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Scientific Research Programmes: Toward a Synthesis and Evaluation of CRM Archaeology

Alan J. Osborn

INTRODUCTION

> A central issue in CRM for several years centered on the apparent problem of reconciling management and research aims or goal. The problem really existed in the form of a dilemma: how to collect or develop scientifically useful data within the constraints of a contract specifying that only a highly delimited area be studied?. . . Keel (1979) states the problem succinctly, pointing out that most "contract" archaeological research is necessarily circumscribed geographically and by data collection requirements, and that data so collected are basically for management of compliance purposes. . . . From a strictly management perspective, this position is defensible; but it glosses over a much more basic question, one which underlies most of the management versus research quandry, that is, why are cultural resources being protected, conserved, and managed at all? (Fowler 1982:21)

Archaeologists involved in conservation archaeology and/or cultural resource management have frequently been confronted with the dilemma described by Fowler (1982). Cultural resource management projects most generally have to be conducted within a restricted geographical area within a specified period of time.

Many archaeologists have chosen to deal with the resource management dilemma in one of three ways. First, there are those that have chosen to view cultural resource management primarily as a professional service. Practitioners of "service" archaeology conduct archaeological surveys and excavations in order to determine the frequency, location, and extent of cultural remains within a specified area. Investigations conducted by service-oriented archaeologists are primarily designed to satisfy the inventory, mitigation, and clearance requirements of federal agencies and private industry. Second, a number of archaeologists have managed to develop creative research designs within which they have been able to address scientific questions about the past while fulfilling their contractual agreements with the federal government and/or private industry. And, third, many other professional archaeologists particularly those affiliated with universities have chosen not to become involved in CRM projects at all.

Now that CRM/contract archaeology is disappearing we must ask if this dilemma was resolved. And, if so, what has CRM archaeology ultimately contributed to our understanding of the past?

In the following discussion the implications of the research/management dilemma for American archaeology is examined. As a result, the concept of "research programme" is suggested as a tool applicable for assessing the ultimate success of CRM in resolving the research/management dilemma. A research programme developed for the investigation of prehistoric adaptations in the Great Plains is presented as an illustration of the analytical concepts and management potential.

"Real World" Versus "Ivory Tower" Archaeology

The emergence of CRM/conservation archaeology has created a schism in the discipline of archaeology which has separated a number of archaeologists involved in management and industry from those involved in academia. Fowler (1982:36) has referred to this schism as one involving "real world" (management/industry) versus "ivory tower" (academic) archaeologists. Patterson (1980) has chosen to exacerbate this situation further by characterizing archaeologists as "full-time" versus "part-time" professional archaeologists. This rather absurd dichotomy separates archaeologists into CRM field archaeologists who then "do archaeology" year-round versus academicians who "do archaeology" during their summer vacations!

Fowler (1982:36) also states that there is "...a latent (i.e., *verbalized, but not printed*) antagonism toward agency and corporate archaeologists by some 'elitist' academics...". There are some who would perhaps not be willing to accept this dichotomous interpretation of contemporary archaeology in the United States. However, this divergence of interests in North American archaeology involves much more than just semantic wrangling. Significant changes have occurred within our society that have led to the appearance of management, corporate/industry, and academic versions of conservation archaeology. These changes have come about as a result of a surge in funding, shifts in professional demographics, and a corresponding quantum increase in archaeological information.

One of the most significant contributors to the separation of the "ivory tower" and "real world" archaeologists has been money. In 1974, Congress passed the Moss-Bennett Bill or the Archaeological and Historical Conservation Act. This bill provided federal funds for numerous legislatively-mandated CRM projects which followed.

Judge (1982:24) comments in this regard,

> The effect of this was almost revolutionary. Due to the rules of federal procurement, all procedures of competitive bidding were suddenly introduced into scientific archaeological research. "'Contract archaeology' was born, much to the horror and doomsday predictions of the traditional (academic) archaeologists" (McGimsey and Davis 1982:19).

Cultural resource management projects, unlike proposals submitted to the National Science Foundation or Wenner Gren, were frequently awarded based on cost effectiveness; scientific research in the context of such archaeological projects (CRM) was frequently accorded secondary status. In fact, CRM proposals for the U. S. Army Corps of Engineers were not supposed to include any references to scientific research. Such CRM projects were deemed as service archaeology.

Fowler (1982) describes the evolutionary development of North American archaeology in response to the advent of CRM archaeology. He (1982:35) discusses the emergence of "agency" and "corporate" archaeologists who were to soon predominate in the discipline. Prior to the late 1970s, "perhaps 98% of all practicing archaeologists (those who earned their living 'doing archaeology') were in an 'academic' setting (i.e., universities and museums)" (Fowler 1982:35).

Federally-funded contract archaeology in the United States has been estimated to have cost $100-200 million dollars per year (Comptroller General 1981:47; cf. Judge 1982:28-29). If we assume, as the inductivists and empiricists do, that our knowledge and understanding of the past is a direct function of the number of sites investigated and number of artifacts found, then we must have certainly learned a great deal about the past during the last decade.

Fowler (1982:19) espouses the traditonalist view of the archaeological record and states, "Cultural resources may be thought of as 'containers' of information, or potential information, about past human activities."

Hill (1972:64) discusses the broader theoretical and methodological implications of such an empiricist perspective and states,

> The implications of this view for archaeology is that artifacts and features (and even artifact associations) are regarded as discrete independent entities, each having a single meaning to be discovered. . . . It is then, our task to perceive this inherent meaning. In a sense, then, our inferences about the data are contained in the artifacts and features themselves.

A number of archaeologists have argued that the appearance of CRM archaeology marked the resurgence of the normative, empiricist archaeology. Keene and MacDonald (1980:1) state for example, ". . .that most of the archaeological work currently conducted under the (inaccurate) euphemism 'cultural resource management' is strictly and rigidly empiricist, almost totally devoid of theoretical interest, and largely irrelevant to anthropological research."

We know that there are, in fact, a number of CRM projects that have contributed both theoretically and substantively to archaeology. A discussion of these specific contributions to our understanding of the past is beyond the scope of this chapter. However, what we might ask at this point is to what extent has the overall approach to CRM studies in archaeology brought us closer to the goals of anthropological archaeology aimed at explanation of past human behavior? Is there any effective way in which archaeologists could proceed within the recognized constraints of conservation archaeology toward this goal of behavioral explanation? I believe that several philosophers of science have provided us with an effective scientific framework in which archaeologists could integrate (or could have integrated) cultural resource management goals and scientific archaeology. This epistemological framework will be discussed in the following section of this chapter. I will then present an example of such scientific framework that has been applied in CRM archaeology in the North American Great Plains.

Research Designs, Strategies, and Programmes

Discussion of scientific research designs are not uncommon in conservation archaeology. In 1964, Binford (1964:25) summoned archaeologists to develop a ". . .methodology most appropriate for the task of isolating and studying processes of cultural change and evolution. . .one which is regional in scope and executed with the aid of research designs. . . ." This call for consideration of research designs derives from a positivist philosophy in which rigorous, systematically-collected data is used to evaluate theoretically-based research problems. The inanimate record of the past was now to be given meaning in the context of questions about human behavior and its variation.

Archaeologists and anthropologists have become increasingly aware of the essential importance of scientific research design(s) (e.g., Struever 1968, 1971; Levine 1970; Hill 1972; Brim and Spain 1974; Reher 1977; Goodyear 1977; Raab 1977; Johnson 1978; Harris 1979; Judge 1981; Thomas 1983).

Considerable discussion has been devoted to archaeological research designs in conservation archaeology. Yet, as Schiffer and Gummerman (1977:129) point out, little evidence exists for successful formulation and implementation:

> An appraisal of modern archaeology. . .is that precious little is known about how to design the kinds of projects that address timely research questions in a realistic manner. . . .(R)esearch is characterized by a poor fit between questions and resources, the use of techniques of recovery and analysis without adequate justification, and a failure to achieve sufficiently credible results to serve as a foundation for future research or a basis for management recommendations. The shortcomings in many investigations (cultural resource management and others) highlights the need to accord the study of research design to high priority.

As Raab (1977:167-68) points out, many archaeologists involved in conservation/contract archaeology have confused research design with work plans, activity schedules, data collection methodologies, or lists of archaeological questions. Several recent overviews of survey methodologies employed by conservation archaeologists contain no discussion of research designs (e.g., Schiffer, Sullivan, and Klinger 1978; Plog, Plog, and Wait 1978; Hayes, Brugge, and Judge 1981).

Research designs formulated for purposes of scientific investigation involve problem formulation and empirical testing. Levine (1970:183) states that a research design ". . .is an advance plan for organizing the collection of data so that they are maximally relevant to the validity of certain generalizations concerning the relations between variables."

Johnson (1978:2) reiterates this view and states, "The purpose of research design is to use theoretical arguments to develop expectations about the world, and then to test them by collecting empirical data that either do or do not conform to the theoretical expectations, the ultimate goal being to add to our store of scientific truth about nature."

Frequently, archaeologists have attempted to develop research designs within a narrow inductivist perspective (cf. Hempel 1966:11-15, 18). And, they have equated research designs with project and/or site specific "puzzle solving" activities (cf. Kuhn 1970). As Kuhn (1970:35-42) emphasizes, puzzle-solving focuses on questions which lack broader explanatory significance. Archaeologists conducting CRM investigations have frequently generated "research designs" which have been concerned solely with site-specific questions that have little, if any, relevance to regional-level behavioral problems. Empirical generalizations and particularism characterize much CRM research.

Harris (1979) has proposed that the concept of scientific research strategy be used by anthropologists instead of paradigm. A research strategy is ". . .an explicit set of guidelines pertaining to the epistemological status of the variables to be studied, the kinds of lawful relationships or principles that such variables probably exhibit, and the growing corpus of interrelated theories to which the strategy has thus far given rise" (Harris 1979:26-27). Unlike scientific paradigms, research strategies are utilized by investigators in a very deliberate and explicit way. Research strategies are consciously changed in response to the feedback between ideas and empirical observations.

The concept of research programme was proposed by philosopher of science Imre Lakatos in the early 1970s. Lakatos (1970a; Lakatos and Musgrave 1970) was reacting primarily to Thomas Kuhn's (1962a, 1962b) concept of scientific paradigm and the nature of scientific revolutions. Kuhn (1962a, 1962b) viewed the history of Western science as a series of oscillations between periods of normal science and revolution. Kuhn's (1970) writings have served as a basis for interpreting epistemological changes in the discipline of archaeology (e.g., Leone 1972; Metzer 1979 Binford and Sabloff 1982).

During periods of normal science, a community of specialists share a common body of theory and confirmatory tests. Alternative explanations, anomalous and contradictory evidence, and novelties accumulate during periods of normal science but they are generally ignored. Revolutions in science occur as a consequence of irreconcilable differences between theory and evidence.

Lakatos and others did not find Kuhn's ideas about the structure of scientific revolutions very helpful. For example, Suppe (1977) points out that periods of normal science and scientific revolution frequently occur simultaneously. Lakatos (in Lakatos and Musgrave 1970) argued that Kuhn's view of scientific paradigms and

revolutionary change were 'subjectivistic', 'psychologistic', and 'irrational' (Radnitzky and Andersson 1978:6).

Lakatos and others argued that Kuhn ignored the dynamic aspects of scientific discovery. Furthermore, Lakatos believed that scientists could control the process of discovery. The notion of serendipity has been overemphasized. Urbach (1978:99), like Lakatos, suggests that scientists may utilize a "forward-looking" methodology for assessing the relative merits of scientific theories. Unlike the Kuhnian view of science, Lakatos sees the scientist as a self-conscious researcher equipped to differentiate between robust and non-robust explanatory theories.

Suppe (1977:645) states in this regard,

> Such doctrines (Kuhnian view) seem to preclude the rational assessment of the relative merits of competitive theories during revolutionary science, thus subjecting Kuhn to the charge that scientific progress in his view is fundamentally irrational.

Lakatos describes scientific research programmes as sequences of interrelated theories and basic assumptions which form the "hard core", as well as negative and positive heuristics. The "hard core" is maintained in a research programme even if empirical evidence appears to contradict it.

The positive heuristic consists of a body of ideas

> . . .about how to 'fill in', make more precise, draw consequences from, these statements, and also about how to elaborate on them, introduce new assumptions. . . that. . .apply to new fields, and how to modify them when difficulties arise (Worrall 1978:59).

The negative heuristic consists of statements regarding research directions and sets of theory that have proven to be unproductive.

Scientific research programmes are deemed better than their rivals if they exhibit "greater empirical content" or predict "new, hitherto unexpected facts" (Radnitzky and Andersson 1978:9). In other words, a robust sequence of theories and the enhancement characteristics of the positive heuristic enable us to go beyond the knowledge that served as the background for the original, individual theories. We are able to predict new facts and to identify new interrelationships in the empirical world. The heuristic power and explanatory capabilities of a scientific research programme are certainly greater than the sum of their parts.

Therefore, the application of scientific research programmes will greatly enhance our abilities in anthropology and archaeology to integrate, test, and go beyond what we currently know about human behavior. Empirical laws allow us to explain the interrelationships between two or more variables. Scientific theory systematically integrates a sequence of these empirical laws and it defines the explanatory limitations of these empirical laws. As a result, theory exhibits much greater explanatory power than empirical laws. And scientific research programmes can now be used to expand further our discovery, integrative, and explanatory capabilities in behavioral science.

The concept of scientific research programmes is proposed as an effective means for evaluating the contributions that CRM investigations have made to anthropology and archaeology. We should ask how CRM archaeology has served the short-term needs of management and industry and carried out research that furthered our scientific understanding of past human behavior.

PREHISTORIC ADAPTATIONS IN THE GREAT PLAINS: A RESEARCH PROGRAMME

Science is not a static enterprise (cf. Suppe 1977:670), and neither is archaeology. The Great Plains region, however, constitutes one of the least disturbed theoretical backwater areas of North American archaeology. The issues raised in North American archaeology during the late 1960s and the early 1970s went by unnoticed on the Plains. Explanation of past human lifeways on the Plains was equivalent to locating one's archaeological observation on the master time-space-content grid. At best, archaeological explanation was nothing more than "thick description" - literally and figuratively.

