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Hunter-gatherers depend on naturally occurring resources and, in order to survive, must overcome resource procurement challenges inherent in their environment. One challenge relates to the temporal and spatial availability of resources, which hunter-gatherers address, in part, through the strategic use of space to position themselves for optimal access to necessary resources. This can be seen on the Columbia River Plateau in northwest North America where late Holocene hunter-gatherers solved problems of resource acquisition associated with seasonality and geographic variability by utilizing a subsistence-settlement strategy known as the "winter village pattern."

There is minimal archaeological research addressing local and sub-regional variations in the winter village pattern. This thesis explores how winter economic activities could have factored into the selection of late Holocene winter village locations in the lower Salmon River Canyon, Idaho. It provides a GIS modeling methodology

applicable to further research and contributes to a greater understanding of the archaeological record of both the canyon and the Plateau.

The winter village is viewed as a central location from which foraging activities could take place to supplement winter food stores. Models are developed in GIS, based on an analysis of game habitat in the environments surrounding winter village sites, showing various levels of hunting payoff expected under a central place foraging strategy. These models are used to evaluate the degree to which ancillary economic concerns played a role in positioning winter villages, assuming that locations were chosen to potentially minimize travel time to areas in the landscape with expected high densities of game. The models are also used to examine how the payoff-related movement of economically motivated hunters could be expected to differ according to variation in the structure and distribution of game habitat.

Results of the analysis show that in portions of the canyon where the environmental structure creates spatial inconsistency in the type and distribution of game habitat, villages may have been positioned to facilitate easy access to areas in the landscape providing a relatively greater chance of hunting success. General predictions for hunter mobility strategies and the spatial distribution of hunting-related archaeological sites are made based on the models. The predictions generated by this GIS method are well suited for evaluation by future archaeological survey. The methodology employed in the analysis can be applied throughout the Columbia River Plateau to sites of varying ages in an examination of the economic aspects of the relationship between hunter-gatherer subsistence and settlement, and thus enhance archaeologists' ability to reconstruct past lifeways.

Central Place Foraging and the Winter Village: A Settlement Pattern Analysis in the Lower Salmon River Canyon of Idaho

by
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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Kendra Carlisle, Author

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Chapter 1. Introduction and Literature Review

Hunter-gatherers depend on naturally occurring plant and animal resources for food, medicine, and raw materials for shelter, clothing, and tools. The temporal and spatial availability of these resources is conditioned by a combination of environmental factors. Climate, hydrology, elevation, and physiography (relief, slope, aspect, geology) constrain the type, distribution, and density of plant species. Distribution of plant species, in concert with physical variables, affects the distribution and behavior of many faunal species. The manner in which other key resources, such as water, fuel, and raw materials, are distributed in the landscape adds another dimension to the problem. In order to survive, hunter-gatherers must overcome the challenges of resource procurement specific to their environment.

One of the ways hunter-gatherers address the problem of resource availability is through the strategic use of space to position themselves for optimal access to necessary resources (Smith 2003). These "mobility" strategies are closely related to the structure of food resources in an environment (Binford 1980; Kelly 1983 and 1995). This is evident in a comparison of ethnographic hunter-gatherer cultures at a global level.

In tropical and subtropical environments, food resources are distributed relatively homogeneously in the landscape and are temporally interspersed throughout the year. Hunter-gatherers in these latitudes tend to employ high residential mobility, moving in dispersed groups from location to location while exploiting the resources available within the daily foraging radius of their settlement (Binford 1980; Kelly 1995). With increased distance from the equator, the distribution of food resources generally becomes more restricted spatially and temporally due to increased seasonality. In temperate and boreal environments, hunter-gatherers tend to have lower residential mobility, at least on a seasonal basis, establishing settlements near key food or non-food resources and dispatching task groups to procure other, more distantly located, necessary food items (Binford 1980; Kelly 1995). Groups in these latitudes often depend on storage to mitigate the seasonal scarcity of food. An exception to this trend is observed in high arctic environments, where some hunter-gatherer groups engage in high residential mobility to exploit spatially discrete resources that are seasonally available throughout the year (Binford 1980).

How far hunter-gatherers move between residential locations is closely related to the spatial distribution of food resources. Groups in the lower latitudes do not need to shift a long distance to access a new foraging area since resources are relatively continuous across the landscape. Hunter-gatherers at higher latitudes, however, have to move greater distances, on average, since resources are aggregated in patches (Kelly 1995).

In addition to spatial distribution and temporal availability, resource accessibility influences hunter-gatherer mobility, specifically, the frequency of residential moves (as measured on an annual basis) (Kelly 1983 and 1995). Kelly (1995: 121) notes that primary biomass, "the total amount of standing plant matter in an environment," is inversely correlated with abundance and density of plants and animals that can be extracted and used by humans. In high primary biomass environments, such as tropical, temperate, and boreal forests, most of the energy is bound in inedible portions of plants and thus unavailable to humans or their animal prey. In addition, the useable seeds are difficult to reach, being high above the ground, and require extensive processing to be rendered palatable (Kelly 1983). The opposite is true in low primary biomass areas, such as tropical and temperate grassland, and tundra. The structure of faunal (non-aquatic) resources in terms of size, distribution, and density reflect adaptation to these different conditions. In low primary biomass environments, animals tend to be larger and terrestrially oriented (as opposed to arboreal). Where these environments occur in warmer climates, the animals are also generally gregarious, becoming increasingly dispersed with lower temperatures (Kelly 1995) and corresponding reduced amounts of forage. With regard to human consumption, low primary biomass environments tend to offer greater quantities of useable and easily procured food resources (in the form of plant material and/or animal prey species). This means it will take longer for hunter-gatherers to deplete the resources within a given foraging area, requiring fewer residential relocations. Thus, it makes sense that as primary biomass increases, so does the frequency of residential moves (for terrestrial-resource based groups; those groups dependent on aquatic resources actually move less often) (Kelly 1983).

