for the early disappearance of the herds east of the Mississippi better than does the simple hypothesis that they were hunted to extinction. If large numbers of bison did move west they would inevitably have increased the density of animals in the areas to which they emigrated and, thus, have triggered the changes outlined above, particularly increasing herd size, spacing, and mobility.

The evidence for changes in patterns of human predation on the bison living on the Plains themselves during the Historic period is much clearer. Although the Plains tribes obviously exploited the herds intensively prior to European contact, the development of the fur trade in the eighteenth century led them to produce meat and hides not only for their own needs but also for those of the traders (Ray 1974:125-135). Such surplus production can only have been achieved through an increase in native hunting intensity with its attendant effects on the bison.

The native Plains tribes used a variety of communal hunting techniques to take large numbers of bison in pre-horse times. Archaeologists have emphasized drives where the herds were stampeded over a precipice or into a corral or other trap (Frison 1974; Kehoe 1973; Reher and Frison 1980; Wheat 1972; and many others), at least in part because these procurement methods leave archaeologically visible remains more often than most other modes of hunting. Although drives of this type may indeed have been the most widely used technique, other means of carrying out mass kills are known, including surrounds and fire drives (Arthur 1975:61-95; McHugh 1972:60-82). Ethnohistoric evidence indicates that one of the important aspects of these types of hunts, particularly the communal drive, was the conscious effort made to kill every member of the herd being attacked, in order to minimize the disruptive effects of escaping animals (Morgan 1980:146; Roe 1970:631-632). Although any increase in hunting pressure in a region would almost certainly increase the wariness and mobility of the game there, this mode of hunting is well-designed to minimize the effects of such an increase.

The traditional communal drive relying on a jump or specially constructed pound was clearly used well into the 1800's, at least on the northern Plains. However, the adoption of the horse by the Plains tribes and the advent of white "sportsmen" and commercial hunters introduced a different approach to hunting which ultimately brought the bison to the brink of extinction by the second half of the nineteenth century, and must have seriously disrupted the herds long before that time. As the tribes began to rely on the horse, the traditional drive was used less frequently, and retained a major role only among horse-poor tribes such as the Cree and the Assiniboine. Instead, the Plains tribes began to rely on the horse surround and simply running the bison down on horseback (Arthur 1975:72).

Although these modes of bison procurement were obviously effective and often resulted in killing entire herds, the latter method, in particular, must have often caused the loss of large proportions of the animals in the herds which were attacked. Roe (1970:636), for example, cites one instance where only 41 of a herd of 2000 head were killed in a surround in 1872. This was a great disappointment to the observer of this hunt, who expected the hunters to have killed at least 100. This clearly suggests that it was normal to take only part of a herd this way. The hunters' increased mobility on horseback would certainly have mitigated some of the disruption of the herds which a greater emphasis on these kinds of hunting must have created, perhaps minimizing the effects of these changes on the ability of the Plains

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tribes to exploit the bison. However, anthropological analyses of references to bison herd sizes and locations in historic documents dating after the extensive use of the horse on the Plains must bear these disruptions in mind. Such a change probably increased herd size and almost certainly made the animals far more mobile than in prehorse times.

The advent of white bison hunters and the commercial slaughter of the 1800's, in addition to the changes in native hunting practices, clearly increased the human pressure on the herds far beyond the capabilities of the Plains tribes. Allen (1876), Hornaday (1889), and Roe (1970) have extensively catalogued the extent and results of the slaughter of the Plains bison which began systematically after 1830 and increased steadily in intensity until the species was almost completely exterminated by the end of the nineteenth century. This slaughter not only increased hunting pressure on the herds to almost unimaginable levels, but almost seems to have been purposefully designed to be as disruptive to the bison as possible. Hunters systematically camped at water sources to kill as many animals seeking water as possible and drive the rest away. Other preferred techniques of taking many animals included running the bison on horseback and shooting a herd down from ambush until the survivors fled. "Sport" shooting of bison from passing trains was common. By continuously reducing the bison population on the Plains throughout the nineteenth century, this predation must have affected records of their ecology: if there were fewer animals in any region, for instance, travelers through that region would have encountered them less often.

Given conditions such as these, it is surprising that as careful an analyst as Roe denied that they exerted a profound effect on the herds. In fact, some of his data are suggestively consistent with the effects predicted here. Although good data on herd sizes are few, Roe (1970:334-366) has brought much of the available information together and, furthermore, provides general estimates of bison numbers near three settlements on the Canadian Plains over extended periods of time (Carlton [1776-1863], Victoria [1863-1875] — Roe 1970:591-594). These data can be used to examine the predictions that: 1) bison herd sizes increased throughout the Historic period and 2) herd movements became less patterned and tended to avoid human settlements over time.