The traditional interpretations of prehistoric and historic life in the Great Plains are based heavily on ethnohistoric accounts. Many of these descriptions of aboriginal lifeways in the Plains have now been accorded status as "divinely inspired truth". Few people have seriously questioned the anthropological abilities of these EuroAmerican observers.

For example, George Catlin lived among the villagers of the Middle Missouri for years during which time he accurately documented aboriginal life in paintings and in his journals. Yet Catlin left these groups behind thinking that they were the descendents of Madoc, son of the Prince of Wales! The reliability of all EuroAmerican accounts of Plains life must be subject to close scrutiny. Anthropologists and archaeologists must make use of contemporary behavioral theory in order to delineate anomalies and inconsistencies in the ethnohistoric record.

Much of Plains prehistory was written decades ago and little effort has been made to revise it. Childe's (1936) ideas about the "neolithic revolution" and agriculture form an integral part of extant interpretations of past lifeways in the Central Plains and the Middle Missouri sub-area. Archaeologists and anthropologists unquestioningly adopted Childe's reconstructions of Neolithic life.

Wedel's (1978) writings reflect the impact of the "neolithic" concept on Plains culture history. He (1978:187) states,

> In the mixed and tall-grass prairies of the eastern Plains, where climate and soils were suited to maize horticulture, there were settled communities of village Indians. Fertile, easily worked valley bottom soils made possible an increasingly productive subsistence economy, often with sufficient crop surpluses to support trade with nonhorticultural bison hunters to the west. . . Their way of life, in its horticultural practices and crops, its houses and settlement patterns, its ceramic and other industries, reveals strong relationships with the easten Woodland cultures of the Mississippi-Ohio valley. . . .

This reconstruction is based on generalizations proposed by Childe in the early 1900s that have now been rejected. Archaeologists have been quick to assume that a handful of charred maize kernels, bison scapula "hoes", and numerous subterranean "cache" pits are irrefutable evidence for a "neolithic revolution" along the floodplains of the Missouri River.

In keeping with ethnohistoric accounts, archaeologists in the Plains have adopted the view that prehistoric peoples practiced a "schitzophrenic" pattern of specialized maize farming and bison hunting. It is difficult to understand why two specialized subsistence strategies would be practiced in this region particularly when both would require significant inputs of labor for processing the resources prior to storage. Summer-fall communal bison hunts would conflict with weeding and harvesting activities. Furthermore, these specialized strategies tend to be an "all-or-nothing" adaptive response to a region characterized by short growing seasons and long food-poor winters.

There are additional reasons for skepticism regarding the traditional interpretations of past Plains lifeways. We know for example that there was considerable variability in aboriginal settlement/subsistence systems that have not been accommodated within the traditional view.

For example, Hurt (1969:32) in a description of the Hidatsa/Crow in the early 1800s speaks of the ancestors of the Awatixa, Awaxawi, and the Mirokac as both village agriculturalists/nomadic hunters, agricultural villagers, and nomadic River Crow/agricultural Hidatsa, respectively. This range of adaptive variation, as well as the existence of previously unanticipated land use systems cannot be accommodated within the usual farmer/hunter dichotomy of the normativist perspective.

There has been a plethora of paleopathological studies in the past five years that have focused on aboriginal dependence on agriculture (e.g., Cook and Buikstra 1973, 1979; Turner 1978, 1979; Lallo and Rose 1979; Larsen 1982; Cohen and Armelagos 1984). Based on these studies we would expect to observe a number of pathologies e.g, Harris lines, enamel hypoplasias, porotic hyperostosis, and caries in maize horticultural populations. Furthermore, we should expect to observe high ratios of strontium to calcium and low $^{13}C/^{12}C$ carbon isotope ratios among Plains Village Tradition peoples if maize had been a dietary staple.

Few studies of prehistoric diet and paleopathologies have been conducted to date in the Plains. However, preliminary analyses of prehistoric dentition for Central Plains groups suggest that horticulture played an insignificant role in subsistence strategies. Masters (1984) has recently examined teeth wear patterns for 59 prehistoric/historic individuals (22 Woodland/Lower Loop, 20 Nebraska Phase, and 17 Pawnee) spanning more than 3,500 years. Results of this study were compared with those obtained for 66 individuals examined by Smith (1984). None of the Woodland/Lower Loop and Nebraska Phase individuals exhibit evidence for a horticultural adaptation. The Pawnee individuals appear to occupy an intermediate position between hunter-gatherers and horticulturalists. All individuals examined show little, if any, evidence for caries and dental insult attributable to horticulturalists.

The disparity between our expectations for aboriginal Plains life and many aspects of the traditionalist interpretations warrants a great deal of further investigation. For this reason I began to examine a series of interrelated issues in Plains archaeology and anthropology. These studies began in the context of formulating research problems for several CRM projects in the Plains.

The following discussion of these studies of Plains adaptations is meant to illustrate how archaeologists might approximate a research programme. There is insufficient space to offer the complete theoretical bases for these investigations but brief references will be made to certain bodies of theory when possible. The most important aspect of this "research programme" is the set of interrelationships which link each study to a central problem and to each other. It is through this set of interrelationships and their theoretical background that "new facts" can be revealed and the future directions(s) of this research can be plotted.

Ecological Diversity and Aboriginal Foraging Behavior

> In the real world, environments are patchy. Factors influencing the proximate physiological or behavioral state or the ultimate fitness of individuals exhibit discontinuities on many scales in time and space. The patterns of these discontinuities produce an environmental patchwork which exerts powerful influences on the distributions of organisms, their interactions, and their adaptations. (Wiens 1976:1)

The Niobrara River valley parallels the north-south transition between the Pine Ridge Escarpment of southern South Dakota and the vast Sand Hills region of north-central Nebraska (Figure 2.1). Approximately half way along its course from south-eastern Wyoming and the Missouri River this spring-fed and deeply entrenched stream crosses the Hundredth meridian which coincides closely with the boundary between eastern tall grass prairies and western shortgrass plains.

The central Niobrara drainage exhibits considerable patchiness and ecological diversity within a more homogeneous regional Plains environment. Precipitation decreases along this east-to-west gradient and it becomes more unpredictable. Deciduous vegetation exhibits a "dwarf effect" due to increased xerophytism toward the west. Ponderosa pine extend eastward to the limits of their distribution along the rugged, sheltered terrain of the Niobrara trench.

The central Niobrara River valley provides archaeologists with a very suitable natural laboratory in which to examine the relationships between environmental patchiness and human foraging behavior. It was in this portion of the Plains that a cultural resource survey of more than 26,000 acres was conducted. This survey was for the Bureau of Reclamation's proposed Norden Reservoir Project.

Ecological Theory

In the late 1970s, ecologists were developing and testing models of optimal feeding strategies as an integral part of evolutionary ecology. These ecological concepts were used to develop a model of aboriginal foraging. This model was felt to be useful in examining the underlying causes of subsistence variability within the Niobrara region.

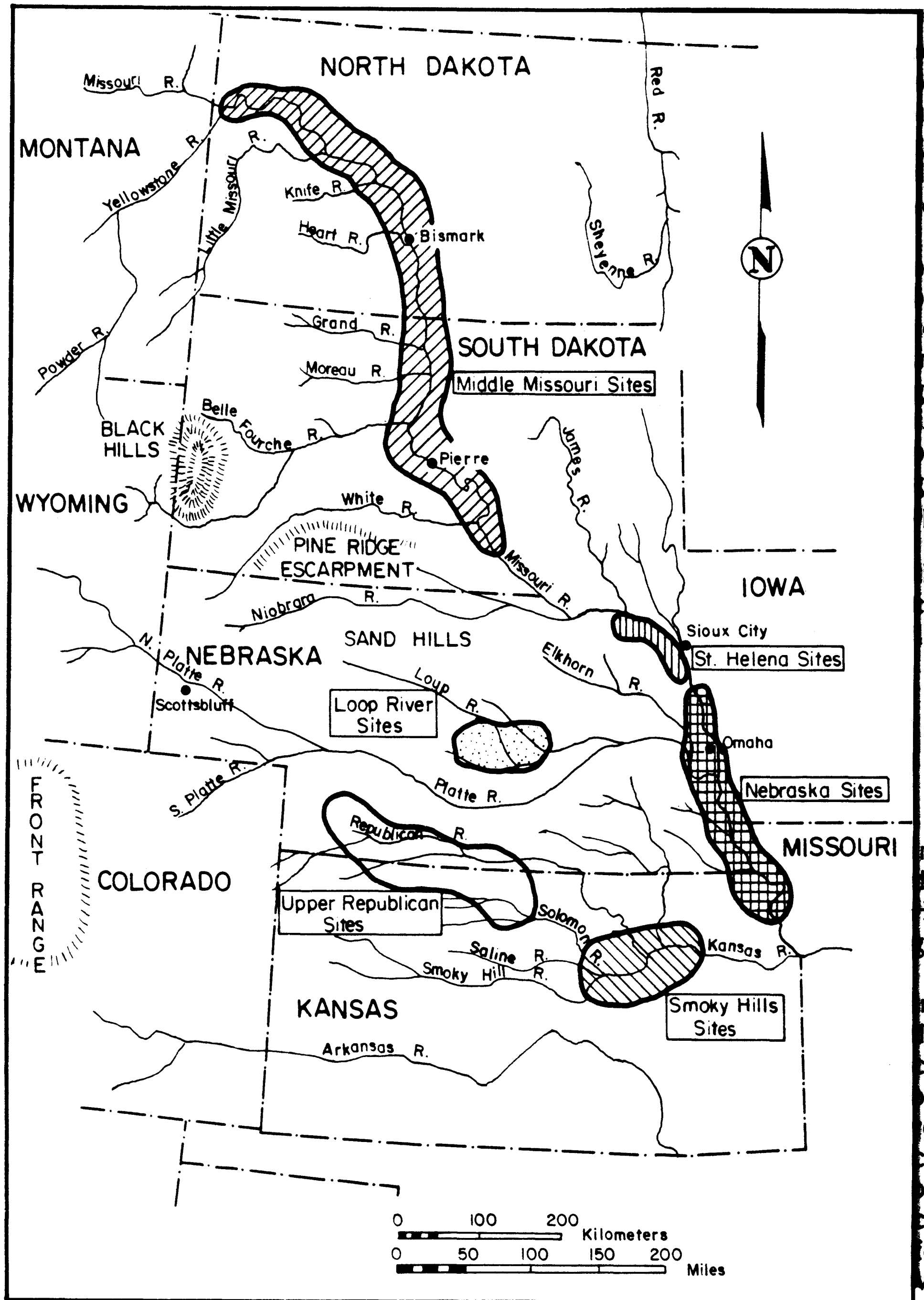


Figure 2.1 Map of the Central Plains and Middle Missouri Sub-Areas.

Wiens (1976), for example, has emphasized that patchiness is a elative concept. Patches result from the discontinuous distribution f resources in environmental space and ecological time. The scale sed was based on the foraging radii of known pedestrian hunter-atherers. Therefore, patchiness in this case pertains to the istributional properties of resources considered to be relevant to oragers travelling on foot in this region.

Forager adaptation to environmental patchiness is referred to y Wiens (1976:85) as grain response which ". . .is interpreted as a ehavioral response to an environmental mosaic." These grain esponses can either be fine grained in which resources are exploited n proportion to their occurrence in space and time; or, coarse rained in which resources are exploited disproportionately. A ine-grained response tends to exhibit a more random spatial attern of occurrence and is a generalist strategy. A coarse-rained response, on the other hand, tends to exhibit a non-random patial pattern and is considered a specialist strategy.

In addition, ecologists have devoted considerable attention to he concept of ecological diversity and related aspects of ommunities (e.g., MacArthur 1965, 1972; Pianka 1966; Margalef 968; Pielou 1975). McIntosh (1967:392) states, for example, that,

> Diversity has been said to increase in a successional sequence to a maximum at climax, to enhance community stability, and to relate to community productivity, integration, evolution, niche structure, and competition.

Considerable debate surrounds the underlying bases for such nterrelationships between ecological diversity and community ynamics and structure (cf. May 1973; Pielou 1975; Pianka 1983). lowever, such ecological correlations can still be utilized to eneralize about the character of a community given its diversity.

Table 2.1 summarizes a number of these ecological nterrelationships between diversity (plant/animal) and community ynamics and structure. Given these characteristics of ecological ommunities we can begin to predict what kinds of environmental atches would be better suited for prehistoric hunter-gatherer esidential and logistical site location. Low species diversity ommunities are more apt to contain aggregated resources that will e relatively abundant. For example, grassland communities will ontain large areas dominated by one or two species of grass suited or supporting large herbivore populations e.g., bison or antelope. More diverse forest communities will exhibit greater species diversity, greater equitability, and more evenly distributed resources. These communities are most apt to contain greater

Table 2.1 Ecological diversity and community dynamics and structure (Odum 1969:265, Table 1).

Community Characteristic	Diversity Low	High
Gross production/respiration	or 1	Ca. 1
Gross production/biomass	High	Low
Biomass/unit energy flow	Low	High
Net production yield	High	Low
Food chains	Linear	Web-like
Total organic matter	Small	Large
Species diversity-variety	Low	High
Species diversity-equitability	Low	High
Biochemical diversity	Low	High
Spatial heterogeneity	Unorganized	Organized
Life cycles	Short	Long
Nutrient exchange rate	Rapid	Slow
Reproductive strategy	r-selected	K-selected
Nutrient conservation	Poor	Good
Stability	Poor	Good
Entropy	High	Low
Information	Low	High

diversity of biochemical resources e.g., resins, alkaloid poisons, and medicinal items.

Behavioral Expectations

Given this ecological background, we can present several expectations for aboriginal behavior concerning land use along the central Niobrara drainage (cf. Table 2.2). High bulk, aggregated resources like bison, antelope, prairie dogs, cattails, wild rice, or grass seed would be found in low diversity settings. Their exploitation would require cooperative labor for procurement, processing, and transport. This labor would be recruited from a coresident group of producers and consumers. Residential sites associated with such land use practices would be "large" and would exhibit a relatively diverse archaeological assemblage. We would expect to observe features e.g., hearths, pits, middens, burials, and shelters at such locations in addition to artifactual assemblages reflecting a broad range of maintenance activities. Archaeological evidence for logistically-organized activities e.g., procurement of raw materials, herbs, resins, and "chemicals" would probably consist of a number of "small" unobtrusive sites e.g., isolated finds. These would most likely be located in settings characterized by greater ecological diversity.