The strategic use of space by hunter-gatherers in response to structural variation in resource availability can also be seen on a regional level. The Columbia River Plateau in northwest North America is an area of substantial environmental diversity (Figure 1). Seasonality and geographic variability in the timing and distribution of resources created

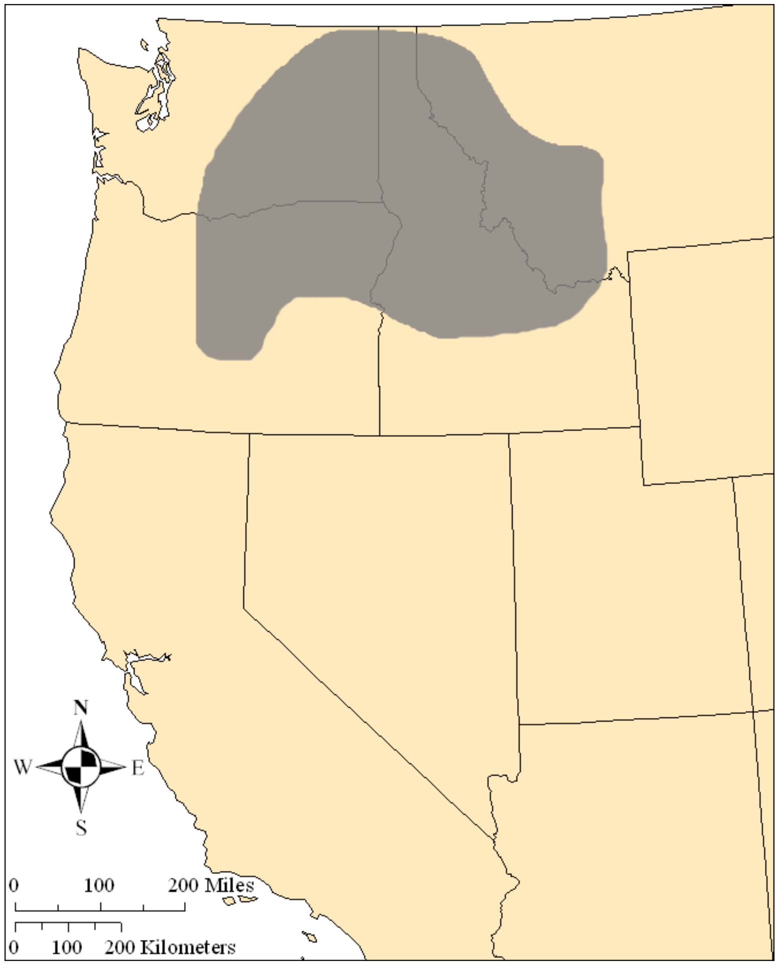

Figure 1. Location of the Columbia River Plateau (shaded area) in northwest North America (based on Ames et al. 1998 and Roll and Hackenberger 1998).

an array of opportunities and challenges for prehistoric hunter-gatherer subsistence. This is evident on a broad scale during the late Holocene (Chatters and Pokotylo 1998). During this time, the majority of Plateau cultures had access to highly productive salmonid runs and geophyte (in particular camas) grounds, which they intensively exploited along with ungulates and other plant species when seasonally available. The resulting quantity of food, in excess of their immediate needs, was stored for consumption during the winter. Hunter-gatherers were typically dispersed in smaller groups during the spring through fall as they collected resources. They aggregated in larger groups in permanent villages situated in low elevation riverine environments during the winter. At this time, stored food supplies were augmented by hunting and fishing (Andrefsky 2004; Kimball 2005; Chalfant 1974; Marshall 1977).

This semi-sedentary subsistence-settlement strategy, labeled the "winter village pattern," is quite different than that identified in the far north and east portions of the Plateau (Roll and Hackenberger 1998). Unlike the rest of the Plateau, the eastern margin lacks anadromous fish populations and abundant camas crops, as well as other highly productive and localized food resources. Prehistoric hunter-gatherers were thus unable to acquire bulk amounts of food resources for delayed consumption during the low productivity time of year (Roll and Hackenberger 1998; Thoms and Burtchard 1987). They instead relied predominantly on hunting ungulates, which they exploited year round in small mobile groups (Prentiss et al. 2005).

The winter village pattern was originally identified through observation of ethnographic hunter-gatherers on the Plateau. Archaeologists have determined that the pattern was widely established on the Plateau by at least 2,500 years B.P. (Ames et al. 1998; Chatters 1998) and appeared in some areas as early as 4,000 to 4,500 years B.P. (Chatters and Pokotylo 1998; Schalk and Cleveland 1983). Most archaeological research relating to the winter village pattern has been directed toward clarifying its origin and antiquity (e.g. Ames and Marshall 1981; Chatters 1989; Lohse and Sammons-Lohse

1986). A topic that has received little attention is how the subsistence-settlement strategies of hunter-gatherers, which were sufficiently similar to allow identification of a regional pattern, varied at the local and sub-regional scale in relation to the structure of the environment and resource availability. There are many aspects to this question relating to relative proportion of resource use, timing and organization of resource procurement behavior, strategy of residential and logistically organized movement, and placement of settlements. I explore the latter issue in this thesis, looking at how the economic needs of hunter-gatherers during the winter may have influenced their selection of winter village location.

Settlement Archaeology

The study of human settlement patterns is an established field of inquiry among archaeologists. A settlement pattern is "the distribution of human activities across the landscape and the spatial relationship between these activities and features of the natural and social environment" (Fagan 1996: 636). Archaeologists seek to define the functional relationships underlying the spatial organization of human activity in order to explicate past economic and social processes. Settlement patterns may be examined at three levels: the individual building or structure; the arrangement of structures within a site (which is often conceived as the material correlate of a community); and the distribution of sites (communities) over the landscape (Trigger 1968: 55). The latter level of analysis is considered the realm of "settlement archaeology."

Different factors and processes are assumed at each level to have exerted greater influence on the organization of human activity. At the landscape scale, which is the focus of this thesis, "the overall density and distribution of a population is determined to a large degree by the nature and availability of the natural resources that are being exploited" (Trigger 1968: 66). Accordingly, settlement pattern studies at this level frequently are oriented toward articulating how past subsistence strategies are linked to the spatial distribution of archaeological phenomena. This is especially the case in prehistoric hunter-gatherer research, which has a strong focus on subsistence due to the "relatively great archaeological visibility of food-getting behavior" (Jochim 1979: 84). The interrelationship between subsistence and settlement is such that these behaviors are often investigated as a unit, the subsistence-settlement pattern.

