Modeling Archaeological and Historical Cognitive Landscapes in the Greater Yellowstone Region (Wyoming, Montana, and Idaho, USA) Using Geographic Information Systems

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Abstract: Geographic Information Systems (GIS) have been employed in the field of archaeology for more than a decade. Few archaeological studies, though, have taken advantage of the ability of GIS to provide a greater depth and understanding to issues of a theoretical or cognitive nature. In this sense GIS can be used as a tool for outlining and understanding the ways in which people have thought about and utilized their surroundings; in other words cognitive landscapes. A series of examples are provided from the Greater Yellowstone Region of Wyoming, Montana, and Idaho (USA), which illustrate the ability of an ArcView-based GIS to integrate theoretical and cognitive issues of site selection/placement into a more thorough evaluation of regional settlement. The study also incorporates structures developed in the fields of complexity research and artificial intelligence. Effective cognition-based hypotheses explaining the patterns suggested by previous research and historical documentation are then developed and evaluated.

Key words: GIS, Cognition, Modeling, Complexity, Site Selection

Introduction

Lying at the junction of Idaho, Montana and Wyoming, the Greater Yellowstone Region includes most terrain above 1500 meters in altitude between Pinedale, Wyoming and Bozeman, Montana, and between Driggs, Idaho and Cody, Wyoming. The region includes two national parks (Yellowstone and Grand Teton) as well as portions of nine national forests. Eight major mountain ranges (the Tetons, the Absarokas, the Wind River Range, The Wyoming Range, The Gros Ventre Range, the Gallatins, the Madisons, and the Beartooths) lie within the project area (fig. 1).

Research goals were initially to develop an archaeological site predictive model that could be applied to the landscape using Geographic Information Systems (GIS) technology and evaluate the results in the context of the known sites recorded in the region. The traditional means of creating and applying predictive models, however, relies on largely inductive methods where known site information is assessed on its relationship with available environmental data and a multiple regression (or some other form) of analysis is conducted to identify the predictive value of each environmental variable in an overall formula (or series of formulas).

For the Greater Yellowstone Region, a very limited amount of previous archaeological research has been carried out, and almost all of that has been in low altitude portions of the region that have undergone recent human settlement (see Whitley 2000:188-190). The database of recorded sites kept by the National Park Service does not provide an unbiased assessment of prehistoric sites from the entire region. Thus, a traditional archaeological predictive model would not be possible and more than likely would not be enlightening.

I took a different approach with the project instead. The basis of my research was focused on identifying the nature of site selection behavior. This implies that the locations of known sites were not integral to the creation of the settlement model, but instead a model was created involving the cognitive decision making process of selecting suitable site locations (site selection) and then placing sites in some of those locations (site placement). Fundamentally this involves creating a decision making model, employing some of the ways in which we model human cognition; namely analytical structures from dynamical systems research, fuzzy logic (otherwise known as approximate reasoning), and neural network analogues.

Once a suitable model of decision making was created, it could be applied to the landscape via the use of GIS analysis. The process would involve identifying some of the environmental, ecological, and sociocultural factors which were available to the region's prehistoric and historic inhabitants and are currently observable, or can be projected today. Those factors can then be referenced to the classification scheme used by the decision making model and projected as cost and benefit surfaces - reflecting the value-adding or energy expending nature of each factor across the landscape. A summary of cost and benefit surfaces will then produce an approximation of the cognitively assigned value for each land unit in the region. In other words, this is the GIS application of a cost-benefits analysis based on projections of prehistoric and Historic period cognitive decisions.

Mechanisms

To briefly address the mechanisms employed in building the model; the first consideration is: what sort of system is involved in site selection processes? The process of identifying a suitable site location involves complex highly idiosyncratic decisions which are not always based on economic principles. It cannot be conceived of as simple or static; and thereby reducible to covering law type explanations. Instead, it involves dynamical processes which are very much responsive to minor influences, and the initial conditions within which they exist. The term "dynamical" is a standard term used in Chaos Theory (more appropriately called the study of complexity) as a variant of the term dynamic - the term "dynamic" itself does not convey the highly reactive, self-organizing, and unpredictable nature of complex phenomena in its definition (cf. Gleick 1987; Waldrop 1992; Casti 1994).

Static covering law types of explanation often fail when the subject matter shows self-organizing or dynamical tendencies. This failure comes principally from the focus on inductively modeling the subject matter, through perceived rules (or laws) and attempting to predict the results. When the predictions are not met, the explanation is not forthcoming (for a discussion of the relationships between archaeological phenomena and scientific explanation see Salmon 1982). Dynamical systems research includes several different approaches for modeling extremely complex systems in a manner which does not require prediction to fulfill the goals of explanation. Dynamical systems, instead, are grounded to a much greater degree in statistical relevance and approximate rules or tendencies (e.g. causal reference type explanations - Salmon and Salmon 1979; and Salmon 1984).

An important consideration to bear in mind is that although chaos theory and dynamical systems research often deal with very complex mathematical devices, archaeological or other cultural data is not always easily reduced to mathematical relationships. As such, I do not argue that complexity-based mathematics should (or even could) be applied to all archaeological datasets. Rather, I believe that some general concepts are applicable in very real ways, particularly how we organize archaeological models and conceptualize of prehistoric cognitive processes. These concepts, though, greatly affect how we utilize GIS and other spatial types of information.

A second question about site selection decision making is: how are decisions made? This involves not only the process of decision making but the elements employed in the process. For instance, a typical pattern of evaluating surroundings, applying general knowledge to the observations, and choosing between options can be the model for the process. But it is important to understand the nature of the individuals or groups who make the observations, process the information, and choose between alternatives as well. Research into neural networks has been used to approximate the nature of decision making in artificial intelligence (e.g. Haykin 1994; Russell and Norvig 1994; Bishop 1995).