Given these ideas we might propose the following hypotheses:

1. Archaeological site size (as well as complexity/internal differentiation) should vary inversely with associated ecological diversity.
2. Artifactual assemblage size and diversity should vary inversely with associated ecological diversity.

Archaeological Analyses/Tests

Archaeological data collected during the Ft. Niobrara National Wildlife Refuge survey was used to test these anthropological/archaeological hypotheses. The first test involved data presented in Table 2.3. A linear regression of site area (area of surface artifact scatter) and setting diversity (i.e., associated vegetative diversity, H') demonstrated that ecotonal sites (site situated in transition between two or more vegetative communities) constituted anomalies (cf. Figure 2.2). If these sites are removed from the present analysis, we find that the correlation coefficient (r) equals -0.88 ($R = 0.77$; $df = 5$; $p > .001$). This means that 77 percent of the variability in observed site size can be explained in terms of associated vegetative diversity.

A second test was performed to test the expected relationships between site assemblage diversity and associated vegetative diversity (Table 2.4). Artifact assemblage diversity computations are provided in Table 2.5. It should be pointed out

Table 2.2. Archaeological correlates of grain responses to patchy environments.

Archaeological Correlates	Patch Species Diversity: Low	Patch Species Diversity: High
Site size	Large	Small
Site frequency	Low	High
Site distribution	Nonrandom	Random
Occupation episodes	Multiple	Single/Few
Occupation duration	Long-term	Short-term
Artifact assemblage diversity	High	Low
Intrasite variability	High	Low
Intersite variability	Low	High
Features	Present	Absent
"Visibility"	High	Low
Logistical sites	Few	Many
Residential sites	More Numerous	Less Numerous

Table 2.3. Archaeological site size/area and vegetative diversity, Ft. Niobrara Wildlife Refuge, Valentine, Nebraska (Osborn 1979).

Site Designation	Size/Area m^2	Size/Area $\log_2 m^2$	Setting	Vegetative Diversity (H')
25CE232	30,000	14.86	Grassland	1.1022
25CE230	15,182	13.88	Grassland	1.1022
25CE229*	3,864	11.91	Grass./M. forest	2.3571
25CE226	760	9.56	Lowland forest	1.4232
25CE225	700	9.44	Lowland forest	1.4132
25CE227	386	8.59	Mixed forest	1.5747
25CE223*	385	8.58	Grass./M. forest	2.3571
25CE231*	333	8.37	Grass./M. forest	2.3571
25CE228*	-	-	Grass./M. forest	2.3571

*Ecotonal sites

Table 2.4. Archaeological assemblage diversity and vegetative diversity, Ft. Niobrara National Wildlife refuge, Valentine, Nebraska (Osborn 1979).

Site Designation	Environmental Setting	Assemblage Diversity (H')	Vegetative Diversity (H')
25CE232	Grassland	2.3694	1.1022
25CE230	Grassland	1.3928	1.1022
25CE227	Mixed Forest	1.2177	1.5747
25CE231*	Grassland/Mixed Forest	1.6382	2.3571
25CE229*	Grassland/Mixed Forest	0.9033	2.3571
25CE223*	Grassland/Mixed Forest	1.0506	2.3571

*Ecotonal sites

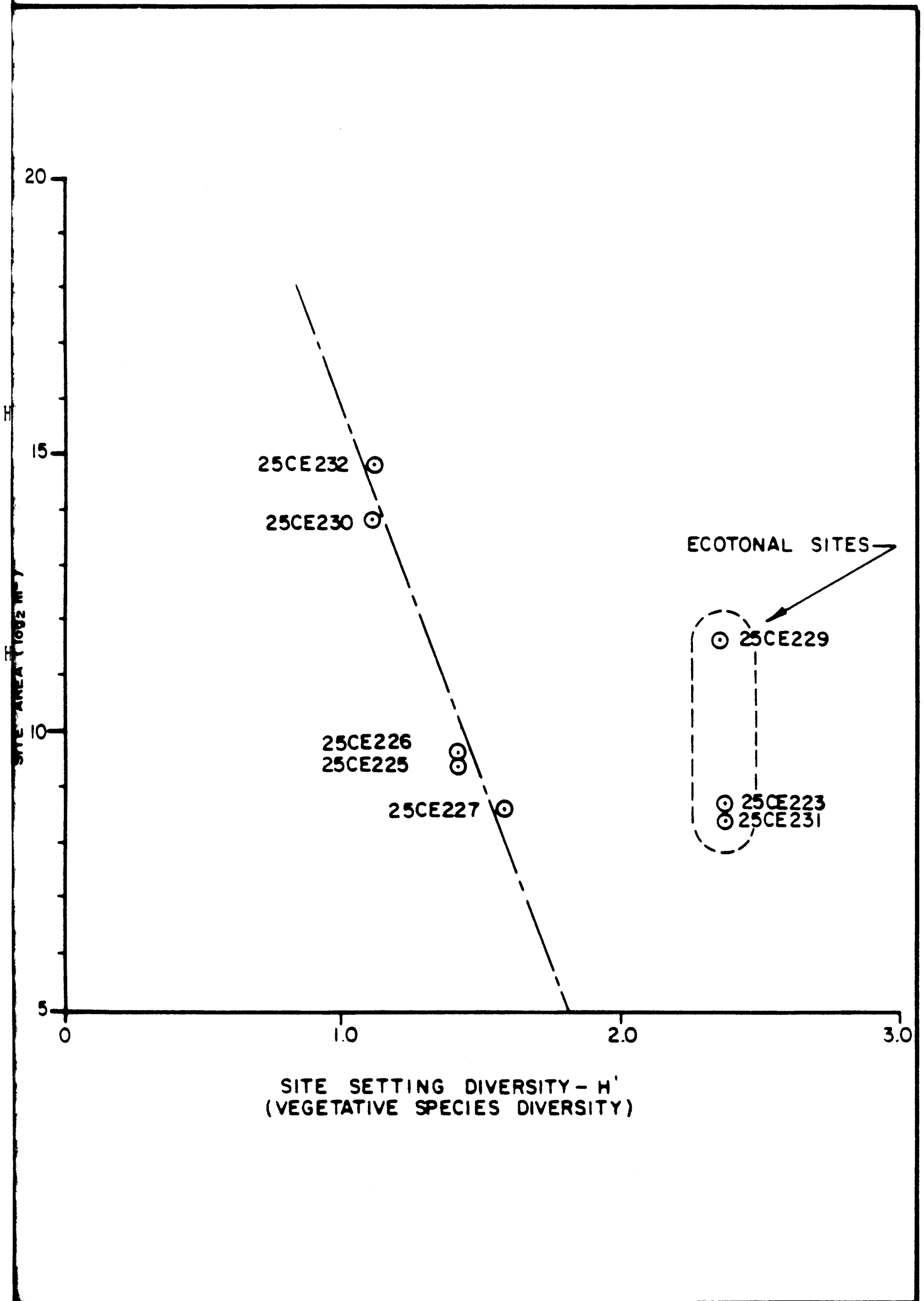
Table 2.5. Archaeological assemblage diversity for sites located on the Ft. Niobrara Wildlife Refuge, Valentine, Nebraska (Osborn 1979).

Site	Artifact Category	Raw Material	#/pi	1/pilog2pi	
25CE232	D	Cy	18/.34	0.5289	
	D	Qzt	8/.15	0.4103	
	D	SW	2/.04	0.1856	
	D	SS	16/.30	0.5209	
	D	Ct	5/.09	0.3125	
	D	J	1/.02	0.1128	
	T	SS	1/.02	0.1128	
	T	Cy	2/.04	0.1856	
			=	2.3694	= H'
25CE227	D	SW	2/.05	0.2160	
	D	Qzt	16/.42	0.5253	
	D	CT	9/.24	0.4938	
	D	SS	1/.03	0.1517	
	D	Misc.	8/.21	0.4725	
	T	Cy	1/.03	0.1517	
	T	Ht	1/.03	0.1517	
			=	1.2176	= H'
25CE223	D	Ct	15/.79	0.2685	
	D	SW	2/.11	0.3501	
	D	SS	1/.05	0.2160	
	D	Cy	1/.05	0.2160	
			=	1.0506	= H'
25CE230	D	Cy	13/.31	0.5235	
	D	PCy	3/.07	0.2684	
	D	Ct	5/.12	0.3668	
	D	SW	1/.02	0.1128	
	D	Qzt	8/.19	0.4550	
	D	Misc.	10/.24	0.4938	
	T	Ct	2/.05	0.2195	
			=	1.3928	= H'

Table 2.5. Cont'd.

Site	Artifact Category	Raw Material	#/pi	1/pilog2pi	
25CE229	D	Qzt	34/.13	0.3854	
	D	Cy	20/.08	0.2913	
	D	Ct	187/.73	0.3312	
	D	SW	2/.008	0.0557	
	D	J	2/.008	0.0557	
	D	Misc.	12/.05	0.2160	
			=	0.9033	= H'
25CE231	D	Cy	4/.10	0.3320	
	D	Qzt	10/.26	0.5050	
	D	Qzt*	3/.08	0.2913	
	D	SW	4/.10	0.3320	
	D	Ct	6/.15	0.4103	
	D	SS	3/.08	0.2913	
	D	Misc.	9/.23	0.4863	
			=	1.6382	= H'

1. Artifact categories include: D, debitage; T, tool (complete or incomplete).
2. Raw material types include:
   Chalcedony - Cy
   Plate chalcedony - PCy
   Quartzite, local Bijou Hills variety - Qzt
   Quartzite, non-local - Qzt*
   Chert - Ct
   Silicified wood - SW
   Silicified sediment - SS
   Jasper - J
   Hematite - Ht



igure 2.2 Graphical Plot of Site Size and Associated Vegetative Diversity for Ft. Niobrara National Wildlife Refuge, North-Central Nebraska.

that in each of these analyses all $\log_2$ values were transformed int antilog values for Pearson product moment correlational analysis In this case, the correlation coefficient (r) equals -0.601 (R = 0.36 df = 1; not significant). Vegetative diversity, then, accounts fo only 36 percent of the observed artifactual variability at these sites

If we return to the ecotonal sites, we find that they appear t be anomalously large given the higher diversity of their ecologica settings. This anomalous finding may be informing us abou locational behavior associated with logistically-organized extractio activities along ecotones. Unexpectedly large sites along thes ecotones may have been produced through accretion - repeated us of the same general area along the borders of several juxtapose vegetative communities. Without a set of a priori expectation grounded in ecology we would not be able to isolate these cases no study their broader implications.

The ecologically-based model for aboriginal foraging and lan use described in this study enables us to examine not only the degre to which archaeological data fits our ideas about hunter-gathere land use but also about the obverse situation i.e., horticulture. Th central Niobrara drainage in north-central Nebraska does no contain prehistoric village sites, tipi ring sites, burial mounds, o large bison kills. It probably was used by residentially-mobil foragers and by logistically-organized collectors througho prehistory. The degree to which the archaeology fits our idea regarding ecological diversity and grain response tells about th relative use of this region by hunter-gatherers versus specialize horticulturalists.

Prehistoric Household Size and Horticultural Labor Demands in the Eastern Plains

Considerable effort has been expended by archaeologists i order to gain some insight into prehistoric subsistence patterns an diet. Much of this work has focused directly on the recovery o floral and faunal remains (e.g., White 1952, 1953a, 1953b, 195 1955; Gilbert 1969; Falk 1969, 1977; Angus 1975; Chomko 197 Benn 1974; Nickel 1974, 1977; Peterson 1980; Mick 1983; Dallma 1983). Many of these studies demonstrate, however, that a stric empiricist approach poses a number of operational problems. Ho do we compare charred cobs, stalks, and kernels of maize or wil plant seeds, husks, or nut shells?

The following study is designed to escape a number of suc theoretical and methodological problems associated with analyses o archaeological subsistence remains (cf. Cohen 1972-1974; Binfor

and Bertram 1977; Binford 1978, 1981, 1984; Carbone and Keel 1985). In order to evaluate the relative dependence upon maize horticulture a more effective use of prehistoric house floors is needed (cf. Figure 2.3). Recent studies by ethnologists of domestic group composition and labor organization provide an alternative dimension to examine horticultural adaptations.

Anthropological Theory: Horticultural Labor Organization

Reyna (1976:182) states, for example, that, "There is empirical data indicating that the quantity and amount of labor needed for successful crop production is a determinant of household composition." A number of recent studies further substantiate this relationship (e.g., Erasmus 1956; Sahlins 1957; Netting 1965, 1968, 1974, 1976; Chayanov 1966; Minge-Kalman 1977; Pasternak 1972; Pasternak, Ember, and Ember 1976; Stone, Johnson-Stone, and Netting 1984).

Maize production in a temperate environment would be limited primarily by precipitation and length of the growing season (frost-free period). Precipitation or drought has been emphasized in the plains literature as the major determinant of prehistoric maize farming (e.g., Van Royen 1937; Bryson and Wendland 1967; Bryson, Baerris, and Wendland 1970). Short growing seasons, however, would greatly restrict the time available for planting, replanting, weeding, harvesting, and storing food required to over-winter in the Plains. The short growing season and concomitant long over-wintering time would impose a "bottleneck" on aboriginal labor (cf. Tiffen 1975; Norman, Simmons, and Hays 1982; Stone, Johnson-Stone, and Netting 1984).

The environmental constraints which impose this bottleneck phenomenon on horticulture involve variation and predictability of late spring-early fall killing frosts. Late spring killing frosts are particularly critical for maize horticulturalists. If the last spring frost occurs after maize plants reach six inches in height, there would not be sufficient time to replant crops in many areas of the eastern Plains. Mean length of the frost-free season is useful as a measurement of the environmental stress imposed on prehistoric/historic Plains horticulturalists.

Behavioral and Archaeological Expectations

If maize was an important over-wintering food, then we should expect to observe associated adjustments of household size to shorter, more unpredictable growing seasons. In subsistence horticultural societies, households must recruit necessary labor from adult producers within the domestic unit.