One of the techniques employed in the study of past settlement patterns, termed site catchment analysis, is particularly well suited for examining subsistence. Site catchment analysis is commonly used to assess the resource potential of the landscape around a site in order to infer the probable economic function of a settlement, size of settlement population, and subsistence strategy of the settlement inhabitants (Dennell 1980: 14). The fundamental premise of site catchment analysis is based on ethnographic observation of hunter-gatherer and agricultural economies and states that resources located near a settlement will be more likely utilized than those located farther away. This maxim is based on an economic understanding that greater amounts of energy are required to acquire resources as one moves farther from the settlement. Eventually, it becomes uneconomical to obtain resources beyond the point where the energy expended to acquire a resource exceeds the energy value of that resource. Settlement strategies can help hunter-gatherers reduce the cost of travel to and from desired resource exploitation areas (Findlow 1980: 158). The concept of examining past human decision-making in terms of economic costs and benefits is a key component of human behavioral ecology and foraging models, which will be discussed later in this chapter.

Typically, the first step in a site catchment analysis involves defining the spatial extent of the surrounding landscape that likely provided the resources procured by a settlement's inhabitants. The resources within this area are then inventoried and classified, which forms the basis for further examination of hunter-gatherer economic behavioral patterns. A distinction is made between the site exploitation territory, or the area immediately "surrounding the site which is exploited habitually by the inhabitants of the site" (Vita-Finzi and Higgs 1970: 7), and the site catchment, which is the entire area "from which all the materials found in the archaeological deposit were derived" including non-food resources (Bailey and Davidson 1983: 90). Thus, examination of site exploitation territories occurs at the local or sub-regional level and is concerned primarily with subsistence, while analysis of site catchments may be conducted at the regional level, often through comparison of site exploitation territories, and focuses on explicating "long distance social and economic interactions" (Bailey and Davidson 1983: 90). In this thesis, I make use of site exploitation territories to investigate how the economic needs of hunter-gatherers during winter may have factored into the placement of winter villages.

The methodologies for delimiting site exploitation territories have evolved since their introduction in the 1960s and 1970s when studies employed circular territories with fixed radii or time contours (Roper 1979a: 123). More recent site exploitation territory studies account for topographic variability in the landscape surrounding a site, and the corresponding time/energy expenditure associated with travel, providing more realistic analyses. This research has taken advantage of a newer technology, Geographic Information Systems (GIS), to efficiently model mobility allowing for the production of site exploitation territories that are based on calculated travel costs over a particular length of time within a specific topographic context. GIS technology greatly facilitates the management, manipulation, and analysis of large amounts of descriptive and spatial data.

Watanabe's (2004) study of the effect of environmental change on settlement behavior during the final phase of the Jomon period (approximately 3,000 BP to 2,300 BP) in Japan illustrates the benefits of using GIS in site catchment analysis. Watanabe defined the exploitation territories of two contemporaneous inland and coastal settlements in the Tokai region by applying Tobler's hiking formula (Tobler 1993) to a digital elevation model and calculating the distance that could be traveled from each site in two-hour period given the topographic variation in the surrounding landscape. Based on examination of environmental zones and associated potential food resources within each site exploitation territory and the artifacts and faunal remains excavated from each site, Watanabe inferred a broad spectrum subsistence strategy for the inland site and a specialized strategy emphasizing marine resources and terrestrial game for the coastal site. He then modeled the local shift in coastline that would have resulted from a climate-induced sea level regression that occurred approximately 2,650 years ago. The results indicated that occupants of the coastal site would have had to travel twice as long in order to reach essential marine resources. Watanabe sees this as an explanation for the abandonment of the coastal site around 2,650 BP, suggesting that the marine-focused economy could not be maintained given the increased distance to the ocean. As support for his argument, he points to the continued occupation of the inland site where utilization of a broad resource base allowed the inhabitants to maintain their established mode of production despite environmental changes.

Gaffney and Stancic (1991) used a similar GIS approach by incorporating a cost surface in their catchment analysis of Iron Age/Bronze Age hillfort sites on the Island of Hvar in Yugoslavia. Using a digital elevation model, they modeled the effect of topography on travel distance given a walking rate of 5 km in 90 minutes on flat terrain. The resulting site exploitation territories extended the work equivalent of 5 km from the originating sites. They then measured the percentages of different soil types contained in each site exploitation territory. Based on the proportion of soil types contained within the site exploitation territories and the positioning of the sites on hilltops and ridges, the authors inferred that the forts were strategically placed to defend access to high quality farming land. They further identified two locations on the island where forts likely were located in the past, according to the demonstrated spatial relationship between this site and soil type, and that warrant further archaeological examination.

Getting at the Processes behind Hunter-Gatherer Settlement Patterns

Binford's Forager-Collector Model

Interpreting past cultural processes from the archaeological record requires archaeologists to somehow "bridge the gap between the known, observable archaeological contexts and the unknown, unobservable systemic contexts" (Thomas 1979: 396). Archaeologists studying hunter-gatherers are assisted in this undertaking by an area of research called middle-range theory, which is a set of arguments and methods that relate empirical archaeological data to explanations of human behavior generated by high level cultural theories (Fagan 1996). Binford's forager-collector model (Binford 1980) is an important contribution of middle-range theory that attempts to articulate variation in ethnographic hunter-gatherer cultural systems to archaeological patterns in order to infer past aspects of economy, social organization, and settlement patterns.

Drawing on ethnographic examples, Binford (1980) identified a range of hunter-gatherer subsistence-settlement strategies that are determined primarily by the distribution of critical food and material resources. One end of the strategic spectrum corresponds to foragers, who typically live in environments where resources are spatially and temporally homogeneous. Forager strategies are typified by high residential mobility, which allows hunter-gatherers to "map onto" resources, and a lack of long-term storage (Binford 1980). Instead, foods are acquired on an encounter basis for immediate consumption during daily foraging excursions from the residential base. Collectors occupy the opposite end of the strategic spectrum and are often associated with environments featuring a heterogeneous distribution of resources across space and time.