Neural networks are models which utilize traditional concepts of information flow but outline them in a dynamical manner. Modeled on the way in which our brains process information, they are essentially very complex parallel processors. The neural network of the human brain can process extremely complex tasks (such as perceptual recognition) on the order of milliseconds, whereas it can take days for a digital computer system to do the same.

The process which makes human neural networks so efficient is that the neurons process information in both parallel and hierarchical manners. They also act dynamically by learning from experience. Traditional computer systems can be programmed to carry out a task, but they will always do it in the same fashion and cannot adaptively alter their behavior. Neural networks in the brain build algorithms to carry out tasks and frequently repeated tasks are strengthened by having larger amounts of neurons dedicated to the process.

Neural network models provide an analogy for the process of site selection decision making since the dynamical cognitive rules for site placement have to be evaluated both concurrently and hierarchically. They are analogous to site placement decision making in that both neural networks and human decision making are a means for processing large amounts of information to make generalizations, classify, or evaluate. Human sociocultural systems, in general, are analogous to neural networks as well, since all individuals within a group act as "neurons" processing information and carrying out learned behavior in accordance with the needs of the group. On the individual scale, however, neural networks in our brains are exactly how this is done. In other words, neural networks and human sociocultural systems are both analogous and homologous.

Computerized neural networks have been used to identify patterns within certain types of datasets. One example from this conference is the "training" of computerized neural networks to evaluate osteological measurements to recognize distinctions within datasets of skeletal remains (Bell and Jantz 2001). For GIS applications at least one neural network extension has been developed within the ArcView environment (Looney and Yu 2000). The DataXplore module is designed to work within the Arc-SDM (Spatial Data Modeller) Extension for ArcView 3.2. It provides tools for addressing spatial data using both fuzzy clustering and neural network statistics. At the time my research was conceived and carried out there were no ArcView GIS-based extensions available that could evaluate cost-benefit surfaces using neural networks, but perhaps new tools such as Arc-SDM and DataXplore will prove useful for future research.

Another question about the process of decision making is; how are potential alternatives evaluated? If the rules of site location acceptability are conceived in terms of the surroundings, are environmental factors amenable to rigid evaluation or are approximate measures used instead? Once again, in dynamical systems research a methodology is often used which simulates approximate reasoning in complex systems: fuzzy logic.

Fuzzy logic was originally a conceptual model for mirroring human "grayscale" cognitive behavior which eventually evolved into a formal fuzzy set theory (Zadeh 1965; Yager and Filev

1994). Traditional set theory (referred to as crisp set theory) is the classification of objects, or numbers, into groups in terms of sets, unions, and intersections. Membership in any group is a black-and-white issue and most day-to-day categorizations that we use tend to follow suit. The distinction between sites and non-sites, or sterile and artifact-bearing deposits are examples.

Fuzzy set theory, however, argues that classification is not always so distinct. Many objects (or whatever we are measuring) tend toward being members of multiple groups. Or, categories tend to gradually merge, rather than be distinct. Therefore membership in any class can vary on a scale of intensity. And, in reality the differences between sites and non-sites, or sterile and artifact-bearing strata, are also not so distinct. Likewise our examination of the relationships between sites and environmental variables (such as "distance to water") should be seen as examples where fuzzy relationships are common.

If categorical distinctions are employed and we make the assumption that people were placing their sites according to a cognitive rule regarding those categories (such as "nearness to water"), then it is important to be able to grasp that the prehistoric definition of "near" will most likely be fuzzy. People are not likely to have used tape measures in determining where to pitch their tipi. The theory of approximate reasoning is integral to human cognitive processes.

In the process of site selection decision making, an inherent need to observe the surroundings and evaluate them against the needs of the group or the individual is implied. How is that evaluation carried out? Are there "rules" of acceptability that can be judged on the basis of observable criteria? In the conceptual framework of dynamical systems, attractors are used to represent states or values toward which systems tend to gravitate. In the examination of site placement dynamics it is possible to use a more literal interpretation of the terms "attractor" and "landscape" since we are actually talking about landscapes and attractive places for settlement within them (fig. 2).

Attractors are modeled in what are known as Vector/Manifold diagrams (Casti 1994). In our experience, manifolds are landscapes across which archaeological sites are placed - in more conceptual dynamical research manifolds could represent state-space (not actual physical locality). Vectors are the time sensitive paths established across the manifold (based on the rules of the system). In our experience, they equate to seasonal rounds or routes of travel.

Attractors can be seen as the representation of the observable characteristics of the rules of the system. Some represent benefits extractable from a location (lithic raw materials, utilitarian plants or hunted animals), while others represent costs accumulated while trying to extract benefits (distance from the lithic source or the terrain slope which needs to be crossed to gather plants or hunt animals).

The simplest kind of attractor is fixed at a permanent point (fig. 2a). A high quality lithic source, such as Obsidian Cliff (in Yellowstone National Park), is a good example. Sites are keyed to Obsidian Cliff to such a degree that they can be virtually indistinguishable. During the human occupation of the Yellowstone Region Obsidian Cliff has not moved, and even today it can be seen as an attractor for tourist itineraries.

A second kind of attractor is a periodic attractor (fig. 2b). An example for site placement would be seasonal, migrating resources. In the Yellowstone Region elk and bison herds spend much of the year migrating between lowland and upland areas. Likewise, some periodic attractors may actually be fixed in place, but their attractiveness as potential resources may, in fact, vary from season to season. Plants are such a resource, and Blue Camass the prime example from the Greater Yellowstone Region.