Archaeologists have made considerable use of empirical generalizations which systematically link house floor area and

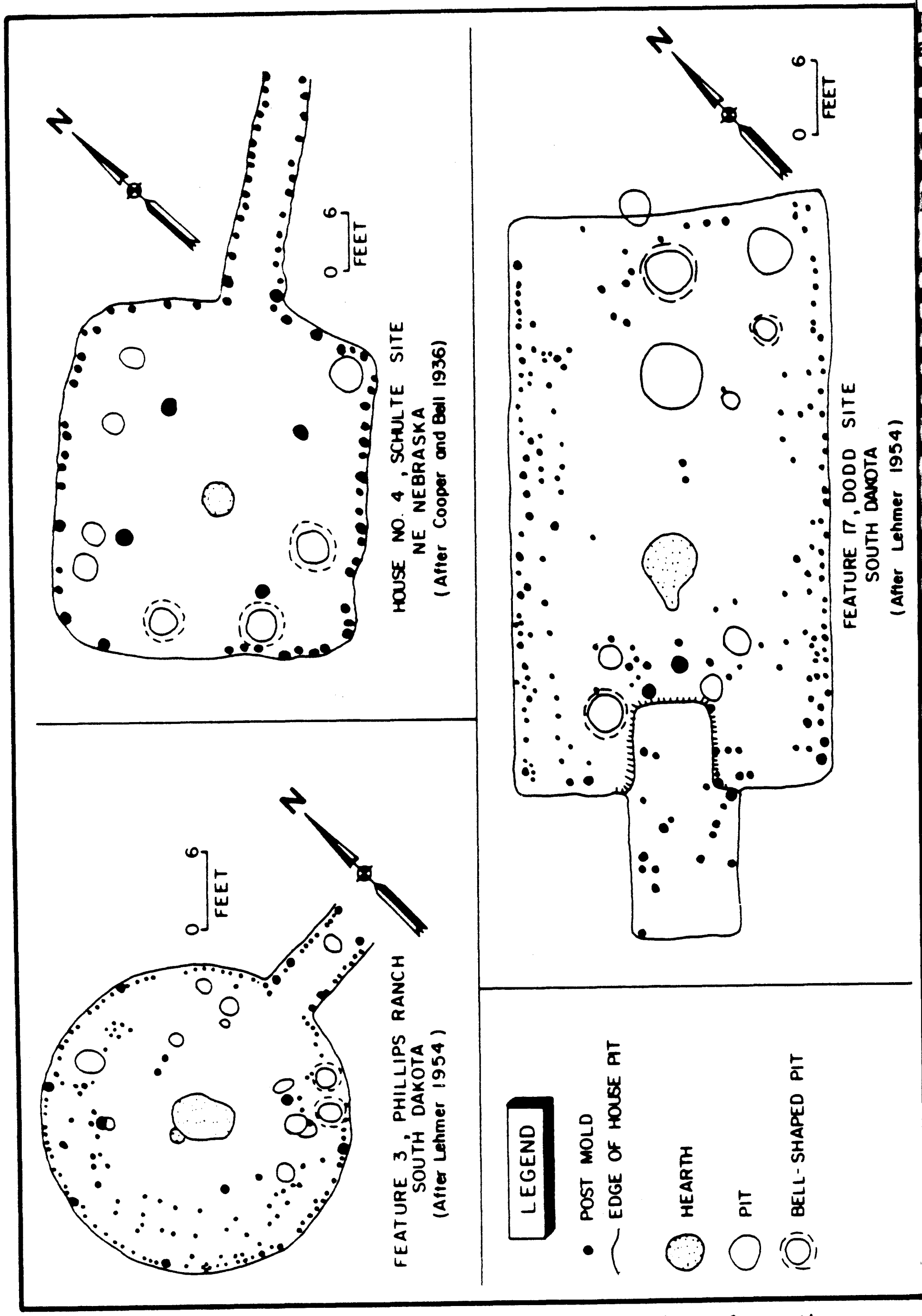


Figure 2.3 Examples of prehistoric house floor plans from the Eastern Plains.

population size (e.g., Cook and Treganza 1950; Naroll 1962; Cook and Heizer 1965, 1968; Soudsky 1964, 1966, 1969; LaBlanc 1971; Ember 1973; Wiessner 1974; Casselberry 1973; Milisauskas 1972; Divale 1977; Kelly 1982). Such approaches have also been applied on the Plains (e.g., Deetz 1965; Krause 1970; Lippincott 1976, 1978; Ludwickson 1978; Roberts 1977; Wedel 1978b, 1979; Richtsmeier 1980).

In areas characterized by shorter growing seasons an increased dependence on larger households should be observed. House floor areas would increase as the mean length of the growing season decreases in the eastern Plains. Although house floors need not be translated into estimates of absolute population size they do reflect household composition, i.e., the relative number of adult producers. Therefore, household size reflects the domestic group's ability to meet the labor organizational needs for maize production.

<u>Archaeological Analyses</u>

Our behavioral expectation is that intensive aboriginal dependence on maize (ripe) horticulture as a basis for over-wintering in the eastern Plains will be reflected by a pronounced positive relationship between household size and labor intensity. In other words, as the mean length of the growing season (a measure of horticultural labor intensity) decreases, aboriginal house floor area (as a measure of domestic group size) should increase.

A linear regression analysis was performed using archaeological data for 156 Plains Village Tradition (A.D. 900-1675) houses located along the Missouri River drainage between the White and Knife-Heart Rivers (Figure 2.1). Regression analysis results ($r = -0.462$; $R = 0.213$; $df = 154$; $p = .001$; $K = 0.887$) indicate that the horticultural strategy predicted by traditional Plains archaeological theory is not met. More than 88 percent of the variability in house size is <u>not</u> explained by the south-to-north decrease in mean length of the growing season.

A second linear regression of mean house floor areas for 50 archaeological components (occupations) provides similar results ($r = 0.40$; $R = 0.16$; $df = 48$; $p = .005$; $K = 0.92$). This analysis suggests that less than 16 percent of the variation in average house size/household size could be explained as an effort to establish optimal labor groups to meet the requirements of maize farming.

A third regression analysis involving only Initial Middle Missouri Variant (A.D. 900-1400) houses was conducted. These houses were singled out for analysis because Lehmer (1970) has suggested that these people originally moved into the Middle Missouri area in order to farm following the amelioration of climate during the neo-Atlantic episode. Such climatic changes were supposed to have been particularly well suited for maize production. Regression results do not suggest a specialized horticultural strategy (r = -0.49; R = 0.24; df = 21; p> .01; K = 0.87). The coefficient of alienation (K) tells us that 87 percent of the variation cannot be explained using a horticultural argument.

In summary, these preliminary regression analyses indicat that prehistoric/ethnohistoric peoples in the Middle Missour sub-area of the Plains were not meeting the labor demand necessary for specialized maize production. Greater variation i aboriginal diet and feeding strategies is indicated. Certainly, w cannot rely solely on these preliminary analyses to nullify existin interpretations of past Plains lifeways. The point of this discussio is, however, that archaeologists have become too complacent abou what we think we know about the past in this region.

Prehistoric Ceramics and Maize Horticulture in the Eastern Plains

There is perhaps no other "culture trait" which has bee assigned greater interpretative significance in archaeology tha shell-tempered ceramics in eastern North America. Its spatial temporal distribution has been viewed primarily as a result of trai diffusion and/or migration from the American Bottoms o "Mississippian Culture heartland" centering on Cahokia (e.g., Holme 1886a, 1886b, 1903; Griffin 1937, 1943, 1952; McKern 1934; Ha 1962; O'Brien 1978; Brose 1978; Walthall 1980; Prufer and Shan 1970).

Shell-tempered ceramics in the eastern Plains has bee attributed to "Mississippian" influences and/or population movemen from the eastern woodlands, the Mississippi Valley, and the Steed Kisker sites near Kansas City (e.g., McKern 1934; Strong 193 Wedel 1935, 1959; Bell and Gilmore 1936; Griffin 1937, 194 Henning 1967, 1970; Calabrese 1969; Gibbon 1972, 1974; O'Brie 1978).

In general, archaeologists working in the eastern Plains hav regarded variability in artifactual assemblages, in this cas involving shell-tempered ceramics, to reflect differential contac and resulting adoption of ideas/culture traits.

Henning (1967:185) states, for example,

> The traits (e.g., polished jars. . .decorated with trailed curvilinear designs. . .seed jars, bowls, plates, and "bean pots". . .) alluded to above will be used as indicators of the degree to which Mississippian peoples might have influenced occupants of the eastern margin of the Central Plains.

Mississippian Adaptations

The observed distribution of shell-tempered ceramics in eastern North America and along the margins of the eastern Plains can be explained more productively in terms of ecological/ nutritional relationships (Osborn 1981, 1986). More specifically, shell-tempered ceramics represent an adaptive technological response to the problems associated with increased dependence on ripe maize and food storage along the margins of the eastern deciduous forests.

Recent archaeological studies have called for a relatively extensive revision and reformulation of our ideas regarding Mississippian cultures throughout the eastern woodlands (cf. Peebles and Kus 1977; Smith 1978). There is considerable archaeological evidence for marked population growth throughout the Midwest, the Lower Great Lakes, and the Mississippi-Ohio River drainages between A.D. 800-1400.

Accompanying this population surge we see intensification of maize horticulture, intensive exploitation/overexploitation of the "terrestrial trinity" - whitetailed deer, turkey, and racoon; expansion of the diet to include smaller, less optimal foods including aquatic resources; increased socio-religious/socio-political complexity; the appearance of larger population aggregates; and increased evidence for a deterioration of nutrition and health (cf. Peebles and Kus 1977; Smith 1978; Cohen and Armelagos 1984).

Maize Diet and Nutritional Disorders

Like many cereals, maize is deficient in certain essential nutrients including tryptophan, lysine, the B-vitamin niacin, ascorbic acid, calcium, iron, and zinc. It exhibits a low protein score (41) in comparison to eggs (100) and fish (70). Maize consumption has been casually linked to the nutritional disorder pellagra (e.g., Goldberger 1914; FAO 1953; Roe 1973; Katz, Hediger, and Valleroy 1975; Robson et al. 1976; Sebrell 1981). Pellagra is a very debilitating physiological disorder involving dermatitis, dementia, and diarrhea. It was originally thought to have been caused by a niacin deficiency and was a particular problem in populations heavily dependent on maize or sorghum and deficient in animal protein (Goldberger 1914; Roe 1973; Sebrell 1981).

Pellagra has also been linked to imbalances in other amino acids that affect the tryptophan-niacin metabolic pathway in the liver. Some investigators suggest that pellagra results from excessive levels of leucine and the resulting imbalance of leucine and isoleucine (Gopalan and Srikantia 1960; Rao 1972; Gopalan and

Rao 1975). Most recently, pellagra has been attributed to fungi-contaminated grain and trichothecene toxicosis (Schoental 1980).

Maize Consumption and Shell-Tempered Ceramics: Systemic Interrelationships

More than a century ago Mexican physician Ismael Sala described in detail the methods used to prepare and cook maize i MesoAmerica. It was this method of preparation that Sala attributed to the absence of pellagra in Mexico and Central Americ (Roe 1973). Since that time others have investigated the alka processing techniques used in Latin America and in North Americ (e.g., Cravioto et al. 1945; FAO 1953; Behar 1968; Katz, Hedige and Valleroy 1975; Carpenter 1981).

It has been pointed out that alkali processing serves to softe the tough outer kernel, to free lysine and tryptophan, to improv amino acid balance i.e., leucine and isoleucine, and to add calciu potassium, magnesium, phosphorus, copper, and zinc to the treate maize (FAO 1953).

A cross-cultural analysis conducted by Katz, Hediger, an Valleroy (1975) demonstrates that alkali processing is highl correlated with high production/consumption levels of maize. Th study, as well as those conducted by Nations (1974) and other describe additional maize processing methods e.g., wood ash/ly soaking, green roasting, ash roasting, and "seasoning" with slake marine/freshwater mollusk and gastropod shells.

Prehistoric shell-tempered ceramics used throughout much the eastern woodlands of North America may have served the sam function. In the "Mississippian" case burned, freshwater mollus shells were added directly to the paste of prehistoric cerami cooking vessels. Burned, crushed mollusk shells served to increas vessel porosity and possibly to lessen the effects of thermal sho (DeAtley 1973; Stimmel 1978). Vessels could also be fired within broader range of firing temperatures (Stimmel 1978).

This technological response would serve to enhance th nutritional value of maize, to reduce the manufacturing costs culinary vessels, and possibly to increase their uselife. In additio we find that alkali processing affected by shell-tempered culinar vessels probably served to detoxify any food contaminated by leth mycotoxins - particularly aflatoxins produced by *Aspergillus* sp and *Fusarium* spp. fungi (Schoental 1980). Alakali processing is on of the few known methods for detoxifying mycotoxins. Thes extremely toxic substances cause a number of physiologic problems that are almost identical to those associated with pellagr (Schoental 1980).

Implications of Shell-Tempered Ceramics Distribution

Shell-tempered ceramics have been recovered from archaeological sites from New York to Minnesota and south from the Gulf Coast to northern Florida (Osborn 1981). The temporal range of these ceramics spans the entire Mississippian culture period (A.D. 800-1500) and extends well into the historic period in eastern North America. EuroAmericans observed the Pamunkey Indians making shell-tempered pottery vessels circa A.D. 1878 in Virginia (Mason 1877:627).

Little, if any, shell-tempered ceramics is observed north of 46 degrees N. lat. or west of 99 degrees W. long. in North America. This geographical distribution coincides well with the northern and western limits of aboriginal maize farming (Yarnell 1964). The northern limit for the distribution of aboriginal maize production closely approximates the mean summer/mean summer night isogram of 19 degrees C. (66 degrees F.) and 13 degrees C. (55 degrees F.), respectively. As Jenkins (1941:310) points out, these temperature thresholds are critical for maize production. The western edge of the distribution of shell-tempered ceramics is defined by a precipitation threshold of the 21 cm (8 inch) mean summer (June, July, August) isogram (Jenkins 1941).