A collector strategy is characterized by low residential mobility and high logistical mobility wherein specific resources are procured by specialized task groups that may travel extended distances from a residential base to exploit particular areas in the landscape at key times. Collectors gather food in bulk amounts to store for consumption during future periods of low resource availability.

Binford's model offers a significant contribution to settlement pattern analysis by identifying "material consequences of hunter-gatherer behavior in terms of site types and intersite variability in associated tool assemblages" (Habu et al. 2002: 2). Foragers are expected to discard material in two spatial contexts, the *residential base* and the *location*. Residential bases are the "hub of subsistence activities…where most processing, manufacturing, and maintenance activities take place" (Binford 1980: 9). Locations are places in the landscape where resources are procured and are typically utilized for brief periods of time during the extraction of limited quantities of materials. Because artifacts associated with locations are generally sparse and may be dispersed in the landscape, locations tend to have low archaeological visibility. Residential bases tend to have greater archaeological visibility and intra-assemblage variation than locations, due to the longer occupation and greater range of activities producing waste material and artifacts.

In contrast, collectors generate five different types of sites. *Residential bases* and *locations* serve the same function as in the foraging system, although the latter tend to have greater archaeological visibility due to the bulk procurement of resources. *Field camps* serve as temporary residences for specialized task groups procuring resources located far from the main residential base. Like locations, field camps are "differentiated according to the nature of the target resources" (Binford 1980: 10). *Stations* are used by task groups for gathering information by reconnaissance in order to develop a strategy to obtain a target resource. *Caches* are used to store the bulk resources procured by task groups for delayed consumption, as well as to store specialized equipment used in extracting a particular type of resource.

Like settlement organization, technological complexity varies among hunter-gatherer groups according to the strategy of resource exploitation, with important implications for interpreting the archaeological record. Foragers typically use tools that are versatile and easily manufactured, which they then discard after use. Their technological needs are relatively simple as they do not store food, and therefore do not need to procure resources beyond what is immediately necessary. Collectors, in contrast, use a range of specialized tools to facilitate the efficient procurement of specific resources in bulk quantities. These tools often require significant effort to manufacture and are stored for re-use (Bettinger 1991: 69).

According to Binford's model, the winter village pattern on the Columbia River Plateau can be understood as a collector-type response to incongruities in the temporal and spatial availability of food resources. During productive seasons, relatively small residentially mobile groups (who may have utilized logistically organized task groups) obtained key resources where and when these were most abundant for delayed consumption during winter months. These small groups then aggregated at villages during the winter where they subsisted on their cached food supply and additional resources obtained by individuals or specialized task groups to supplement and stretch bulk stores. Supplemental resources may have been obtained through short expeditions within the daily foraging radius of the village as well as through extended trips that required establishment of field camps (the latter is documented ethnographically, see Miller 1998). Depending on the type of resource and degree of resource patchiness influenced by environmental conditions, it is reasonable to expect that different mobility strategies may have been used in searching for these supplemental resources. Where the environmental structure near a winter village produced a homogeneous resource distribution, task groups (and individuals) could be expected to range widely in the landscape, procuring desired resources as encountered (as in a forager mobility strategy). In environments with a heterogeneous resource distribution, task groups could be expected to move more deliberately and target specific areas in the landscape in order to procure desired resources within those patches (as in a collector mobility strategy).

If Plateau hunter-gatherers evaluated the structure of their local environment in terms of relative degrees of economic payoff, we should expect to see locations and field camps distributed in relative accordance with those areas that hold resources of interest. The assertion that hunter-gatherers operated as rational economically-minded individuals is theoretical, of course, and deserves further explanation.

Optimal Foraging Theory

The application of concepts and methods from human behavioral ecology, in the form of optimal foraging theory, has proven to be "an excellent framework for formalizing the forager/collector model into a more testable set of hypotheses" (Habu et al. 2002: 5) and added a diachronic dimension to Binford's ecological explanation of hunter-gatherer settlement systems. Both Binford and optimal foraging theory seek to explain variability in subsistence-settlement behavior according to "conditions of variability, uncertainty, constraint, limitation, and the like imposed by environment" (Kirch 1980: 130).

Optimal foraging theory originated in the biological sciences and has been adapted by anthropologists to operationalize the neo-Darwinian framework of human behavioral ecology for analysis of subsistence and settlement behavior. Human behavioral ecology, also variously manifested as evolutionary human ecology or sociobiology, employs principles of natural selection to explain human behavioral diversity (Bettinger 1991: 153). According to this theory, behavior may be understood in terms of fitness, which is "the genetic contribution to the next generation" (Jochim 1979: 78). Behaviors are selectively retained that contribute to an individual's adaptedness, or the ability to survive and reproduce, in a specific environment. Cultural selection is assumed to operate primarily at the level of the individual, as this is the case in genetic evolution. However, it is reasonable to expect selection to also operate at the group level, particularly in the context of settlement behavior. As Kirch (1980: 118) explains:

> Human groups characteristically act as functional units both in decision-making and in carrying out those decisions in terms of interaction with the environment. The human group is frequently the unit of adaptation in the sense that all members face the same set of selective pressures…Individual behavior is constrained by the group as a whole, with sanctions against deviation or 'outlawery.' Thus the group as a whole directly impinges upon the individual's range of behavioral variability.

Although the basis for selection remains debatable, energy efficiency has been widely accepted. This is certainly the case with regard to subsistence-related behavior as modeled by optimal foraging theory. Optimal foraging theory models predict how an individual will behave according to a "decision-making algorithm" applied in a given context (Bettinger 1991: 105). In striving to achieve fitness in the short-term, humans select from a *set of alternative behaviors* using a form of *currency* to measure the costs and benefits of each option according to social and environmental *constraints* that set the parameters for the types and benefits of alternative behaviors (Kelly 1995). Since energy is required by all living organisms for survival and reproduction, and is easily measured, it serves as the currency in most optimal foraging theory models. These models assume that in terms of resource selection, patch choice, foraging time, and settlement location, humans seek to "maximize the net rate of energy capture, since this means either more food acquired absolutely, or more time made available to devote to other (fitness-related) activities once a 'sufficient' amount of food is in hand" (Broughton and O'Connell 1999: 154). From this standpoint, energy efficiency is the ultimate goal of optimal foraging and serves as a proxy for fitness (Smith 1987: 204). More efficient behavior strategies are favored as these increase the likelihood that an individual will survive and reproduce.