The third and most unusual type of attractor is the strange attractor (fig2c). This is the most indicative of dynamical systems. The nature of the strange attractor is that it is responsive to other systems not under study or minute effects that have major implications for the whole system. A cultural example would be the placement of sites in areas not controlled or inhabited by enemy groups. An attractive place for settlement is dependent upon the location of the enemy at any given time. In this manner it is not possible to predict where attractive places for settlement will occur without knowing all of the movements of the enemy. Archaeologically it may be extremely difficult to model for such an effect.

Bearing all of these ideas in mind, I created a decision making model for site selection that relied on a dynamical systems approach, employed neural network analogues, and classified environmental, ecological, and sociocultural factors into five fuzzy categories; *Geophysical Constraints*; *Resource-Effort Constraints*; *Cultural Biases*; *Time-Place Constraints*; and *Individual Preferences* (fig. 3).

Geophysical constraints can be thought of simply as spatial or physical barriers to site placement. Resource-effort constraints primarily reflect energy expenditure and economics. Cultural bias types of constraints are typically conscious or subconscious "taboos" for or against placement of sites in some areas for largely unspecified or strictly cultural reasons (such as a learned site placement constraint with no explicit rationale). Time-place constraints are indirect preferences for an area merely as a result of its being adjacent-to or in between consciously (or subconsciously) selected areas. Given two distant points on the landscape, for example, the likelihood of a cultural group placing their site in between the two points is greater than it would be elsewhere, if they are traveling from one to the other (such as in a seasonal round). Individual preferences are those factors which cannot be modeled or easily fit into one of the other categories. They are not predictable, often not explainable, and are much more likely to be dominating factors in situations where only a few people, or one individual, are making site placement decisions. For instance, there are countless aesthetic reasons for people to choose certain areas within which to live, or build a house. We know intuitively that they play a large role in our own lives and cannot be subsumed as mere economic concerns.

An interesting characteristic of these categories is that they are not mutually exclusive, nor are they simple black-and-white distinctions. In fact, any single variable can be seen as a member of one, two, or any number of the categories. For example, a bias against choosing to live on a steep slope may partially be a geophysical constraint (it is difficult to live on a steep slope), but may also be related to economic, or resource-effort, constraints (it is difficult to obtain water). Therefore the best way in which to conceptually model the constraint factors is with a five-dimensional matrix. Each category can be seen as one axis in the matrix with relative degrees of fuzzy membership represented along the edge. Ironically, it is not possible to depict a five dimensional fuzzy matrix in a two-dimensional medium. Therefore, fig. 3 is merely an abstraction which only conceptualizes some of the relevant characteristics. The categories are overlapping and relative membership in any class or set of classes is depicted by distance away from other categories.

Constraint factors (or rules about observable environmental variables - i.e. attractors) can be represented by points in this five dimensional categorical state-space matrix. Each constraint factor, however, plays a varying role in the site placement decision making process. Some constraints are variably more important to the cultural groups at different times, and may be highly unstable.

Each constraint factor is also linked to others. Changes in one may significantly alter the importance of similar or related constraints. For instance the bias against putting sites on steep slopes may be moderated somewhat by the preference for hunting mountain sheep (which may require a bias toward putting sites near them - on or near steep slopes). If the hunting of mountain sheep were to cease, then the steep slopes constraint might become more important and shift toward the geophysical constraint category. In fact, the Sheepeater population in Yellowstone (the Native American inhabitants during the Historic period) would have had a very different definition of "steep slopes" (since they spent so much of their time hunting mountain sheep) than perhaps the plains-dwelling Blackfeet or Crows.

Conceptualized this way, the matrix of constraint factors can be seen as a network of shifting, linked cognitive rules that each individual maintained with regard to the process of site placement decision making (in other words a neural network). Individuals who belonged to the same cultural group may have shared very similar cognitive rules but it is unlikely that they ever would be identical. The process by which such cognitive rules were employed to determine the most suitable location for a site would, however, be the same; a flow chart shows the steps involved in the process. Such steps include identifying important attractors, summarizing them and the knowledge related to them, updating stored information, and evaluating their suitability (fig. 4).

There are at least two scales at which the network of constraint factors is consulted; the regional, and the local. Regional constraints may play a larger role in the location of seasonal rounds or settlement strategies, whereas local constraints reflect more immediate necessities such as suitable slope or distance to a water source. Site placement constraint factors are going to be quite different on each of those scales. In some situations the regional goals for the group are not going to be affected by locally important factors. Rather the use of heuristic devices to assess the presence of attractors at either scale may be quite common. Given the nature of each scale, though, it is also most likely that locally important attractors will be assessed far more frequently than regional scale ones. This was the ultimate site selection decision making process which was applied to the Greater Yellowstone Region.

Regional Background

The Greater Yellowstone Region is a series of high altitude plateaus located along the continental divide, surrounded by steep mountain ranges which have always been considered largely wilderness areas. Cutting through the heart of the plateaus are several large river systems; including the headwaters of the Yellowstone, the Snake, the Madison, the Gallatin, and the Wind River.

Some areas within the region lie at lower altitudes (between 900 and 1500 meters) and their adjacent ranges create rainshadow effects. Consequently, the vegetation is drier and more arid in the northern portions of the Greater Yellowstone Region, particularly in Montana. South of Yellowstone National Park, the Teton Range includes some of the most impressive peaks in the Rockies. Rising from the Snake River floodplain at Jackson Hole, the Tetons reach over 4000 meters in altitude and present a near vertical face of approximately 1800 meters.