This spatial and temporal distribution of shell-tempered ceramics is isomorphic with aboriginal maize-based adaptations. All maize producing societies, of course, did not use shell-tempered ceramics. We know that there are notable exceptions in North America including the Iroquois and Huron in the Northeast and the Anasazi in the American Southwest. Other factors that must be considered include adoption of alternative processing methods e.g., use of wood ash/lye solutions and green roasting and increased availability of animal protein resources. Both pellagra and mycotoxicosis are counteracted by increased consumption of high quality protein.

Yet, the marked absence of shell-tempered ceramics throughout most of the eastern Plains bordering the "Oneoto culture" is extremely interesting. The paucity of such ceramics, in-and-of itself, does not necessarily mean that maize farming was not practiced. However, if we also consider the evidence for greater subsistence variation and the absence of the extending strategy for horticultural labor organization, one begins to wonder.

Ecology of Fire and Whitetailed Deer: An Alternative Determinant of Central Plains Adaptations

Prehistoric peoples of the Central Plains Nebraska and Uppe Republican regional variants (cf. Krause 1969) have generally bee labelled "sedentary/semi-sedentary" maize horticulturalists (e.g. Wedel 1940, 1941, 1961, 1978a, 1979; Krause 1969; Wood 1969 Gradwohl 1970). These prehistoric groups did grow maize but little if any, attempt has been made to determine how intensively it wa used. We know that throughout much of the Central Plains "over wintering" presents evolutionary, adaptive problems for all lif including human populations. If stored maize and other plan resources did not serve to solve this adaptive problem fo prehistoric Central Plains peoples, then what did? I have suggeste that Nebraska and Upper Republican regional variant groups solve this problem by exploiting one mammal species that successful over-winters in the eastern Plains - the whitetailed dee (Odocoileus virginianus).

Archaeologists are certainly aware that whitetailed deer wer included in the diet of prehistoric/historic Plains peoples. Onc again, however, we must ask how this food item, like maize, wa integrated into the overall feeding strategy. How much did dee contribute to the diet in terms of energy and/or nutrients? Whe was it consumed throughout the annual cycle and in wha proportions? To what extent did it comprise a major over-winterin food resource? Answers to such questions will enable us to bette understand aboriginal adaptation(s) to ecological constraints in thi region.

Significance of Whitetailed Deer for Aboriginal Adaptation(s)

McCabe and McCabe (1984) estimate that aborigina populations of Canada and the United States killed approximatel 4.6-6.4 million whitetailed deer each year during ethnohistori times. This annual deer harvest provided more than 194 millio kilograms (427 million pounds) of meat to approximately 2.34 millio persons occupying 7.8 million km^2 (3 million miles^2). Gramly (197 estimates that the Huron of the Great Lakes region require approximately 7 hides/person/year or a total of 62,000 dee skins/year for clothing.

Hickerson (1965) argues that whitetailed deer were a critica food resource for the Sioux and the Chippewa of the Uppe Mississippi Valley. Buffer zones or no-man lands surrounded thei populations and served as "preserves" for whitetailed dee populations. He (1965) remarks that deer were the only foo

resource available to these populations during the long, harsh winters. Warfare and feuding between these populations is explainable, Hickerson (1965:62) argues, in terms of the distribution and abundance of this limiting resource. Based on these observations, I propose that eastern Plains peoples were limited in number and distribution by ecological relationships which ultimately limited whitetailed deer.

Whitetailed Deer Ecology

Local quantities of suitable forage impose limitations on whitetailed deer - particularly during the winter months. Plant production stops during the winter and forage becomes less accessible due to snow cover. McCabe and McCabe (1984:117) state, "Movement in snow greatly increases energy expenditure, with highest values occurring when deer sink to depths of 25 to 30 centimeters (10-12 inches) or more. . . ."

Whitetailed deer require a number of nutrients including water, nitrogen, magnesium, essential fatty acids, calcium, phosphorus, sodium, chlorine, potassium, sulfur, iron, copper, iodine, cobalt, manganese, selenium, chromium, fluorine, nickel, silicon, vanadium, tin, arsenic, molybdenum, vitamins A, D, and E (Verne and Ullrey 1984:116). Deer energy demands are a function of body weight or approximately 155-160 kcal per kilogram of body weight$^{0.75}$ (Verne and Ullrey 1984:117).

Whitetailed deer derive the greatest portion of their diet from forest edges or ecotones, in patches of young forest, and in windfall or recently burned areas (Harlow 1984:606). With respect to the Central Plains, Menzel (1984:450) states,

> Stream courses are the primary habitat of whitetails. . . The quality and quantity of these habitats - which vary in width from several meters to about 2 kilometers (1.2 miles) - normally are the limiting factor for whitetails.

During winter, whitetailed deer greatly reduce their mobility - collapsing their home range to about 10 percent of the area used during the growing season. Due to a dramatic decrease in forage availability at this time, "yarding areas" must possess relatively high quality browse. Yarding behavior involving decreased mobility and aggregation in winter has been discussed at length by Dahlberg and Guettinger (1956), Hickerson (1965), Telfer (1967), Rongstad and Tester (1969), Mellars (1976), Moen (1976), Hall (1984).

Marchinton and Hirth (1984:134) state in this regard,

> Heavy use of deer yards is associated primarily with cold temperatures rather than snow depth, although the two factors often are related (Ozoga and Gysel 1972). In most years deer enter the yards in January and leave in

March. However, the timing of the arrival and departure depends on the severity of the winter.

Yarding is perhaps best understood in terms of behavior designed to reduce threats from predators e.g., wolves and to reduc energy loss during periods of extensive snow cover. Moen (1976 points out that deer conserve up to 1,000 kcal/day and from 0.25 t 0.50 kg. of foreage by yarding.

Fire Ecology

Fire ecology involves the interrelationships between natura and human-induced fires and their impact on the structure an dynamics of ecological communities. Fire became an importan component of ecological dynamics in North America during the lat Cretaceous/early Tertiary periods (cf. Komarek 1965:170). Intens mountain building and alterations in air circulation patterns ove North America produced squall line thunderstorms in the interio regions. Decreased precipitation and increased lightning activity particularly during the summer months - produced the Great Plain grasslands (Komarek 1965).

The significance of lightning fires cannot be underestimate with respect to the environment. For example, the number o lightning fires per year in the United States ranged from 5,159 t 11,459 fires between 1951 and 1960; the average number of lightnin fires per year was 8,391 (Komarek 1966:98). Given these figures w find that there was one lightning fire for every 90,500 acres o forest in the country (Komarek 1966:98).

Effects of Fire on Deer Habitat

Whitetailed deer utilize forest stands in inverse proportion t their age (Carmichael 1981:8). Natural and/or human-induced fire of low to moderate intensity greatly enhance the quantity an quality of forage required and preferred by whitetailed deer. Fire reduce over story shading effects and expose the forest floor t great amounts of solar radiation. A number of studies provide u with more detailed information about changes in soils, specie composition, productivity, and nutrient availability following burn (e.g., Storer 1932; Shantz 1947; DeWitt and Derby 1955; Dills 1970 Taber and Murphy 1971). A number of these effects of fire o forest/grassland communities are presented in Table 2.6.

Dills (1970) studied the effects of a low intensity forest fire i the Catoosa Wildlife Management Area in Tennessee. He (1970 found that three types of preferred whitetailed deer browse i.e., re maple, sourwood, and sassafras increased from 173 lbs/acre befor the burn to 598 lbs/acre approximately 16 months later. During th third year following the burn, forage standing crop increased to 93 lbs/acre or more than a 538 percent increase (Dills 1970:540).

Table 2.6. Summary of the effects of fire on deer habitat.

Improved Soil Quality	
Increased organic content	Lotti 1962:115
Improved physical properties	
Increased nutrients - nitrogen, calcium potash, phosphorus, magnesium	Lotti 1962:116 Taber and Murphy 1971
Reduced Shading Effect	
Stimulates seed germination	Taber and Murphy 1971
Causes vigorous growth of sprouting plants	Taber and Murphy 1971
Allows increased light for herbaceous growth	Dills 1970
Elimination of Majority of Understory Plants	
Increased forage production (350-550 percent)	Dills 1970
Decreased species diversity of understory	
Improved Forage Quality	
Increased protein content (25-145 percent)	Einarsen 1946
Decreased fiber content	DeWitt and Derby 1955
Increased carrying capacity (300-700 percent)	Mellars 1976
Improved Deer Health Status	
Increased body weight	Klein 1970
Increased fertility rate	Taber and Dasmann 1957
Increased resistance to parasites/disease	Taylor 1961; Klein 1970

Deer population may increase considerably following a fores fire. For example, Black-tailed deer in Oregon increased from 2 t 14 per square mile or more than 700 percent following a fir (Longhurst 1961:313). Whitetailed deer increased from 6 to 37 pe square mile in a New Jersey forest that had been logged and burne (Cummings 1969:259).

Studies of the effects of fire on deer habitat have als revealed that animal health and fertility may increase. Klei (1970:30-31) observed that Columbian blacktailed deer were from 2 to 40 percent heavier following a fire. Taber and Dasmann (1957 noted a marked increase in fertility among does in Californi chaparral communities following a burn. Number of fawns produce per 100 does increased from 77 to 135. Does also began t reproduce one year earlier in their reproductive careers in a burne area.

The combined effects of low intensity fires along forest edge are advantageous for whitetailed deer populations. Deer populatio increases markedly, animals may gain more weight, and femal fertility is greatly enhanced. Preferred deer habitat is increased i both area and in quality. Such burns would then be expected t produce optimal deer herds along the grassland/forest edges in th eastern Plains. Fires whether started by lightning strikes o prehistoric hunter-gatherers would have greatly enhanced dee habitat and their own over-wintering abilities in the absence o maize horticulture.

Topography and Grassland/Forest Edge

The essential link between fire, vegetative cover, an topography in the Great Plains region is provided by Wells (1970) He (1970:1580) states,

> Regardless of local or regional variations in climate and. . .species composition of both woodland and grassland in the Plains region. . .the more dissected the topography, the greater the. . .extent and. . .spread of woody vegetation at the expense of grassland. Over and above the droughty climate. . .it is the vast flat or rolling smoothness. . .that. . . appears to have played a powerful role in the development of the great expanses of treeless grasslands on the Plains. . . . The wavelike motion of the wind-swept grass fire across a flat or rolling plain would continue indefinitely until it was quenched by rain or checked by an abrupt break in topography.

Topographical relief in the Loess/Draft Hills of the Centra Lowland Province is relatively pronounced - especially along th

Missouri River valley and major tributaries (Weaver 1965). This heavily dissected area of the Central Plains supports stands of broad-leaf deciduous forest composed of red oak, linden, ironwood, black oak, hickory, dogwood, and hazel (Weaver 1965). Floodplain species including elm, ash, and hackberry also contribute to this forest's composition (Weaver 1965:23). These broad-leaf deciduous forests invade the Central Plains via the more deeply incised, "V-shaped" stream valleys which provide protection from grass fires. It is, then, along this grassland/forest edge that we find optimal whitetailed deer habitat created by frequent, low intensity burns. Additional, but perhaps less productive deer habitat can also be found along stream margins where meanders, oxbow lakes, marshes, and erosion create a patchwork of young forest stands. This secondary area would offer Central Plains hunter-gatherers an additional area for deer hunting. Optimal locations for winter residences would probably be in uplands areas near areas of maximal topographic relief e.g., near the confluence of two or more drainages. These areas would provide a maximum amount of "edge" or optimal deer habitat within the foraging radius of the residence.

Implications for Interpretations of Central Plains Archaeology

One of the most significant adaptive problems for prehistoric Central Plains peoples would have been over-wintering. Over-wintering can either be solved through recourse to food storage or exploitation of animals that have already solved the problem (Binford n.d.). I have argued here that Central Plains peoples "chose" the latter adaptive strategy. Encounter hunting of white-tailed deer would have obviated the need to adopt a labor intensive food storage strategy based on maize farming or specialized bison hunting.

In addition, Central Plains peoples most probably made use of fire in order to increase the productivity and accessibility of winter herds of whitetailed deer. Schalk (1984:42-47) has discussed a similar adaptive response which was made by prehistoric hunter-gatherers in the Middle Kootenai River valley in northwest Montana. Fire technology was probably used in the eastern Plains to maintain optimal deer habitat and to affect deer yarding behavior in winter.

Most interestingly, however, we must investigate the implications of such an over-wintering strategy for traditional interpretations of Central Plains archaeology. Archaeologists have applied the neolithic revolution notions to this region. Substantial, rectangular earthlodges, subterranean pits, pottery, and scattered charred maize have been interpreted as irrefutable evidence for sedentary horticultural lifeways (Wedel 1940, 1941, 1961, 1978a, 1979; Gradwohl 1970; Zimmerman 1977). Wood (1969) argues tha the Nebraska regional variant sites represent sedentary, maiz horticulturalists. He (1969:104) states that alluvial bottomland along the Missouri River and greater maize production capabilitie distinguishes Nebraska from Upper Republican regional variants Hunting along the forest/grassland edge is accorded secondary, i not insignificant, subsistence importance.

If maize horticulture was not the basis for Central Plain Tradition subsistence - particularly for the Nebraska regiona variant - then Plains archaeologists have their work cut out fo them. First, Central Plains population estimates have been based o amounts of arable farmland (e.g., Wood 1969:103; Krause 196 1970). Second, shifts in settlement patterns have been viewed as function of responses to climatic changes affecting maize farmin (e.g., Zimmerman 1977). Third, social organization has bee modelled in terms of empirical generalizations linking matrilo cality/matrilineality and extensive horticulture (e.g., Wood 196 Krause 1969, 1970; Lippincott 1976). Fourth, determinants of lodg placement have been assumed to be related to the availability o arable land, timber, and panoramic vistas. And, fifth, variability i ceramics and house size have been casually linked to the matrilo cality/matrilineality/horticulture correlations (e.g., Zimmerma 1977).

CONCLUSIONS

I have suggested in this paper that it is now time to begin a intensive critical evaluation and synthesis of CRM archaeology i the United States. We are in the twilight years of nearly a decad of well-funded, intensive archaeological investigations. It is no time to ask ourselves about the ultimate returns we have reape from such an enormous expenditure of funds and human labor. Ho well have archaeologists managed to solve the service/researc dilemma? How much have we learned about past human behavior?