Optimal foraging theory assumes that humans are economically rational and will act out of self-interest that is moderated by cultural norms. This assumption has been criticized by researchers who believe that individuals are culturally rational, behaving wholly in accordance with prescribed cultural values (Bettinger 1991). While the two perspectives are at odds, one does not preclude the validity of the other. In fact, it has been argued that human rationality has both a cultural and objective component. Optimal foraging theory provides an opportunity to assess the relative influence of each by using "a yardstick of objective economic rationality as a basis for the comparative study of human behavior" (Bettinger 1991: 106). Most importantly, deviations from expectations of economic rationality and optimization suggest the role of other cultural factors and processes that should be considered.

While it is true that humans will at times strive to optimize, it is unrealistic to assume that this is always the case. Humans engage in a spectrum of economic behavior ranging from minimum return at one end to maximum return at the other. The utility of optimal foraging theory models is not in predicting how people behave all the time everywhere, but identifying what behavior would look like if people sought a maximizing strategy. Essentially, they establish the upper limit to which observed or inferred (as is the case archaeologically) behavior can be compared. This in contrast to the lower limit established by a minimizing model that identifies how behavior would appear if people were for the most part unconcerned with the economics of resource procurement.

Central Place Foraging

One arena of optimal foraging theory focuses on the settlement aspect of subsistence strategies (Bettinger 1991). Humans establish home bases in locations proximal to critical features such as potable water, shelter, or high-ranking food resources. In situations where a home base is maintained for a certain length of time, hunter-gatherers may employ a foraging strategy that involves the exploitation of resources from an area with subsequent return to the home base. Under this strategy, termed central place foraging, foragers will range out from and back to their home base in a radial pattern in search of resources (Winterhalder and Kennett 2006: 16). When target resources are not available in the immediate vicinity of the site, hunter-gatherers utilize more distant patches and transport acquired materials back to the home base. Travel to and from these removed patches incurs costs of time and energy that, in addition to those costs associated within-patch resource search and handling, affect the rate of foraging return. Central place foraging models assume an overall goal of maximizing the rate of delivery of energy to a centrally located residential base, and incorporate the effect of travel costs on, for example, selection of resource patches, prey, and load size (Orians and Pearson 1979: 156).

Given the goal of maximum rate of delivery of energy, the optimally located central home base is one that minimizes travel time to potential resource patches relative to gain (Orians and Pearson 1979: 170). This is very much the same concept underlying site catchment analysis described earlier, which recognizes that the primary strategy employed by hunter-gatherers to reduce the cost of travel to and from desired resource exploitation areas is site placement (Findlow 1980: 158). This explains the "mapping on" behavior of foragers described by Binford (1980).

An example of how central place foraging has been used to examine the relationship of settlement and subsistence is provided by Zeanah's (2000) model of mobility and diet breadth for pre-village hunter-gatherers in the White Mountains of the western Great Basin. A source of debate for archaeologists studying the prehistory of this region has been whether alpine sites dating before 1,350 BP represent logistical hunting camps and locations connected to lowland residential bases oriented toward seed procurement or short-term residential base camps seasonally occupied during exploitation of alpine resources. Alpine site assemblages are dominated by projectile points, bifaces, and mountain sheep bone. In contrast, contemporary lowland sites in the neighboring Owens Valley are characterized by abundant plant processing tools and, in some cases, contain residential features, plant remains, and small mammal and sheep bones. This has commonly been interpreted as support for the first scenario. However, alpine sites also contain marmot remains, carbonized seeds, and small quantities of ground stone, which suggest that women and children lived at alpine sites, "procuring small alpine mammals and processing plant foods while men hunted sheep" (Zeanah 2000: 3). This is more in keeping with the second interpretation.

Zeanah argues that diet breadth and the seasonality and spatial distribution of resources determined the mobility strategy of pre-village populations. Alpine sites were occupied during the late summer and early fall when sheep and marmots were abundant in the higher elevations and seeds were ripe in the lowlands, thus creating a scheduling conflict. To identify optimum base camp location, Zeanah calculated the handling and transport costs of mountain sheep and tanseymustard, which he used to determine the central-place foraging return rate of selected lowland and alpine sites under both logistical and residential exploitation strategies. He concluded that sheep, as the higher ranked resource, would have been procured directly from base camps in the alpine zone when encounter rates were sufficiently high. However, if the rate of sheep procurement dropped below a certain threshold, so that other lower-ranked food resources, such as tanseymustard, gained importance, base camp locations would have shifted to the lowlands.

Madsen et al. (2000) also applied central place foraging in their study of alpine hunter-gatherer subsistence and settlement, to explain the localized distribution of mid-Archaic and Late Prehistoric sites in the Uinta Mountains of northeast Utah. Surveys have revealed a dearth of cultural material in the Garfield Basin, located on the southern slope of the mountain range. In contrast, six sites and multiple flake isolates, all suggested to be hunting-related, have been recorded in the Henrys Fork Basin on the northern flank of the range. Physically, the basins are very similar. However, they differ in two significant ways. Henrys Fork Basin features considerably greater expanses of grassland on the surrounding ridge tops, and has a shorter access route to lower elevations. Based on these differences, the authors hypothesized that the sites in the Henrys Fork Basin were logistical hunting camps and locations used by groups based at the northern foot of the Uinta Mountains. They tested this hypothesis by calculating the central-place foraging return rates for deer/sheep procured logistically in each basin and for other resources obtainable locally at the north and south base of the mountains through residential mobility. Comparison of the logistical and residential return rates on the north side of the mountain indicated that procuring deer/sheep from the Hunters Fork Basin yielded a much higher rate of return than exploiting local resources. On the south side of the mountain, logistical hunting in the Garfield Basin was determined to be uneconomical as the return rate was no greater than that yielded by foraging locally. The authors then used their findings to predict site distribution in two other basins in the mountain range, with initially positive results.