Feeding the Yellowstone River, America's largest alpine lake, Yellowstone Lake, lies at nearly 2400 meters in elevation. The lake is over 100 meters deep and is ringed by steep mountains, thermal basins and more than 100 feeder streams. The north end of the lake includes a complex of marshes in the Pelican Creek valley which provides ideal moose and waterfowl habitat. Similar habitats lie near the shores of Jackson Lake, at 2000 meters elevation and just east of the Tetons.

Some of the interior upland river valleys are moist alpine meadows, largely with open grazing land and bordered by mixed forests of Douglas Fir, Subalpine Fir, Lodgepole Pine, Whitebark Pine or Englemann Spruce. These meadows are ideal places to find many different kinds of edible plants, including; Blue Camass, wild onion, and Yampa. Since the fires of 1988, some of the forests have been reduced to stands of charred timber. Thick brushy undergrowth and small trees have more recently taken over many of these areas as the forests begin to rebuild themselves.

Within the geological feature known as the Yellowstone Caldera, a wide variety of thermal features can be found. Several Geyser Basins, including Midway, Upper, Lower, and Norris lie along the west side of the Grand Loop Road in Yellowstone National Park. Some of the most impressive thermal deposits are found at the Mammoth Hot Springs area.

Settlement began in the region during the early Holocene with scattered Paleoindian and Early Archaic sites. Mummy Cave is one of the oldest and perhaps most thoroughly researched sites in the region. It consists of a stratified rockshelter located along the north branch of the Shoshone River between Cody, Wyoming and the East Entrance to Yellowstone National Park. Much of what we know regarding early upland resource procurement in the region is derived from the information recovered at Mummy Cave.

A few other well stratified sites are known in the region, and they range in age from the Paleoindian through late Prehistoric periods. A large number of sites were identified along the shores of Jackson Lake, of which a small percentage were well stratified multicomponent occupations. A number of sites are also located along the margins of major creeks and rivers, and they occasionally include dateable features.

Many other types of sites are largely undateable through standard radiometric means including lithic scatters. Radiating outward from Obsidian Cliff, lithic scatters are common for miles. Similarly, in many areas of the region, deposition is virtually non-existent and isolated hearths and rock features can be found on the surface. Being repeatedly burned by forest fires over the millennia, such isolated features cannot be dated other than by diagnostic artifacts, if they are present. Isolated diagnostic artifacts are also commonly encountered. Most of what we know regarding Paleoindian settlement in the region is due to the identification of diagnostic characteristics on isolated finds of projectile points.

In the northern and eastern portions of the Greater Yellowstone Region, tipi rings are commonly encountered. Most tipi rings consist of a circle of 5 to 25 large rocks spread out in a diameter of between 2 to 6 meters. The rocks were once used to hold down the edge of hide tipi covers. When the camp was moved the rocks were left behind. Such sites rarely contain any artifact or feature remains.

Another more recent type of site encountered in the region are expedient shelters known as "war lodges". Typically associated with Crow war or hunting parties, they may have been used by a variety of different cultures and for many different purposes. They have been found throughout much of the Absarokas, and the Gallatins, as well as the nearby Bighorn Mountains. Many of these sites are currently in various states of preservation, with forest fires and tree falls occasionally destroying them. Similar types of sites include wooden corrals and traps often found in the extreme uplands and used for hunting and trapping mountain sheep or possibly deer.

The Euro-American occupation of the Greater Yellowstone Region began in the late 1800s, when trapping and mining became the main economic focus of settlements such as Cooke City, and Bottler's Ranch. Early expeditions in the 1860s and 1870s produced little in the way of archaeological deposits. Later, tourism or army based settlements and campsites produced a large number of historic structural remains and artifact dumps scattered throughout the lower altitudes. The influx of Euro-Americans and especially the first national park tourists at the end of the 1800s produced additional types of sites which are in the process of reverting back to a more natural condition. Old roads and trails are still visible in many portions of the region.

Analysis

Much of the digital GIS data was downloaded through a number of federal, state and locally sponsored web sites; including digital elevation models, polygon data and digital raster themes. Some of these websites included; the United States Geological Survey (National Spatial Data Infrastructure pages), Wyoming, Montana, and Idaho pages (state mapping programs and GIS source links), the National Park Service (for Yellowstone and Grand Teton National Parks), the Bureau of Land Management, the U.S. Forest Service (for the Shoshone, Gallatin, Targhee, Custer, Beaverhead, Caribou, and Bridger-Teton National Forests), the University of Wyoming, the University of Montana (Greater Yellowstone GIS Clearinghouse and the University of Montana Library), the Soil Conservation Service, the Fish and Wildlife Service, the ESRI homepage, NASA's Jet Propulsion Laboratory, and Microsoft's Terraserver page (for satellite imagery).

Digital themes were downloaded, translated, rectified and incorporated into ArcView version 3.1 with the Spatial Analyst extension loaded. Operating a 300 MHz Pentium II computer with 128 megabytes of RAM and a 10 gigabyte hard drive, some data layers were projected through the use of ArcView's built-in utilities (such as the hydrologic modeling or least cost path evaluations) or were written in Avenue script. All data layers were translated into a continuous surface of 90 meter grid pixels. In other words each measurable land unit represents a square 90 meters on a side. Since the time of analysis (1995 through 1997) additional data layers have become available, and many of them are at higher resolution than those used here. In the future some of this more accurate data could provide greater interpretive potential especially if used in the context of more sophisticated modeling tools (such as Arc-SDM, Geospatial Analyst, and DataXplore).