I have proposed that such a synthesis and critical evaluation o countless CRM studies could be conducted through recourse to th concept of scientific research programmes. This philosophy o science concept might be used in order to assess our overall succe in conducting productive research - that which produced "ne facts". Furthermore, the development of a scientific researc programme would enable archaeologists to integrate much of wha we already know about the past. And, such a concept will b essential for guiding all significant archaeological research in th future.

Archaeology was undergoing significant theoretical and methodological change when current CRM archaeology emerged in the early 1970s. Keene and MacDonald (1980) have vehemently argued that "cultural resource management" archaeology was for the most part the antithesis of processual or new archaeology. I would agree with such an assessment.

Time constraints and anti-intellectualism of many federal agencies and big business forced many archaeologists to concentrate their efforts on inventorying and describing bits and pieces of the archaeological record. Archaeologists became the reconnaissance teams that were sent out in advance of development projects to clear the path of insignificant, as well as significant, cultural resources. Much could be said about the anthropological aspects of archaeologists behavior during the past decade. However, the intent here has been to explore the potential of the scientific research programme concept.

The foundation of the research programme presented here is based on contemporary ecological, nutritional, anthropological, and archaeological theory (cf. Figure 2.4). These relationships integrate what we know about aboriginal adaptations in the eastern Plains. This research programme was not originally defined in toto but evolved during the course of CRM-based studies in the Central Plains and the Middle Missouri sub-areas. The present form of this research programme derives from an underlying evolutionary ecological view of human behavior. The dynamic relationships between aboriginal populations and their environment provide continual guidance for future archaeological research.

In the preceding discussion, four distinct, yet related, research problems addressed during the course of CRM projects and archaeological fieldschools have been outlined. A study of ecological diversity and hunter-gatherers along the central Niobrara River drainage enabled us to compare our expectations about foraging behavior with the archaeological record. The extent to which our expectations were met informed us about aboriginal foraging versus horticulture. This research was conducted in the context of two CRM inventory surveys along the Niobrara River.

House floor data from the Middle Missouri sub-area of the Plains was used in the context of an inventory survey of the eastern shoreline of the Oahe Reservoir to test traditional assumptions about aboriginal dependence on maize horticulture. This research made use of existing data but was also designed to incorporate current survey information. Archaeological data from the Central Plains was added later in order to examine the nature of house size

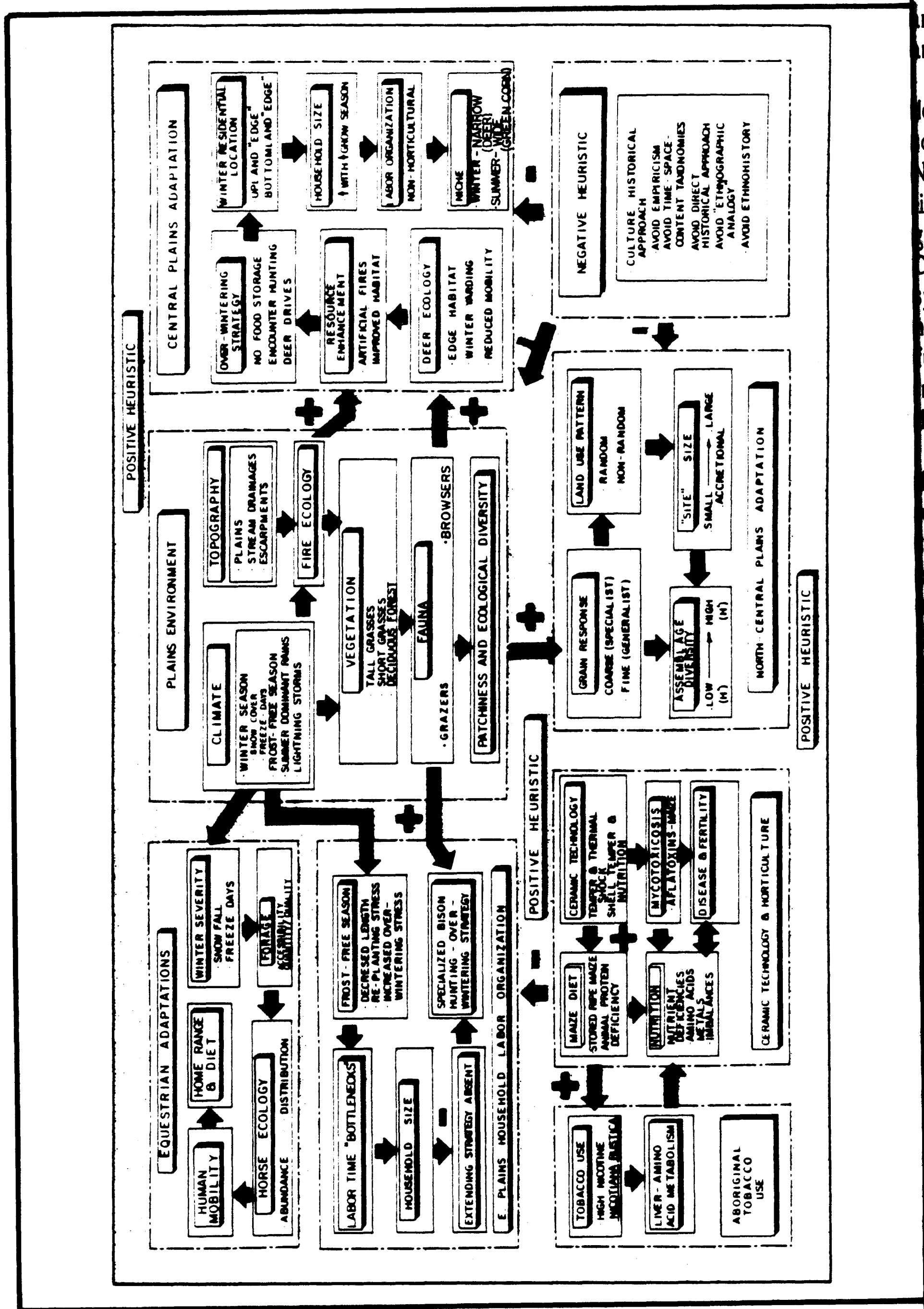


Figure 2.4 Schematic View of a Schematic Research Programme for the Investi tion of Aboriginal Plains Adaptations.

nd climate along a south-to-north gradient from the Smoky Hill rea in Kansas to Knife River in North Dakota.

The argument concerning shell-tempered ceramics and lependence on maize horticulture arose during archaeological field- chool investigations in the Weeping Water locality of southeastern Jebraska. Nebraska phase sites in southeastern Nebraska contain ittle, if any, shell-tempered ceramics. I began to investigate the eographical and temporal distribution of such ceramcis e.g., Dneota and Mississippian in order to address this problem. The ystemic interrelationships betweeen ceramic technology, diet, utrition, and disease offer archaeologists a number of problems for uture investigation. This argument also allows us to make nferences about relative dependence on maize based on ceramic lata in the eastern Plains.

Finally, the argument concerning fire ecology and whitetailed leer suggests the basis for a significant and overlooked "over- vintering" strategy for Central Plains inhabitants. It is not enough o suggest that maize horticulture was an insignificant component f Central Plains adaptation(s). This study of fire ecology and deer long the eastern Plains margins is offered in order to explain the onclusions produced by the study of house floor area, climate, and orticultural labor organization.

The positive heuristic for this research programme derives rimarily from the interconnections which link ecological theory nvolving patchy environments/grain responses, hunter-gatherer land se, fire/wildlife ecology, and maize horticulture with human utrition/physiology and anthropological theory regarding domestic roups and labor organization. These various theories possess dditional empirical and theoretical implications. This web of ideas nd empirical correlates serve to "fill in" and elaborate on the nitial set of theories which guide the research programme. These nterconnections also serve to generate "new facts".

And, finally, the negative heuristic or unproductive research irections in this case would include the culture historical approach n archaeology. For more than a century Plains archaeology has nade intensive use of the normative concept of culture, "ethno- istoric" analogy, and an empiricist philosophy. This culture istorical approach has not successfully organized the archaeo- gical record in spatial and temporal terms. Its reconstructions of ast lifeways are questionable and they exhibit limited research otential.

The concept of scientific research programme in contrast ffers archaeologists a means for making most effective use of CRM archaeology. The challenge which lies ahead involves synthesis and evaluation. Much CRM archaeology has bee[n] published in relatively obscure "technical papers series" an[d] "laboratory notebooks". Regional syntheses will probably have to b[e] completed by individuals who were directly involved at thi[s] geographical level. The ultimate challenge, however, will entail us[e] of CRM information to evaluate and test contemporary explanation[s] of human behavior. The research programme concept will greatl[y] facilitate this work.

[R]EFERENCES CITED

[A]ngus, C. A.
1975 A faunal study of the larger mammalian species from the Bagnell Site (32OL16), Oliver County, North Dakota. M. A. Thesis, Department of Anthropology, University of Nebraska.

[A]rmelagos, George J.
1969 Disease in ancient Nubia. Science 163:255-259.

[B]ehar, M.
1968 Food and nutrition of the Maya before the Conquest and at the present time. In Biomedical challenges presented by the American Indian, Proceedings of the Special Session, Pan American Health Organization, Scientific Publication No. 165, Washington, D.C.

[B]ell, E. H. and G. H. Gilmore
1936 The Nehawka and Table Rock foci of the Nebraska aspect. In Chapters in Nebraska archaeology, ed. E. H. Bell, pp. 301-356. Lincoln, Nebraska: University of Nebraska Press.

[B]ender, D. R.
1967 A refinement of the concept of household: families, co-residence, and domestic functions. American Anthropologist 69:493-504.

[B]enn, D. W.
1974 Seed analysis and its implications for an Initial Middle Missouri site in South Dakota. Plains Anthropologist 19(63):55-72.

[B]inford, L. R.
1964 A consideration of archaeological research design. American Antiquity 29 (4):425-441.

1978 Nunamiut ethnoarchaeology. New York: Academic Press.

1981 Bones: ancient man and modern myths. New York Academic Press.

1984 Faunal remains from Klasies River Mouth. New York Academic Press.

Binford, L. R. and J. Bertram
1977 Bone frequencies and attritional processes. In Fo theory building in archaeology, ed. L. R. Binford pp. 77-153. New York: Academic Press.

Binford, L. R. and J. A. Sabloff
1982 Paradigms, systematics, and archaeology. Journal o Anthropological Archaeology 38(2):137-153.

Blakeslee, D. J.
1975 The Plains interband trade system: an ethnohistoric an archaeological investigation. Ph.D. dissertatio Department of Anthropology, University of Wisconsin.

1978 Assessing the Central Plains tradition in easter Nebraska: content and outcome. In The Central Plain tradition: internal development and externa development and external relationships, D. J. Blakeslee ed., pp. 134-143. Iowa City: University of Iowa Press.

Brim, J. A. and D. H. Spain
1974 Research design in anthropology: paradigms an pragmatics in testing of hypotheses. New York: Holt Rinehart and Winston.

Brose, D. S.
1978 Late prehistory of the Upper Great Lakes area. I Handbook of North American Indians, Vol. 15: Northeas ed. B. G. Trigger, pp. 569-582. Washington, D. C Smithsonian Institution.

Bryson, R. A. and W. M. Wendland
1967 Tentative climatic patterns for some late glacial an post-glacial episodes in central North America. In Life land, and water, W. J. Mayer-Oakes, ed., pp. 271-29 Occasional Papers Department of Anthropolog University of Manitoba.

Bryson, R. A., D. A. Baerreis, and W. M. Wendland
1970 The character of late-glacial and post-glacial climatic changes. In Pleistocene and recent climatic environments of the Central Great Plains, eds. W. Dort, Jr. & J. K. Jones, Jr., pp. 53-77. Lawrence: University of Kansas Press.

Calabrese, F. A.
1969 Doniphan phase origins: an hypothesis resulting from archaeological investigations in the Smithville Reservoir area, Missouri: 1968. Lincoln, Nebraska: Midwest Archaeological Center, National Park Service.

1972 Cross Ranch: a study of variability in a stable cultural tradition. Plains Anthropologist Memoir 9.

Carbone, V. A. and B. C. Keel
1985 Preservation of plant and animal remains. In The analysis of prehistoric diets, eds. R. I. Gilbert, Jr. and J. H. Mielke, pp. 1-20. New York: Academic Press.

Carmichael, P. H.
1981 Smokey the bear syndrome versus positive feedback between fire ecology and human populations. Manitoba Archaeologist Quarterly 5(3):2-19.

Carpenter, K. J.
1981 Effects of different methods of processing maize on its pellagragenic activity. Federation Proceedings 40(5): 1531-1535.

Casselberry, S. E.
1973 Further refinement of formulae for determining population from floor area. World Archaeology 6(1):117-122.

Chayanov, A. V.
1966 The theory of peasant economy, (eds.) Thorner, D., B. Kerblay, R.E.F. Smith. Homewood, Illinois: Richard D. Irwin for the American Economic Association.

Childe, V. G.
1936 Man makes himself. London: Watts.

1952 New light on the most ancient East. New York: Praeger.

Chomko, S. A.
1976 Faunal exploitation in the Initial Middle Missouri variant. In Fay Tolton and the Initial Middle Missouri variant, ed. W. R. Wood, pp. 35-41. Missouri Archaeological Society Research Series No. 13.

Cohen, M. N.
1972-1974 Some problems in the quantitative analysis of vegetable refuse illustrated by a Late Horizon with on the Peruvian coast. Nawpa Pacha 10-12:49-57.

Cohen, M. N. and G. J. Armelagos
1984 Paleopathology at the origins of agriculture. New York Academic Press.

Comptroller General (of the United States)
1981 Are agencies doing enough or too much for archaeological preservation? guidance needed. Report to the Chairman, Committee on Interior and Insular Affairs, House of Representatives, United States General Accounting Office CED-81-61. Washington, D.C. U. S. Government Printing Office.

Cook, D. C. and J. E. Buikstra
1973 Circular caries: a new tool in nutritional assessment in the past. Paper presented at meeting of the American Association Physical Anthropology. Dallas.

1979 Health and differential survival in historic populations prenatal dental defects. American Journal Physical Anthropology 51:649-664.

Cook, S. F. and R. F. Heizer
1968 Relations among houses, settlement areas and population in aboriginal California. In Settlement archaeology, K. C. Chang (ed.), pp. 79-116. Palo Alto: National Press.