It is clear from this discussion that central place foraging models can provide important insight into hunter-gatherer subsistence-settlement strategies. This speaks to the utility of this approach in an examination of how winter economic activities could have factored into the choice of winter village location in the Columbia River Plateau. Factors influencing village positioning have been identified ethnographically and archaeologically (Table 1).

Table 1. Factors influencing selection of Plateau winter village locations.

Author	**Positioning Factors**
Schalk and Cleveland (1983)	-proximity to "good" fishing sites -positioning "along the floodplains of the major drainages and their principle tributaries," specifically at • mouths of tributary streams • canyon mouths • alluvial fans • river islands • lakes (occasionally) • areas adjacent to river channel constrictions
Ames and Marshall (1981)	-easy access to uplands -absence of spring flooding -good drainage -proximity to • early spring plant resources (critical) • springs • wood
Sisson (1985)	-proximity to streams with anadromous fish (based on modern distribution) -generally southern exposure -low elevation

Table 1 continued.

Author	Positioning Factors
Langdon (2001)	-proximity to Class IV, V rapids (postulated as good fishing sites)
Mierendorf et al. (1981)	-proximity to or positioning on tributary streams -access to • shelter • driftwood • fresh water
Walker (1998)	-proximity to or positioning on tributary streams -proximity to fishing sites
Marshall (1977)	-proximity to springs -access to spring plant resources (on flat ridgetops) -proximity to or positioning on tributary streams to take advantage of • habitable landforms above river flood level • spawning non-anadromous fish • driftwood (for fuel)
Schwede (1966; 1970)	-proximity to fish and roots -proximity to large tributary streams -low elevation
Miller (1998)	-proximity to • firewood • water • shelter (from snow and wind)

A few studies (Sisson 1984; Langdon 2001; Schwede 1966) have quantified the co-occurrence of village location and environmental factors, as listed in Table 1. These studies were exploratory in nature and did not attempt to determine whether the observed correlations were statistically significant. Thus, the extent to which any environmental factors figured into village positioning has not been fully determined.

Overall, the identified factors indicate that village placement had a functional component and preference was given to locations “where people could survive most easily during the least resource-rich time of year and where access to spring resources was easiest" (Marshall 1977). Access to resident non-anadromous fish and/or plants was apparently important, which is expected, given the ethnographic use of these resources as "starvation food" during the winter and early spring when stores ran low (Marshall 1977). It is noteworthy that access to game is not listed despite the documented importance of this resource, especially of deer and elk (Miller 1998; Ross 1998; Lahren 1998; Hunn and French 1998), as a supplemental food in winter (Chalfant 1974; Marshall 1977; Ross 1998; Miller 1998). This is a factor worth investigating as winter hunting served to stretch the utility of stored food supplies. If access to game did not factor into placement of villages, this would suggest that access to other food and material resources was of greater concern. Unlike salmon or camas, terrestrial game could be acquired in the vicinity of the winter village during winter months; however, its particular role in the prehistoric economy of Plateau hunter-gatherers has not been explored in this context.

The Winter Village Pattern and Central Place Foraging

As a subsistence-settlement strategy, the winter village pattern was used by hunter-gatherers of the Columbia River Plateau as an adaptation to seasonal incongruities in the spatio-temporal availability of food resources. In particular, the low environmental productivity of the winter months posed considerable risk to hunter-gatherer survival. To address these challenges, hunter-gatherers congregated in winter villages located in the bottom of river canyons, which were warmer and received relatively less snowfall than higher elevation areas of the Plateau. In these villages, Plateau peoples subsisted on stored food supplies amassed during the rest of the year. They supplemented these stores by winter fishing and hunting, with particular emphasis on the latter (Andrefsky 2004; Kimball 2005; Chalfant 1974; Marshall 1977; Ross 1998; Miller 1998).

This was a viable strategy due to the seasonal availability of localized, highly productive food resources such as salmon and camas that could be harvested and processed in bulk quantities for delayed consumption (Roll and Hackenberger 1998). The accumulation of stored food supplies required intensive exploitation of these and other important food resources, such as berries and game, which were located in different areas of the Plateau. Some of the resources overlapped temporally but not spatially, creating scheduling conflicts. To most effectively exploit the resources when and where they were available, village populations dispersed in smaller mobile groups that established camps proximal to specific resources (some groups may have remained at the village to fish) (Aikens 1993; Chalfant 1974). These groups effectively functioned as specialized task groups akin to those identified by Binford (1980) for collector systems. There is evidence to suggest that summer villages were established in some places to serve as seasonal residential bases from which food resources were logistically procured (Chatters 1989; Chalfant 1974). Logistical resource procurement would also have occurred in winter if supplemental hunting trips had extended for multiple days.

Clarifying the antiquity and origin of the winter village pattern has been the focus of much of the research in regard to prehistoric settlement patterns on the Columbia River Plateau (e.g. Lohse and Sammons-Lohse 1986; Ames and Marshall 1981; Chatters 1989). Hackenberger et al. (1989) synthesize archaeological survey data from the Snake, Salmon, and Middle Fork Salmon river drainages to identify a relationship between middle and late prehistoric subsistence-settlement strategies and pithouse size and frequency, as well as to make preliminary estimates of regional population size for central montane Idaho. As part of his master's thesis, Sisson (1984) examines the distribution of recorded archaeological sites along the lower Salmon River relative to specific environmental attributes in an effort to define patterns for use in predicting site location. Using ethnographic description of the subsistence-settlement strategies of Sahaptian speakers and Northern Shoshone and drawing on concepts from formal decision theory, Hackenberger (1984) develops decision-making models for prehistoric hunter-gatherers in central montane Idaho that predict selection of settlement location, proportional resource use, and population aggregation. He uses archaeological data from the Middle Fork of Salmon River in a preliminary evaluation of the utility and accuracy of the models. In her thesis, Langdon (2001) uses GIS to look at the distribution of housepit sites in Hells Canyon relative to rock art sites, cairns, and rapids (possible fishing sites). Chatters (1982) compares locations of sites and isolates of different ages in the uplands of the western Columbia River Basin to soil parent material and physiographic zone in an effort to develop a history of settlement and land use patterns.