Although for most variables the raw data is a series of numeric values to three decimal points, a standardization routine was devised to incorporate the modeled relationship between energy extraction and site placement potential. This means that most variables were reclassified as spatial representations of projected cost or benefit (at each 90m grid pixel) ranging between 0 to 64 for cost variables and 0 to -64 for benefit variables. The use of negative values for benefits is due to the incorporation of least cost path analyses which automatically assume all variables are costs to be analyzed (i.e. beneficial site placement variables were modeled as negative costs). The upper/lower values of 64 and -64 reflect the incorporation of the originally nominal datasets (such as vertebrate diversity) which were translated into doubled integer classes (i.e. 0,1,2,4,8,16,32,64 or -64,-32,-16,-8,-4,-2,-1,0).

Each of the GIS data layers represent characteristic landscapes, such as typical elk/bison grassland habitat or marshy waterfowl and Moose habitat. The state of Wyoming sponsored a study in the early 1990s which looked at the distribution of 445 vertebrate species The model created by the state was translated into standardized digital data and used as a benefit surface. Cost surfaces were also produced, such as cost distance to water; where relative cost reflects the effort required to reach permanent water sources. Effort expended is moderated by distance to water and percent terrain slope.

Other cost surfaces such as the cost distance to toolstone quality obsidian were projected. Although, numerous obsidian sources have been identified in the region, especially within the Yellowstone Caldera, only a few sources, such as Obsidian Cliff, Crystal Springs, Teton Pass, Conant Creek and Grassy Lake are known to have been used. The toolstone quality sources were mapped and a cost distance evaluation was produced.

Today mountain sheep are found in a restricted environment (largely the extreme uplands, in steep rocky areas) or also in lower altitudes, along inaccessible talus slopes or wilderness areas. In the past, however, mountain sheep may have been more widespread throughout the region, including relatively dry and flat sagebrush plains, mostly with easy access to high elevation uplands. Since we have a known subsistence focus on mountain sheep (especially during the Historic period) I also included a benefit surface of potential mountain sheep habitat. Potential mountain sheep habitat was projected using a combination of elevation, preferred slope, ambient sunlight, projected snow cover, and prevailing winds.

The 15 cost and benefit surfaces (which include others such as projected seasonal availability of utilitarian and edible wild plants; and seasonal distributions of migrating ungulates) were weighted and combined into three total net cost-benefit landscapes; summer, winter, and spring/fall. No significant distinction was available to distinguish between spring and fall. Those seasons were modeled mainly as the transitions between the extremes of summer and winter. Their relative positions in the seasonal round did, however, play a part in the least cost path analyses.

The net cost-benefit landscape for summer (fig. 5a) indicates high economic benefits (darker areas equal higher benefit) for site placement in the Hayden and Lamar Valleys, areas to the north, east and south of Jackson Lake, plus much of the Middle Yellowstone, Upper Shoshone, and Clarks Fork River Valleys. As we transition into fall, high benefit areas become smaller and more dispersed, generally retreating down into the lower lying areas surrounding the Central Yellowstone Plateaus (fig. 5b). Winter shows an even greater downward migration with the highest benefit locations consisting of the Jackson Hole area, the Shoshone and Clarks Fork River Valleys, part of Lamar Valley and a few upland winter refugia (fig. 5c).

Point data was created based on the net cost benefit landscapes, modeling just those locations which for each season represent the extreme high end of the benefit scale. I then used a least cost path analysis to fit the travel vectors from summer to fall to winter to spring. Overlaid on the elevation model this shows a projected transient-seasonal residency pattern where people would use the interior of the Yellowstone Plateaus in a dispersed site pattern during the summer, aggregate sites and move downslope in the fall, and potentially spend the winter in the lower valleys surrounding the plateaus, before splitting up again and heading to the uplands in the spring (fig. 6). This data fits well with what has been archaeologically projected for Paleoindian and Early Archaic settlement patterns; periods for which a prey-based nomadism may have been the primary lifestyle.

To this point the data incorporated strictly ecological variables and assumed the prehistoric residents had good familiarity with the distribution of available resources. By including one additional attractor the picture changes dramatically. During the Historic period the Greater Yellowstone's year-round residents (the Sheepeaters) were bordered on all sides by highly mobile plains tribes or linguistically related mountain groups. Since all of the neighboring groups seasonally used interior Yellowstone resources, they would have competed with the Sheepeaters. The situation would have been similar during the prehistoric when social circumscription may have been active.

Three additional seasonal cost surfaces were used which represent the probability of encountering competing groups in each land unit based on projected locations in the lower adjacent river valleys. This was modeled according to a pattern of transient seasonality for neighboring groups. Allowances were also made for the linguistic relatedness between the Sheepeaters, the Plains Shoshoni and Bannocks in three additional cost surfaces during the Historic period (the assumption being better relations between linguistic relatives).

When the additional cost surfaces are included in the net cost-benefit seasonal landscapes the patterns of projected residency change. The summer net cost-benefit landscape shows a much reduced distribution of available high benefit areas (fig. 7a); principally being limited to the Pelican Valley, parts of the Lamar Valley, the flats south of Yellowstone Lake and some of the land along the north branch of the Shoshone River. The picture during the spring/fall shows a much wider diversity of areas but in small dispersed locations (fig. 7b). The winter landscape shows even more clearly the highly dispersed distribution of high benefit locales in the Absaroka uplands (mountain sheep habitat), the very upper reaches of the Shoshone River, a small part of the Lamar Valley and some of the potential winter refugia (fig. 7c).