Table 1 summarizes the reasonably precise quantitative estimates of herd size presented by Roe (1970:334-336). Although these data are relatively few, they do show clearly that the observations of truly immense individual herds, those numbering in the hundreds of thousands, all date later than 1820, and particularly concentrate in the 1860's and 1870's. These observations culminate with Colonel Richard Irving Dodge's sighting of a single herd of four million animals near the Arkansas River in 1871. This sighting occurred in the heart of one of the major areas of commercial hunting, just three years before the bison in that area of the Plains were completely exterminated (Hornaday 1889:493-502). Given the likely effects of intense predation on large herbivores, it is not "a rather curious fact," as Roe (1970:357) puts it, that no herds of this size were recorded before this late date. The data in Table 2 tentatively suggest that a typical herd of bison under relatively undisturbed conditions contained several hundred to several thousand individual animals, with the largest aggregations numbering in the tens of thousands.

Table 2 presents Roe's (1970:591-594) data on bison numbers around the three settlements noted above. These data are coded into four classes: abundant (including records stating that the bison were "abundant," "numerous," "plentiful," or in "large herds"), scarce (including notes that they were "scarce," accessible but more than two days out, or "seen"), absent (notes that they were "absent" or notes that record "starvation" in or around the settlements), and distant ("distant" or "far distant"). The observations in these four classes are summarized by 20 year intervals in Table 3a; because the numbers of observations for the first 60 years are so low, they are collapsed together in Table 3b.

The totals in Table 3b depart substantially from random expectation (chi-square=16.2, df=6, .025)p), largely because all of the records that the bison were "distant" fall into the latest period. In addition, the observations of "scarce" bison are somewhat too frequent

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Table 1: Bison Herd Sizes on the Great Plains During the Nineteenth Century (from Roe 1970:345-366).

Year	Herd Size	Location
1801	1000 and 5000	Edmonton district
1804	3000	Mississippi River
1806	3000	Cimarron River
1806	9000	Arkansas River
1806	10,000	Missouri River
1806	20,000	near White River
1811	600-800	Missouri River
1811	10,000	Bismark
1819-1820	several hundred	near Sioux River
1820	10,000	Forks of the Platte
1825	1 herd over 1350 square miles	Santa Fe Trail
1831	scores, hundreds, thousands	----
1839	100,000	Santa Fe Trail
1842	more than 11,000	Platte River
1847	10,000	Edmonton
1853	200,00	Lake Zisne, North Dakota
1862	1 herd over 200 square miles	Carlton
1865	1 herd over 100 square miles	----
1869	"moving millions"	Fort Qu'Appelle
1871	4,000,000	Arkansas River
1874	"thousands and tens of thousands"	Cypress Hill
1875	500,000	Montana

in the earlier periods and too few in the later periods. These patterns are consistent with the expected effects of human activities on bison behavior. First, the numbers of observations in the "distant" category in the latest period suggest that the bison were avoiding the settlements more than in earlier periods. Second, if herd sizes were increasing, there would necessarily be a parallel decrease in the number of smaller herds and thus a tendency to find either many bison or no bison in a region.

In addition, as overhunting steadily reduced the numbers of bison on the Plains, the survivors must have tended either to use less of their former range or to use it less consistently simply because fewer animals cannot consume the same amount of grasses and cover the same area as larger numbers of them can. Maddock (1979:108), for instance, notes that the dramatic increase in wildebeest numbers in the Serengeti since the early 1960's has led to greater use of the northern long-grass portions of their range; this has probably occurred because the larger modern population exhausts its southern short-grass feeding areas faster than did the smaller earlier population (cf. Pennycuick 1975:84). Similarly, Meagher (1973:32-36) found that recent decreases in the bison population in Yellowstone Park led the remaining animals to forage over smaller areas.

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Table 2: Observations of the abundance of bison near Carlton, Victoria, and Edmonton from 1776 and 1875 (from Roe 1970:591-594). Each entry refers to a single record of bison numbers noted by Roe. 1 = "abundant", "numerous", "plentiful", "large herds"; 2 = "scarce", "seen"; 3 = "starvation", "none"; 4 = "distant", "far distant".