There is little archaeological research that explicitly examines winter village settlement patterns on the Plateau at a sub-regional or local level, while ethnographic information on this topic is also sparse. Schwede (1966) attempts to identify a relationship between specific environmental variables and the distribution of Nez Perce settlements, including winter villages. In her research, Schwede synthesizes data on settlement location and exploited food resource areas that are drawn from the body of

Nez Perce ethnographic literature augmented with extant archaeological survey data and her own ethnographic field research. She examines the spatial relationship between biophysical variables in the landscape and the distribution and frequency of Nez Perce settlements known to have been in use immediately pre-contact. Using a sample of 132 villages and 137 camps, she tests four hypotheses in regard to the positioning of settlements, in each considering the influence of one of the following: elevation, proximity to mouths of streams, size of streams at confluences, and number and type of available food resources.

Schwede determines that villages are typically located at lower elevations than camps, citing the fact that 98% of villages in her sample are below 2,501 feet in elevation, compared to 46% of camps. Using a sub-sample of settlements, she observes that 67% of villages and 59% of camps are located within a one-mile radius of a confluence; 61% of these villages are within a one-mile radius of a confluence featuring a large master stream (7th order), while 62% of these camps are located "near" confluences with large streams (Schwede 1966: 12). She concludes, however, that "most villages are established at the mouths of streams…where streams of intermediate size join their master streams" and "camps usually are established near small streams" (Schwede 1966: 16). Finally, Schwede determines, based on another sub-sample, that the "availability of food resources influenced the establishment of (settlements) since 146 of the 167 settlements considered are found…having food resources immediately available" (Schwede 1966: 14). In particular, villages are most commonly found in association with fish and root resource areas, and camps associated with game and fish localities.

This last interpretation is questionable given the procedure Schwede follows when analyzing the relationship between the locations of settlements and resources. She partitions 72% of the territory considered in her study using a grid of squares, each measuring 6 miles on a side. Of the 840 squares comprising the grid, she considers only the 62 that contained both settlements and ethnographically exploited resources. By ignoring the squares featuring only one or the other variable, she effectively predisposes the data to show a relationship between settlement and resource availability. In addition, the scale of Schwede's analysis is too coarse to support any meaningful association between settlements and resources. Arguably, co-occurrence of settlements and resources in a 36 square mile area can hardly be interpreted as one being in the "immediate vicinity" of the other (Schwede 1966: 13).

Schwede's findings are often considered to be representative of the entire ethnographic territory of the Nez Perce. Her data, however, are taken primarily from the areas around the Clearwater, Snake, and Wallowa rivers. In fact, she tests her third and fourth hypotheses only against data from the Clearwater drainage (Schwede 1966: 11-12). The traditional territory of the Nez Perce encompassed the Salmon, Clearwater, and lower Snake river drainages, an area of considerable topographic, climatic, and biotic variability (Walker 1998). Given this heterogeneity, it is problematic to project settlement pattern trends outside of the local ecological system in which they were observed. Moreover, to assume that the environmental structure of all Plateau canyons is uniform is unwarranted. Physiographic and geomorphic variation between Plateau canyons produces different "environmental problems and opportunities in need of different strategic cultural solutions." (Davis 2003:73) Thus, economic behavior and settlement patterns should be expected to vary between and even within individual canyons.

Ecologically related differences in the relative proportion of resource use, timing and organization of resource procurement behavior, strategy of residential and logistically organized movement, and placement of settlements should generate distinct patterns in the late Holocene archaeological record of the Plateau. Studying these variations adds to our understanding of the relationship of environmental context to hunter-gatherer cultural processes on the Plateau, as well as in general.

Generally, this thesis seeks to provide insight into the question of how hunter-gatherers utilized the lower Salmon River Canyon (LSRC) in west-central Idaho during the late Holocene (Figure 2). This complex issue can productively be studied using a settlement pattern approach wherein I address questions relating to whether the positioning of winter villages was tied to the relative success of winter hunting in variously structured canyon environments. Specifically, I look at the winter village as the central location from which hunting activities could take place to supplement winter food stores. General questions guiding my research include the following:

- Did the local distribution of elk and mule deer influence the siting of winter villages? (It should be noted that bighorn sheep were also an important resource. However, they have different behavior patterns than elk and mule deer and so are not considered in this study.)