A least cost path analysis between the seasonal highest benefit areas (fig. 8) indicates a permanent upland residency pattern where migration is no longer outside the high altitude region. Instead, winter locales become dispersed in either the areas of most concentrated mountain sheep habitat, or some of the upper small river valleys (with nearby access to mountain sheep habitat). Spring sees a downward migration to summer aggregated sites in those areas in which neighboring groups are not likely to be encountered. This permanent residency pattern is dependent on two conditions: first, circumscription by competing neighboring groups; and second the desire and ability to effectively exploit mountain sheep as a primary winter faunal resource.

The archaeological evidence to support the contention of year-round prehistoric residency is scant. There are very few studies which have addressed upland resource utilization, since so much of the extreme uplands is wilderness and so far has not undergone significant impact by modern land use practices. The few studies that have been done, however, support the ideas that:

1) Upland habitats were more intensively exploited than

has been typically suggested by the limited low elevation archaeological reconnaissance.

2) Such high elevation sites were not necessarily small temporary hunting or procurement sites, but may have been returned to on numerous occasions and formed a significant part of the seasonal round.

3) Year-round upland residency patterns may not have been limited to the Historic period Sheepeaters, but could have extended well into the past.

4) Upland patterns are typically associated with a reliance on mountain sheep as a primary dietary component, and specifically communal hunting in the Absarokas.

There is as of yet little evidence to indicate when in the prehistoric past a shift toward year-round upland residency may have occurred; perhaps a result of the pressures of neighboring groups. It could just as well be argued that year-round residency or seasonal exploitation requires a substantial investment in detailed understanding of the regional availability of resources. But what about cultural groups who have only a limited familiarity with a region? We would not expect that sites left behind by transient-occasional populations should accurately reflect available resource distributions, since they may have been unfamiliar with the distribution of local or regional resources. For this area we have a pretty well documented example of a transient-occasional site placement pattern: the Nez Perce.

In 1877, the Nez Perce (a Plateau tribe from western Idaho/ eastern Oregon) migrated through the newly created Yellowstone National Park while being pursued by the US Army. Without going into detail about the causes of the Nez Perce War, it is important to note that the Nez Perce had a passing familiarity with the Bannock Trail (the main east-west artery through the park at the time). A viewshed analysis of all areas immediately visible from, and within easy reach of, the Bannock Trail (in essence a cognitive landscape depiction of the net cost-benefit information available to the Nez Perce at the time of their encampment near Henry's Lake, Idaho) was created. When seen in the absence of knowledge regarding the conflict between the US Army and the Nez Perce, it is not easy to see why a transient-occasional population with limited experience in the region would choose to take an unknown route (fig. 9).

If we include a cost surface which shows the known locations of whites (known or suspected by the Nez Perce) and the risk of encountering them, the familiarity with the Bannock Trail is largely outweighed by the risk of military engagement. The net cost-benefit surface shows a high cost of travel in virtually any direction.

The Nez Perce actively enhanced their risk minimization with two strategies however. First, they engaged in sending out scouting parties with the explicit purpose of both identifying US Army and white civilian locations, and also actively misleading the US Army about the location of the main band of Nez Perce. Second, they increased their available knowledge of the region by kidnaping a number of white tourists. Several were killed but others escaped, with the exception of John Shively. His firsthand knowledge of the Mary Mountain Trail created a cognitive landscape for the Nez Perce which allowed them to make a crucial trajectory decision and minimize the risk of engaging the army along the well known Bannock Trail (fig. 10).

Since we have detailed historical information regarding the conflict we can model how the Nez Perce cognitively assessed their surroundings. But archaeologically, how would we assess the sites which were left behind by the Nez Perce if we didn't know the social context? Similarly, if strange attractors (like warfare) can so fundamentally influence supposedly simple nomadic or semi-nomadic societies, what does it mean for more complex ones? We need to consider dynamical variables in many archaeological situations and GIS is a powerful tool for hypothesizing about decision making processes.

Summary

In conclusion, the research carried out in the Greater Yellowstone Region has so far been limited to the occasional survey of areas likely to be impacted by campers. hikers, or timber harvests. Some of the most extensive work has focused on low altitude areas which have resulted in a biased interpretation of the past. By addressing social as well as ecological factors in a dynamical GIS framework, I have been able to suggest that settlement may have been more complex than was previously understood. Similarly, using GIS technology in conjunction with a theoretical model of decision making mechanisms, we can now begin to address issues of cognitive landscapes in a way which was, until recently, virtually impossible.

My approach to observing spatial patterns in the prehistoric and historic landscapes of the region has focused on providing empirical observations of phenomena that are linked to cognitive decisions. From the perspective of a European style of archaeology it may be seen as quite eco-deterministic, with such a large emphasis on resource procurement and environment. Yet from the perspective of North American archaeology it can be seen as verging on post-processual since it deals with social landscapes, cognition, and the transience of ideas. To span the ocean (so to speak) which separates these perspectives we must begin to employ GIS and related tools in a way which provides depth and meaning to our interpretations of the cognitive past, yet is grounded in a strong scientific philosophy.