1965 The quantitative approach to the relation between population and settlement size. Contributions to the University of California Research Facility No. 14:17-40.

Cook, S. F. and A. Treganza
1950 The quantitative investigation of Indian mounds. University of California Publications in American Archaeology and Ethnology 40(5).

Cummings, J. A.
1969 Prescribed burning on recreation areas in New Jersey: history, objectives, influences and technique. Proceedings of the Annual Tall Timbers Fire Ecology Conference 9:251-269.

Cravioto, O. Y. et al.
1945 Nutritive value of the Mexican tortilla. Science 102:91-93.

Dahlberg, B. L. and R. C. Guettinger
1956 The whitetailed deer in Wisconsin. Technical Wildlife Bulletin 14. Madison.

Dallman, J. E.
1983 A choice of diet: response to climatic change. Office of the State Archaeologist, University of Iowa, Report No. 16. Iowa City.

DeAtley, S. P.
1973 A preliminary analysis of patterns of raw material use in Plainware ceramics from Chevelon, Arizona. Masters Thesis, Department of Anthropology, University of California.

Deetz, J.
1965 The dynamics of stylistic change in Arikara ceramics. Illinois Studies in Anthropology, No. 4. Urbana: University of Illinois Press.

DeWitt, J. B. and J. V. Derby
1955 Change in the nutritive value of browse plants following forest fires. Journal of Wildlife Management 19:65-70.

Dills, G. G.
1970 Effects of prescribed burning on deer browse. Journal of Wildlife Management 34:540-545.

Divale, W. T.
1977 Living floor area and marital residence: a replication. Behavioral Science Research 12:109-115.

Einarsen, A. S.
1946 Crude protein determination as an applied management technique. Transactions of the American Wildlife Conference 11:309-312.

Ember, M.
1973 An archaeological indicator of matrilocal versus patrilocal residence. American Antiquity 38:177-182.

Erasmus, C. J.
1956 Culture structure and process: the occurrence and disappearance of reciprocal farm labor. Southwestern Journal of Anthropology 12:444-469.

Falk, C. R.
1969 Faunal remains. In Two house sites in the Central Plains: an experiment in archaeology, ed. W. R. Wood, pp. 39-50; 79-81; 102. Plains Anthropologist 14(44) Pt. 2. Memoir 6.

1977 Analysis of unmodified vertebrate fauna from sites in the Middle Missouri subarea: a review. In Trends in Middle Missouri prehistory: a festschrift honoring the contributions of Donald J. Lehmer, W. R. Wood, ed., pp. 151-160. Plains Anthropologist 22(78, Pt. 2), Memoir 13.

FAO
1953 Maize and maize diets: a nutritional survey. Food and Agriculture Organization of the United Nations Nutritional Studies No. 9.

Fowler, D.
1982 Cultural resources management. In Advances in archaeological method and theory, Vol. 5, ed. Schiffer, M., pp. 1-50. New York: Academic Press.

Gibbon, G. E.
1972 Cultural dynamics and the development of the Oneota life-way in Wisconsin. American Antiquity 37(2):166-185.

1974 A model of Mississippian development and its implications for the Red Wing area. In Aspects of Upper Great Lakes anthropology: papers in honor of Lloyd A. Wilford, ed. E. Johnson, pp. 129-137. St. Paul: Minnesota Historical Society.

Gilbert, B. M.
1969 Some aspects of diet and butchering techniques among prehistoric Indians in South Dakota. Plains Anthropologist 14(46):277-294.

Goldberger, J.
1914 The etiology of pellagra: the significance of certain epidemiological observations with respect thereto. Public Health Reports 30(43):3117-3131.

Goodyear, A. C.
1977 Regional model building in the contract framework: the Hecla projects of southern Arizona. In Conservation archaeology: a guide for cultural resource management studies, eds. M. Schiffer and G. Gummerman, pp. 413-426. New York: Academic Press.

Gopalan, C. and S. G. Srikantia
1960 Leucine and pellagra. Lancet 1:954-957.

Gopalan, C. and K. S. J. Rao
1975 Pellagra and amino acid imbalance. Vitamins and hormones 33:505-529.

Gramly, R. M.
1977 Deerskins and hunting territories: competition for a scarce resource of the northeastern woodlands. American Antiquity 42(4):601-605.

Griffin, D. E.
1977 Timber procurement and village location in the Middle Missouri subarea. In Trends in Middle Missouri prehistory: a festschrift honoring the contributions of

Donald J. Lehmer, ed. W. R. Wood, pp. 177-185. Plains Anthropologist 22(78, Pt. 2), Memoir No. 13.

Griffin, J. B.
1937 Archaeological remains of the Chiwere Sioux. American Antiquity 2:180-181.

1943 The Fort Ancient aspect. Ann Arbor: University of Michigan Press.

Halls, L. K. (ed.)
1984 White-tailed deer: ecology and management. Harrisburg, Penn.: Stackpole Books.

Hall, R. L.
1962 The archaeology of Caribou Point. Madison: University of Wisconsin Press.

Hames, R.
n.d. Time, efficiency, and utility in the Amazonian protein quest. In A behavioral ecology of the Yanomamo, eds N. Chagnon and R. Hames. New York: Academic Press (forthcoming).

Harlow, R. F.
1984 Habitat evaluation. In White-tailed deer: ecology and management, ed. L. K. Halls, pp. 601-628. Harrisburg, Pennsylvania: Stackpole Books.

Harris, M.
1968 The rise of anthropological theory: a history of the theories of culture. New York: Thomas Y. Crowell.

1979 Cultural materialism: struggle for a science of culture. New York: Thomas Y. Crowell.

Hayes, A. C., D. M. Brugge, and W. J. Judge
1981 Archaeological surveys of Chaco Canyon, New Mexico. Publications in Archaeology 18A. Washington, D. C.: U. S. Government Printing Office.

Hempel, C.
1966 Philosophy of natural science. Englewood Cliffs: Prentice Hall.

Henning, D. R.
1967 Mississippian influences on the eastern Plains border: an evaluation. Plains Anthropologist 12(36):184-194.

1970 Development and interrelationships of Oneota culture in the lower Missouri River valley. Missouri Archaeologist 32.

Hickerson, H.
1965 The Virginia deer and the intertribal buffer zones in the upper Mississippi valley. In Man, culture, and animals.

Hill, J. N.
1972 Methodological debate in contemporary archaeology. In Models in archaeology, ed. D. Clark, pp. 61-107. London: Methuen Press.

Holmes, W. H.
1886a Ancient pottery of the Mississippi valley. Fourth Annual Report, Bureau of American Ethnology, 1882-1883, pp. 361-436.

1886b Origin and development of form and ornament in ceramic art. Fourth Annual Report, Bureau of American Ethnology, 1882-1883, pp. 437-465.

1903 Aboriginal pottery of the eastern United States. Twentieth Annual Report, Bureau of American Ethnology, 1898-1899, pp. 1-201.

Hurt, W. R.
1969 Seasonal economic and settlement patterns of the Arikara. Plains Anthropologist 14(43):32-37.

Jenkins, M. T.
1941 Influence of climate and weather on growth of corn. In Climate and man, pp. 308-20. Washington, D. C.: U. S. Government Printing Office.

Johnson, A. W.
1978 Quantification in Cultural Anthropology. Standford: Stanford University Press.

Judge, W. J.
1982 Will the real archaeology please stand up? Comments o the status of American archaeology, ca. AD 1982. Th George Wright Forum 2(4):17-34.

Katz, S. H., M. L. Hediger and L. A. Vallery
1974 Traditional maize processing techniques in the Ne World. Science 184:765-773.

Keel, B.
1979 A view from the inside. American Antiquit 44(1):164-170.

Keene, A. and W. E. MacDonald
1980 Whatever happened to the "new archaeology"? Pape presented at the 45th Annual Meetings of the Society fo American Archaeology, Philadelphia.

Kelley, K. B.
1982 Ethnoarchaeology of the Black Hat Navajos: historica and a historical determinants of site features. Journa of Anthropological Research 38(1):45-74.

Klein, D. R.
1970 Food selection by North American deer and thei response to over-utilization of preferred plant specie In Animal Populations in Relation to Their Foo Resources, ed. A. Watson, pp. 25-46. Blackwell: Oxfor University Press.

Komarek, E. V., Sr.
1965 Fire ecology - grasslands and man. Proceedings of th Tall Timbers Fire Ecology Conference 4:169-220.

1966 The meteorological basis for fire ecology. Proceedin of the Tall Timbers Fire Ecology Conference 5:85-125.

Krause, R.
1969 Correlation of phases in Central Plains prehistory. Two house sites in the Central Plains: an experiment archaeology, ed. W. R. Wood, pp. 82-96. Plai Anthropologist 14(44, Pt. 2), Memoir No. 6.

1970 Aspects of adaptation among Upper Republican subsistence cultivators. In Pleistocene and recent environments of the central Great Plains, eds. W. Dort and J. K. Jones, pp. 103-116. Lawrence: University of Kansas Press.

Kuhn, T. S.
1962a The structure of scientific revolutions. Chicago: University of Chicago Press.

1962b The historical structure of scientific discovery. Science 136:760-764.

1970 The structure of scientific revolutions. Second edition. Chicago: University of Chicago Press.

Lakatos, I.
1970 Falsification and the methodology of scientific research programmes, In Criticism and growth of knowledge, eds. I. Lakatos and A. Musgrave, pp. 91-195. Cambridge: Cambridge University Press.

Lakatos, I. and A. Musgrave (eds.)
1970 Criticism and growth of knowledge. Cambridge: Cambridge University Press.

Lallo, John W., and Jerome C. Rose
1979 Patterns of stress, disease, and mortality in two prehistoric populations from North America. Journal of Human Evolution 8:323-335.

Larsen, C. S.
1982 The anthropology of St. Catherines Island Part 3: Prehistoric biological adaptation. Anthropological Papers of the American Museum of Natural History 57(2).

LeBlanc, S.
1971 An addition to Naroll's suggested floor area and settlement population relationship. American Antiquity 36:210-211.

Lehmer, D. J
1954a Archaeological investigations in the Oahe Dam area South Dakota. Bureau of American Ethnology Bulletin 158.

1954b The Sedentary horizon of the northern plains Southwestern Journal of Anthropology 10(2):139-159.

1970 Climate and culture history in the Middle Missouri Valley. In Pleistocene and recent environments of the central Great Plains, W. D. Dort and J. K. Jones, eds. pp. 117-129. Lawrence: University of Kansas Press.

1971 Introduction to Middle Missouri Archaeology Anthropological Papers No. 1. Washington, D. C.: U. S Government Printing Office.

Lehmer, D. J. and W. R. Wood
1977 Buffalo and beans. In Selected Writings of Donald J Lehmer, pp. 85-89. Lincoln: J & L Reprints.

Leone, M.
1972 Issues in anthropological archaeology. In Contemporary archaeology, ed. M. Leone, pp. 14-27. Carbondale Southern Illinois University Press.

Levine, R. A.
1970 Research design in anthropological field work. In A handbook of method in cultural anthropology, eds. R Naroll and R. Cohen, pp. 183-195. New York: Columbia University Press.

Lippincott, K. A.
1976 Settlement ecology of Solomon River archaeology National Park Service, Anthropological Papers No. 1.

1978 Solomon River Upper Republican settlement ecology: In The Central Plains Tradition: internal development and external relationship, ed. D. J. Blakeslee, pp. 81-9? Office of the State Archaeologist Report 11. Iowa City.

Longhurst, W. M.
1961 Big-game and rodent relationships to forests and grasslands in North America. La Terre et la Vie 1961, 305-319.

Ludwickson, J.
1975 The Loup River phase and the origins of Pawnee culture. M. A. Thesis, Department of Anthropology, University of Nebraska-Lincoln.

1978 Central Plains tradition settlements in the Loup River basin: the Loup River phase. In The Central Plains tradition: internal development and external relationships, ed. D. J. Blakeslee, pp. 94-108. Office of the State Archaeologist Report No. 11. Iowa City.

n.d. Reconsiderations of Central Plains Tradition house floor areas. Ms. in possession of the author.

MacArthur, R. H.
1965 Patterns of species diversity. Biological Review 40:510-533.

1972 Geographical ecology: patterns in the distribution of species. New York: Harper and Row.

Marchinton, R. L. and D. H. Hirth
1984 Behavior. In White-tailed deer: ecology and management, ed. L. K. Halls, pp. 129-168. Harrisburg, Pennsylvania: Stackpole Books.

Margalef, R.
1968 Perspectives in ecological theory. Chicago: University of Chicago Press.

Mason, O. T.
1877 General notes. American Naturalist 11:627.

Masters, C.
1984 Dental evidence for subsistence patterns among Nebraska prehistoric groups. Paper presented at the Forty-Second Plains Conference, Lincoln, Nebraska.

May, R. M.
1973 Stability and complexity in model ecosystems. Princeton, N. J.: Princeton University Press.

McDaniel, E. G., J. M. Hundley
1958 Alkalai-treated corn and niacin deficiency. Federatio Proceedings 17:484.

McGimsey, C. R. and H. A. Davis
1982 Cultural resource management in the United States. Paper presented at the Transatlantic Colloquium on Comparative Archaeology, Ft. Burgwin, New Mexico August 1982.

McIntosh, R. P.
1967 An index of diversity and the relations of certai concepts to diversity. Ecology 48:392-404.

McKern, W. C.
1934 Certain culture classification problems in middl western archaeology. Committee on State Archaeo logical Surveys, Division of Anthropology an Psychology, National Research Council, Circular series No. 17.

Mellars, P.
1976 Fire ecology, animal populations and man: a study o some ecological relationships in prehistory. Proceeding of the Prehistoric Society 42:15-45.

Meltzer, D. J.
1979 Paradigms and the nature of change in America archaeology. American Antiquity 44(4):644-657.

Menzel, K. E.
1984 Central and southern Plains. In White-tailed deer ecology and management, ed. L. K. Halls, pp. 449-456 Harrisburg, Pennsylvania: Stackpole Books.

Mick, L. S.
1983 An ecological evaluation of faunal diversity in th Central Plains Tradition. M. A. Thesis, Department o Anthropology, University of Nebraska-Lincoln.