Year	Carlton	Victoria	Edmonton
1776	1, 1		
1794	1		
1808	1		
1810			1, 2, 3
1811			2
1820	2		
1821			2
1837	2		
1840	1		1
1841	2		1
1842			1, 3
1843			2
1845	1, 2, 2		3, 3
1846	2		1
1847			1
1848	1		1
1857	1, 1, 1, 2, 3		1, 1
1858	1, 1, 2, 4		2, 3, 4
1859	1		1, 3, 3
1861			3
1862	1, 1, 1, 4		4
1863	3	1, 4	1
1864		4	1
1865		1, 4	1
1866		4	4
1867		4	4
1868			2, 4
1869		1	
1870		4	
1872		1, 4	1, 4
1875		3	1

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Table 3. Summary of the observations of the abundance of bison listed in Table 2. Table 3a summarizes by 20 year interval and Table 3b collapses the intervals from 1775 to 1834 together for analysis.

Table 3a:

Interval	Abundant	Scarce	None	Distant	Total
1775-1795	3	0	0	0	3
1796-1815	2	2	1	0	5
1816-1835	0	2	0	0	2
1836-1855	9	6	3	0	18
1856-1875	21	4	7	15	47
Total	35	14	11	15	75

Table 3b:

1775-1835	5*	4	1	0	10
	(4.7)**	(1.9)	(1.5)	(2.0)	
1836-1855	9	6	3	0	18
	(8.4)	(3.4)	(2.6)	(3.6)	
1856-1875	21	4	7	15	47
	(21.9)	(8.8)	(6.9)	(9.4)	
Total	35	14	11	15	75

* observed total

** expected total

The magnitude of the effects of human hunting and settlement on the bison is emphasized by the fact that these patterns are apparent even without attempting to control for the ecological factors discussed above. The data presented in Tables 1 through 3 were compiled by Roe with no information on the local forage or other conditions associated with them. Despite this, the evidence is consistent with the expectations presented here.

To summarize, the nature of the changes in human settlement and hunting patterns on the Plains and adjacent areas during the Historic period is very likely to have seriously disrupted the adaptations of the bison, particularly herding and migration patterns. Observations of similar disruptions of modern ungulates suggests that the bison should have tended to aggregate into increasing larger, more widely spaced, more mobile herds, which possibly migrated more erratically and avoided areas of permanent white settlement more throughout the eighteenth and particularly the nineteenth centuries. The limited available data are consistent with these predictions.

SUMMARY AND CONCLUSIONS

I have attempted to make two points here. The first is that, in order for anthropologists to derive accurate information about the nature of bison herding and migration patterns from historical documents, we must systematically attempt to examine the factors,

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such as local weather conditions, which had predictable effects on the herds whose presence those documents note. Given the great variation from year to year and from place to place in factors such as rainfall and forage conditions on the Great Plains, analyses which do not take them into account will almost certainly overestimate the capriciousness and unpredictability of the bison, inevitably leading to misinterpretations of cultural-ecological relationships in the region.

Second, we must be suspicious of attempts to use even the most carefully and fully documented historical data to reconstruct prehistoric bison ecology because of the probable disruptive effects of white contact on the bison. Despite the fact that these disruptions are problems to be factored out of analyses of *prehistoric* human adaptations on the Plains, they were an important part of the environment to which the historic tribes had to adapt and hence are critical in understanding the forces affecting those tribes during the eighteenth and nineteenth centuries.

One last possible issue in studying historical data on ungulate ecology has not been considered here: simple observer error. In 1909 and 1910, Theodore Roosevelt travelled through East Africa and later published an account of the fauna of the region. In this book, he describes the overall pattern of wildebeest migration:

> "Usually, wildebeest are very local in their habits, the same herd keeping within a radius of three or four miles . . . when water grows scarce the herd may have to trek to it . . . and if drought dries up the pasturage then all the wildebeests of a locality may have to shift their ground . . . only to halt when they have reached some place which perhaps none of their kind have visited since years before the oldest among them were born (Roosevelt and Heller 1914:364-365)."

In fact, such a pattern of basic sedentism and occasional movement to unknown areas bears no resemblance at all to actual wildebeest migration patterns. Throughout most of its range, the wildebeest is among the most mobile ungulates known, with its annual and extremely regular long-distance migrations being recognized by local Kenyan game wardens as early as 1912 (Talbot and Talbot 1963:53) and subsequently being documented in considerable detail (see Sinclair and Norton-Griffiths 1979 for numerous references). The persistence of the wildebeest in the wild into modern times allows us to see Roosevelt's error, but similar problems in the historic records of the North American bison will often be difficult to detect.

In conclusion, I note that my arguments might be misinterpreted as suggesting that historical documents have nothing to tell us about bison ecology. In fact, these documents are clearly a major source of information about a species existing under conditions which cannot be duplicated in the modern world. My point is simply that our use of these documents must explicitly take into account both the factors which determined the adaptation of the bison to the Plains grasslands and the probable effects of historical processes on these adaptations.

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Anthropology Department
University of California
Santa Barbara, California
May, 1986

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