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Figures

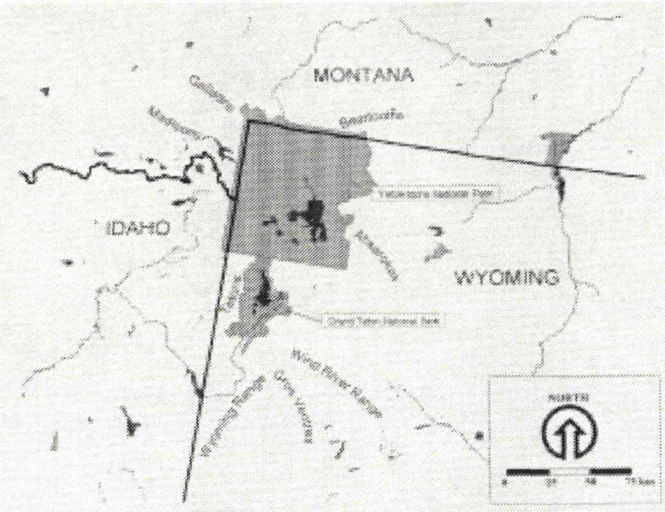

Figure 1. Location of Study Area.

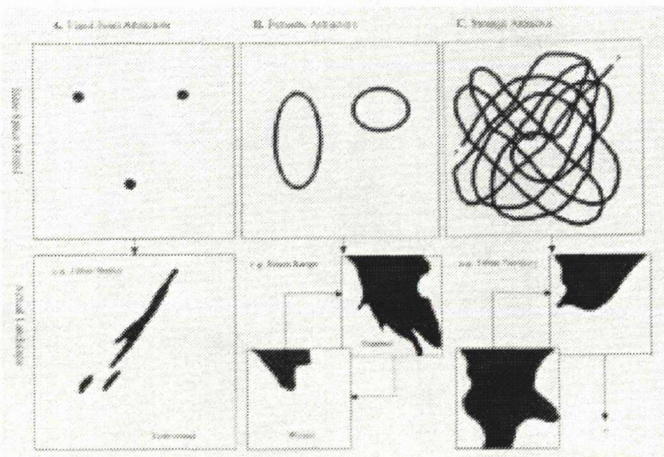

Figure 2. The three types of attractors.

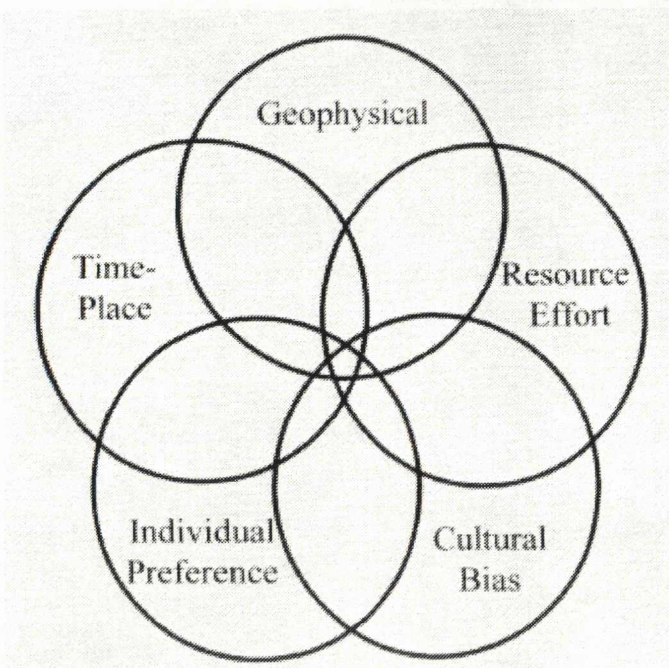

Figure 3. Matrix of site placement constraints.

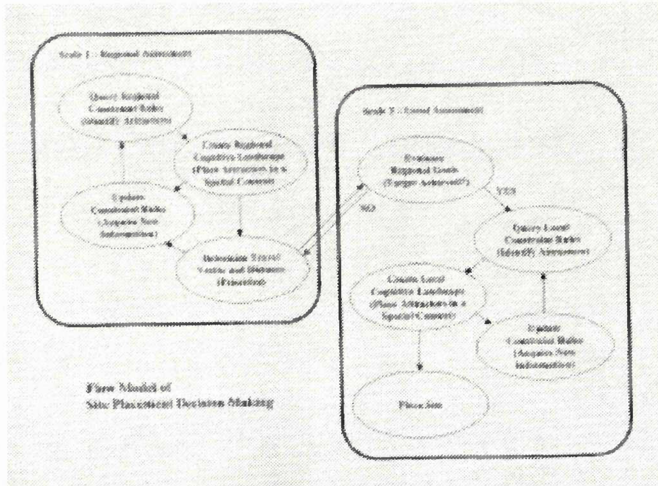

Figure 4. Process of site placement decision making.

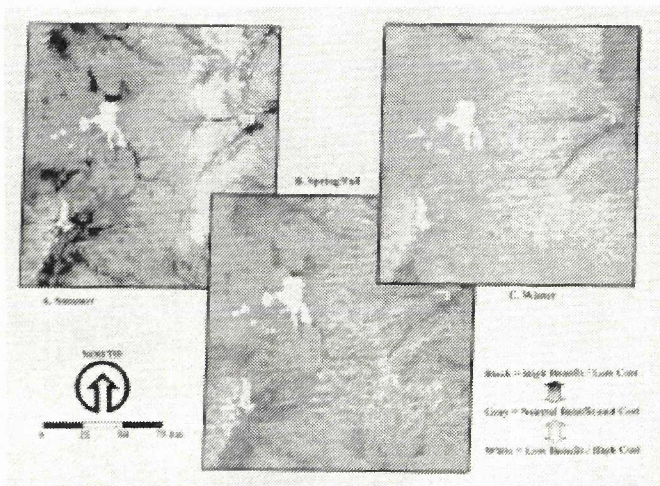

Figure 5. Seasonal cost-benefit surfaces (excluding nearest neighbor costs).