Milisauskas, S.
1972 An analysis of linear culture longhouses at Olszanica Bl, Poland. World Archaeology 4:57-74.

Minge-Kalman, W.
1977 On the theory and measurement of domestic labor intensity. American Ethnologist 4:273-284.

Moen, A. N.
1976 Energy conservation by whitetailed deer in the winter. Ecology 57:192-198.

Nations, J. D.
1974 Snail shells and maize preparation: a Lacandon Maya analogy. American Antiquity 44(3):568-571.

Naroll, R.
1962 Floor area and settlement population. American Antiquity 27:587-589.

Netting, R. McC.
1965 Household organization and intensive agriculture: the Kofyar case. Africa 35:422-429.

1968 Hill farmers of Nigeria. Cultural ecology of the Kofyar of the Jos Plateau. American Ethnological Society Monograph No. 46. Seattle, Washington: University of Washington Press.

1969 Ecosystems in process: a comparative study of change in two west African societies. In Contributions to anthropology; ecological essays, ed. D. Damas, pp. 102-112. National Museums of Canada Bulletin 230.

1974 Agarian ecology. Annual Review of Anthropology 3:21-56.

1977 Cultural ecology. Menlo Park, California: Cummings Publishing Company.

Newman, M. T.
1950 The blond Mandan: a critical review of an old problem. Southwestern Journal of Anthropology 6:255-72.

Nickel, R. K.

1974 Plant resource utilization at a late prehistoric site i north-central South Dakota. Masters Thesis Department of Anthropology, University of Nebraska Lincoln.

1977 The study of archaeologically derived plant material from the Middle Missouri subarea. In Trends in Middl Missouri prehistory: a festschrift honoring th contributions of Donald J. Lehmer, ed. W. R. Wood, pp 53-58. Plains Anthropologist 22(78 Pt. 2), Memoir 13.

Norman, D. W., E. B. Simmons, and H. M. Hays

1982 Farming systems in the Nigerian savanna. Boulder Westview Press.

O'Brien, P. J.

1978 Steed-Kisker: western Mississippian settlement system In Mississippian settlement patterns, ed. B. D. Smith, pp 1-20. New York: Academic Press.

Odum, E. P.

1969 The strategy of ecosystem development. Scienc 164:262-270.

Osborn, A. J.

1979 Cultural resource inventory and assessment for selec areas within the Ft. Niobrara National Wildlife Refug Valentine, Nebraska: A final report. Department o Anthropology, Division of Archaeological Researc University of Nebraska, Technical Report No. 79-07.

1980 Aboriginal adaptations in the Middle Missouri sub-are of the North American Grat Plains: an evaluation o several critical isues. Ms. in possession of the author.

1980 Cache pits, scapula hoes, and antler rakes do not village farmer make: sedentary bison hunters of th eastern Great Plains? Paper presented at the 38 Annual Plains Conference, Iowa City, Iowa.

1981 Amazing paste how sweet the taste! "Mississippia influences", maize horticulture, and shell-tempere ceramics in the eastern Plains. Paper presented at the 39th annual Plains Conference, Bismarck, North Dakota.

1983 Ecological aspects of equestrian adaptations in aboriginal North America. American Anthropologist 85:563-591.

1985 Fire ecology, whitetailed deer, and prehistoric Central Plains adaptations. Paper delivered at the 95th Annual Meetings of the Nebraska Academy of Sciences, Lincoln.

Ozoga, J. J. and L. W. Gysel

192 Response of white-tailed deer to winter weather. Journal of Wildlife Management 36(3):892-896.

asternak, B.

1972 Kinship and community in two Chinese villages. Stanford: Stanford University Press.

asternak, B., C. R. Ember, and M. Ember

1976 On the conditions favoring extended family households. Journal of Anthropological Research 32(2):109-123.

atten, R. C.

1981 Aflatoxins and disease. American Journal of Tropical Medicine and Hygiene 30(2):422-425.

atterson, L. W.

1980 Archaeology in the real world. Practicing Anthropology 2(4):14-26.

eebles, C. S. and S. M. Kus

1977 Some archeological correlates of ranked society. American Antiquity 42:421-448.

eterson, J. E.

1980 Seasonal exploitation of fish resources in the Middle Missouri subarea. M. A. Thesis, Department of Anthropology, University of Nebraska-Lincoln.

ianka, E.

1966 Evolutionary ecology. New York: Harper and Row.

1983 Evolutionary ecology. Third edition. New York: Harpe and Row.

Pielou, E. C.
1975 Ecological diversity. New York: John Wiley and Sons.

Plog, S., F. Plog, and W. Wait
1978 Decision-making in modern surveys. In Advances i archaeological method and theory, Vol. 1, ed. M Schiffer, pp. 383-421. New York: Academic Press.

Prufer, O. H. and O. C. Shane, III
1970 Blain village and the Fort Ancient tradition in Ohio Kent, Ohio: Kent State University.

Raab, L. M.
1977 The Santa Rosa wash project: notes on archaeologica research design under contract. In Conservatio archaeology: a guide for cultural resource managemen studies, eds. M. Schiffer and G. Gummerman, pp 167-182. New York: Academic Press.

Radnitzky, G. and G. Andersson (eds.)
1978 Progress and rationality in science, Boston Studies Seri in the Philosophy of Science 58. Boston: D. Reid Publishing Company.

Rao, K. S. J.
1972 Effects of leucine on enzymes of tyrptophan metabolis American Journal of Clinical Nutrition 25:6.

Reher, C. A. (ed.)
1977 Settlement and subsistence along the lower Chaco Was the CGP survey. Albuquerque, New Mexico: Universi of New Mexico Press.

Reyna, S. P.
1975 Making do when the rains stop: adjustments of domest structure to climatic variation among the Barm Ethnology 14:405-417.

1976 The extending strategy: regulation of the househo dependency ratio. Journal of Anthropological Resear 32:182-198.

Richtsmeier, J. T.
1980 Precipitation, temperature and maize agriculture: implications for prehistoric population density in the Middle Missouri subarea, A.D. 900-1675. M. A. Thesis, Department of Anthropology, University of Nebraska-Lincoln.

Roberts, R. L.
1977 Population estimates, Appendix B, In The Talking Crow Site ed. C. S. Smith, pp. 167-176. University of Kansas Publications in anthropology No. 9.

Robson, J. R. K. et al.
1976 The nutritional significance of maize and teosinte. Ecology of food and nutrition 4:243-249.

Roe, D. A.
1973 A plague of corn: the social history of pellagra. Ithaca: Cornell University Press.

Rongstad, O. J. and J. R. Tester
1969 Movements and habitat use of white-tailed deer in Minnesota. Journal of Wildlife Management 33(2):366-379.

ahlins, M. D.
1957 Land use and the extended family in Moala, Fiji. American Anthropologist 59:449-462.

chalk, R. F.
1978 Foragers of the Northwest Coast of North America. Ph.D. dissertation, Department of Anthropology, University of New Mexico, Albuquerque.

1979 Land use and organizational complexity among foragers of northwestern North America. In Affluent foragers: Pacific Coasts East and West, S. Koyama and D. H. Thomas, eds., pp. 53-76. Senri Ethnological Studies No. 9, Osaka.

chiffer, M. and G. Gummerman (eds.)
1977 Conservation archaeology: a guide to cultural resource management studies. New York: Academic Press.

Schiffer, M., A. P. Sullivan, and T. C. Klinger
1978 The design of archaeological surveys. World Archaeology 10(1):1-28.

Schoental, R.
1980 Mouldy grain and the aetiology of pellagra: the role of toxic metabolites of Fusarium. Biochemistry Society Transactions 8(1):147-150.

Sebrell, W. H., Jr.
1981 History of pellagra. Federation Proceedings 40(5):1520-1522.

Smith, B. D.
1978 Variation in Mississippian settlement patterns. In Mississippian settlement patterns, ed. B. D. Smith, pp. 479-504. New York: Academic Press.

Smith, H. B.
1984 Molar wear in hunter-gatherers and agriculturalists. American Journal of Physical Anthropology 63:233-238.

Soudsky, B.
1964 Sozialokonomische Geschichte des alteren Neolithikums in mitteleuropa. Aus der Ur-und Fruhgeschichte 2:62-81.

1966 Bylany osada nejstarsich zemedelcu z mladsi doby kamenne. Praha.

1969 Etude de la maison neolithique. Slovenska Archaeologia 17:5-96.

Stimmell, C.
1978 A preliminary report on the use of salt in shell-tempered pottery of the upper Mississippi valley. Wisconsin Archaeologist 59(2):266-274.

Stone, G. D., P. Johnson-Stone, and R. McC. Netting
1984 Household variability and equality in Kofyar subsistence and cashcropping economies. Journal of Anthropological Research (Special Issue) 40(1):90-108.

Struever, S.
1968 Problems, methods and organization: a disparity in the growth of archaeology. In Anthropological archaeology in the Americas, ed. B. J. Meggers, pp. 131-151. Washington, D. C.: Anthropological Society of Washington.

1971 Comments on archaeological data requirements and research strategy. American Antiquity 36:9-19.

Strong, W. D.
1933 The plains culture area in the light of archaeology. Plains Anthropologist 35:271-287.

Suppe, F.
1977 The structure of scientific theories. Second edition. Chicago: University of Illinois Press.

Taber, R. D. and R. F. Dasmann
1957 The dynamics of three natural populations of the deer Odocoileus hemionus columbianus. Ecology 38:233-246.

Taber, R. D. and J. L. Murphy
1971 Controlled fire in the management of North American deer. In The scientific management of animal and plant communities, eds. E. Duffey and A. S. Watts, pp. 425-435. Blackwell: Oxford University Press.

Telfer, E. S.
1967 Comparison of moose and deer winter range in Nova Scotia. Journal of Wildlife Management 31(3):418-425.

Thomas, D. H.
1983 The archaeology of Monitor Valley Vol. 1: Epistemology. Anthropological Papers of the American Museum of Natural History 58(1).

Tiffen, M.
1976 The enterprising peasant: economic development in Gombe Emirate, North Eastern State, Nigeria, 1900-1968. Ministry of Overseas Development, Overseas Research Publication No. 21. London: Her Majesty's Stationery Office.

Turner, Christy G., II
1978 Dental caries and early Ecuadorian agriculture. American Antiquity, 43:694-697.

1979 Dental anthropological indications of agriculture among the Jomon people of central Japan, American Journal of Physical Anthropology 51:619-636.

Urbach, P.
1978 The objective promise of a research programme. In Progress and rationality in science, eds. G. Radnitzky and A. Andersson, pp. 99-113. Boston: D. Reidel Publishing Company.

Van Royen, W.
1937 Prehistoric droughts in the Central Great Plains. Geographical Review 27(4):637-650.

Verme, L. J. and D. E. Ullrey
1984 Physiology and nutrition. In White-tailed deer: ecology and management, ed. L. K. Halls, pp. 91-118. Harrisburg, Pennsylvania: Stackpole Books.

Walthall, J. A.
1980 Prehistoric Indians of the Southeast: archaeology of Alabama and the middle south. University, Alabama: University of Alabama Press.

Weaver, J. E.
1965 Native vegetation of Nebraska. Lincoln, Nebraska: University of Nebraska Press.

Wedel, W. R.
1933 Preliminary classification for Nebraska and Kansas cultures. Nebraska History Magazine 15:251-255.

1959 An introduction to Kansas archaeology. Bureau of American Ethnology Bulletin 174.

1940 Cultural sequences in the Central Great Plains. Smithsonian Miscellaneous Collections 100:291-352. Washington, D.C.

1941 Environment and subsistence native economies in the Central Great Plains. Smithsonian Miscellaneous Collections 101(3). Washington, D.C.

1961 Prehistoric man on the Great Plains. Norman, Oklahoma: University of Oklahoma Press.

1978a The prehistoric plains. In Ancient native Americans, ed. J. D. Jennings. San Francisco: W. H. Freeman and Company.

1978b House floors and native settlement populations in the Central Plains. Paper presented at the 35th Annual Plains Conference, Lincoln, Nebraska.

1979 House floors and native settlement populations in the central plains. Plains Anthropologist 24(84, 1):85-98.

Wells, P. V.
1970 Postglacial vegetational history of the Great Plains. Science 167(3925):1574-1582.

White, T. E.
1952 Observations on the butchering techniques of some aboriginal peoples, 1. American Antiquity 17(4):337-338.

1953a A method of calculating the dietary percentage of various food animals utilized by aboriginal peoples. American Antiquity 18(4):396-398.

1953b Observations on the butchering techniques of some aboriginal peoples, 2. American Antiquity 19(2):160-164.

1954 Observations on the butchering techniques of some aboriginal peoples, 3-6. American Antiquity 19(3):254-264.

1955 Observations on the butchering techniques of some aboriginal peoples, 7-9. American Antiquity 21(2):170-178.

Wiens, J. A.
1976 Population responses to patchy environments. Annual Review of Ecology and Systematics 7:81-120.

Wiessner, P.
1974 A functional estimator of population from floor area. American Antiquity 39(2, 1):343-349.

Will, G. F. and G. E. Hyde
1917 Corn among the Indians of the Upper Missouri. Lincoln: University of Nebraska Press.

Wood, W. R.
1952 The square earth lodges of the central Great Plains. Plains Archaeological Conference Newsletter 5(1):5-17.

1967 An interpretation of Mandan culture history. Bureau of American Ethnology, Bulletin 198.

1969 Two house sites in the Central Plains: an experiment in archaeology, ed. W. R. Wood, Plains Anthropologist 14(44, Pt. 2), Memoir No. 6.

1974 Northern Plains village cultures: internal stability and external relationships. Journal of Anthropological Research 30:1-16.

Worrall, J.
1978 The ways in which the methodology of scientific research programmes improves on Popper's methodology. In Progress and rationality in science, eds. G. Radnitzky and G. Andersson, pp. 45-70. Boston: D. Reidel Publishing Company.

Yanagisako, S. J.
1979 Family and household: the analysis of domestic groups. Annual Review of Anthropology 8:161-205.

Zimmerman, L. J.
1977 Prehistoric locational behavior: a computer simulation. Iowa State Archaeologist's Report No. 10. Iowa City.

Zimmerman, K. P.
1977 Corn in Plains culture history. South Dakota Archaeology 1:25-37.