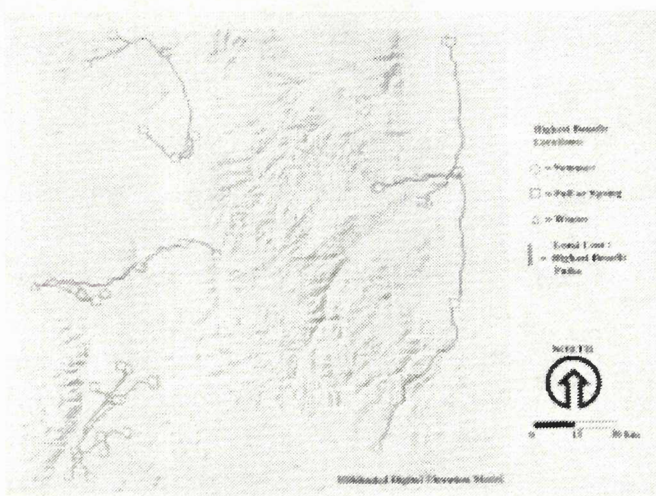

Figure 6. Seasonal least cost / highest benefit paths (excluding nearest neighbor costs).

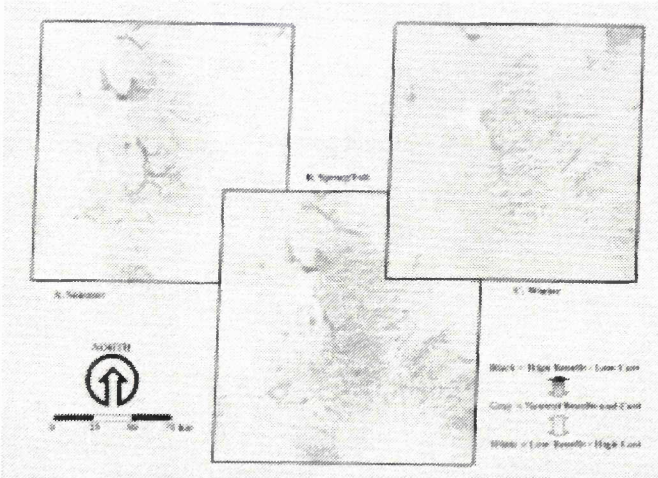

Figure 7. Seasonal cost-benefit surfaces (including nearest neighbor costs).

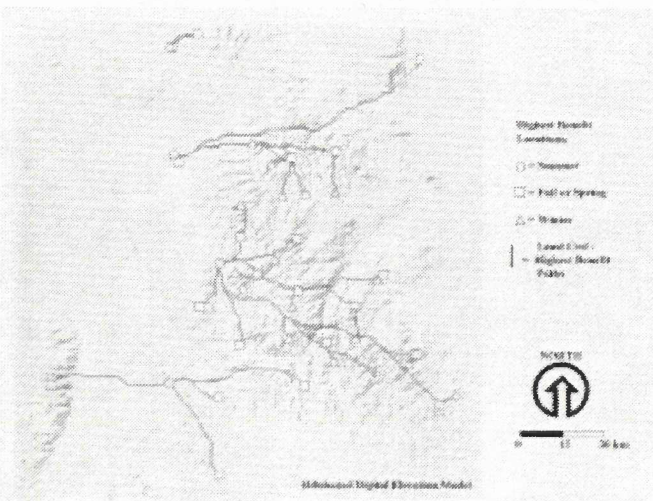

Figure 8. Seasonal least cost / highest benefit paths (including nearest neighbor costs).

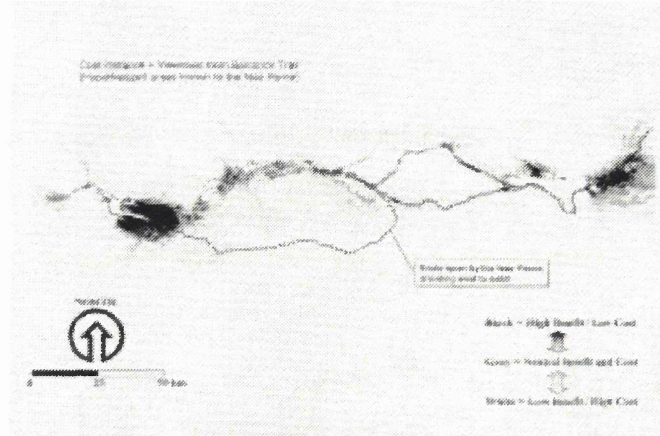

Figure 9. Cost-benefit surface (excluding cognitive variables) and route taken by the Nez Perce in 1877.

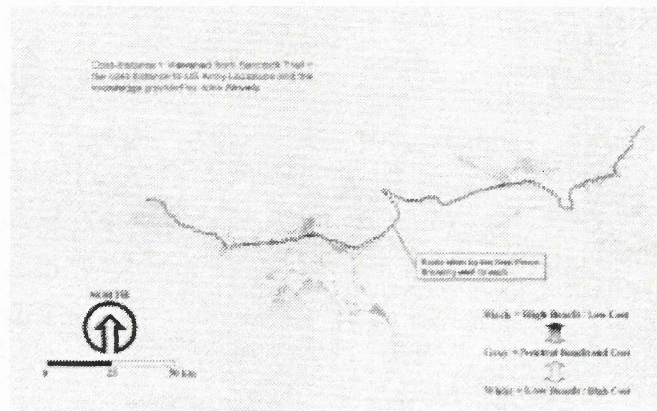

Figure 10. Cost-benefit surface (including cognitive variables) and route taken by the Nez Perce in 1877.