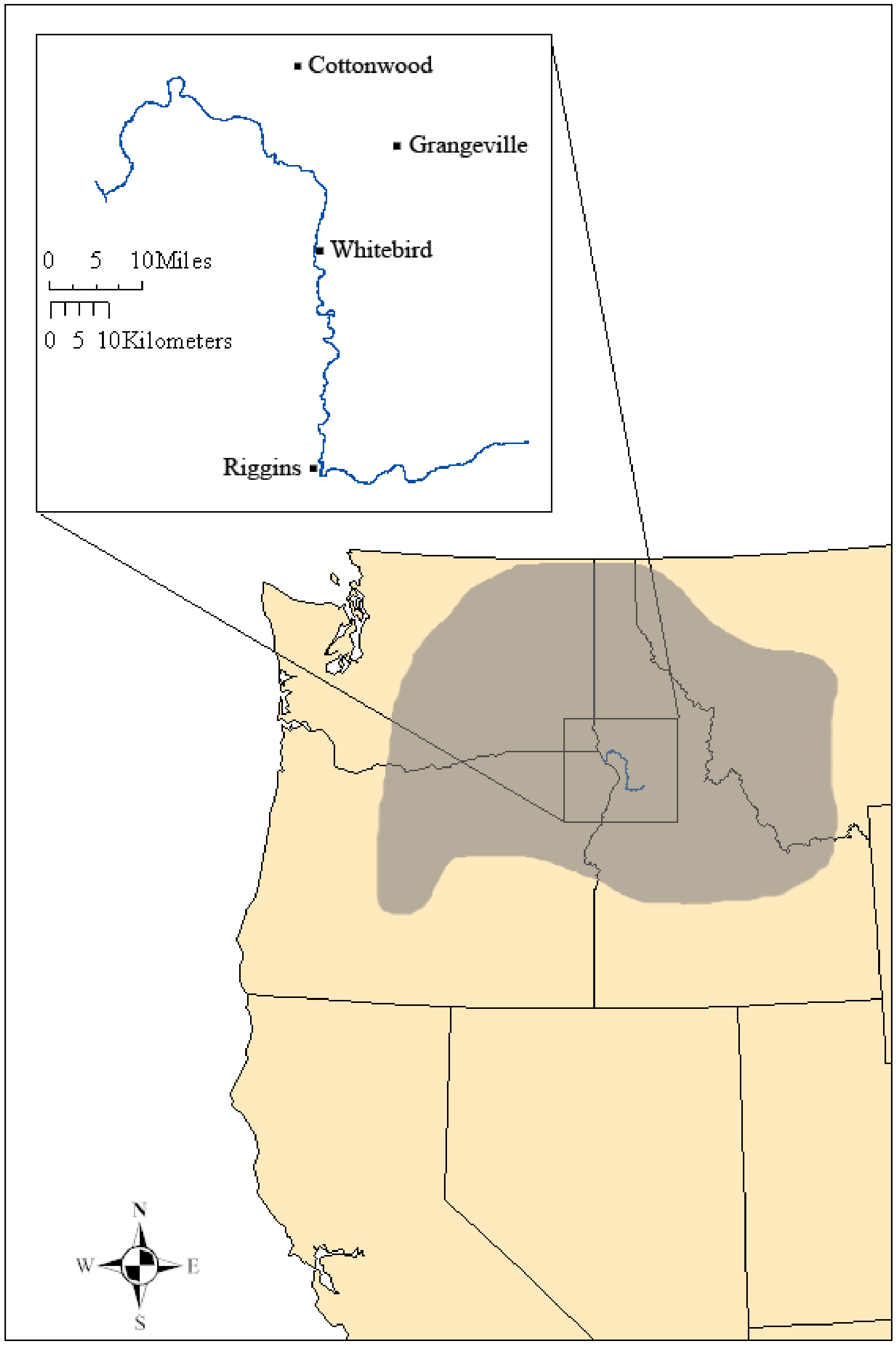

Figure 2. Location of the lower Salmon River Canyon in Idaho. Inset shows the locations of select cities relative to the canyon. Shaded portion approximates extent of the Columbia River Plateau.

- How might a central place foraging strategy have worked, given the environmental context proximal to villages in different parts of the canyon?
- What archaeological signatures might have been generated by a central place foraging strategy?
- How can this knowledge contribute to a greater understanding of the archaeological record in the LSRC and the larger Columbia River Plateau?

Optimal foraging theory in the central place foraging model offers a productive approach to addressing these questions. Optimal foraging theory has considerable heuristic value as it provides maximal predictions on how humans will forage under specific environmental conditions given the goal of maximum return for minimum effort. The additional spatial component of the central place foraging model is particularly pertinent to this study. Under this model, opy-motivated humans seek to maximize the rate of delivery of energy to a centrally located residential base. If this aspect was indeed of primary concern to Plateau peoples, it has implications for understanding the placement of winter villages as well as the movement of hunters seeking to supplement the food stores of their village. In this context, the efficient placement of winter villages could be expected to minimize travel time to areas in the landscape with relatively greater densities of elk and deer. This efficient village placement would have the potential to increase net energy capture since the expenditure of less travel time would allow more time and energy to be dedicated to encountering prey in greater frequencies. The higher frequency of encounters would increase the probability of hunting success. Thus, the movement of an economically-motivated hunter should reflect the structure and distribution of elk and deer habitat around the village. In a landscape where game habitat is generally homogeneous in terms of structure and distribution, the hunter should range broadly and undirected as no one area would offer a significantly greater chance of success than another. Comparatively, in a landscape where the structure and distribution of habitat is heterogeneous, the hunter should move efficiently to target high productivity areas.

To test the idea that the relative proximity of elk and deer factored into winter village placement, it is first necessary to identify the foraging radius within which these game could be expected to be procured. Site catchment analysis refers to this radius as the *site exploitation territory*. The relative or absolute hunting payoff yielded by a central place foraging strategy can then be measured. If a desire to minimize travel time to game-rich patches was an important consideration in the siting of a winter village, then we should see that hunting within the site exploitation territory should yield greater payoff than elsewhere in the landscape.

In my analysis, I incorporate these aspects of optimal foraging theory and site catchment analysis to examine the research questions posed earlier. The analysis consists of three components:

1) Examining the distribution of village and non-village archaeological sites in the LSRC relative to exposure, topography, and distance to the nearest tributary stream in order to identify first order spatial relationships;

2) Testing whether winter villages were optimally placed to enhance access to supplemental elk and deer resources. This entails generating site exploitation territories for village sites and non-site points, modeling the spatial distribution of elk and deer habitat, calculating relative hunting payoff indices, and then evaluating statistically the difference between village and non-site payoff;

3) Modeling optimal payoff movement of hunters within village site exploitation territories to a) examine how mobility strategies could be expected to differ according to variation in the structure and distribution of elk and deer habitat, and b) identify areas in the landscape with high potential for hunting related activity sites.

I use GIS in each component to facilitate and expedite the organization, manipulation, and analysis of descriptive and spatial data relating to the physical environment (e.g. topography, hydrography, elevation) and the cultural environment (e.g. archaeological site distribution, land ownership).

My thesis is organized as follows. In Chapter Two, I describe the physical environment of the LSRC, discuss in general terms the distribution of food resources that would have been available to prehistoric populations within the canyon, and establish the ethnographic and archaeological presence of the winter village pattern in the canyon. In Chapter Three, I summarize how spatial and descriptive data is organized within a GIS and discuss the initial collecting and processing of the data that I use in my analysis. I describe the procedures that I used, and the results of my analysis in Chapter Four. Then, in Chapter Five, I discuss the behavioral implications of the results and the contribution of this thesis to settlement pattern research in the LSRC and the Plateau.

Chapter 2. Environmental and Cultural Context

Located in west-central Idaho on the Columbia River Plateau, the lower Salmon River Canyon (LSRC) extends approximately 105 river miles from its mouth at the Snake River to the confluence of French Creek. The climate of the LSRC is generally warmer and dryer than that of the surrounding upland areas. In the lower elevations of the canyon, the average annual temperature ranges from 5.5˚ C (41.9˚ F) to 19.2˚ C (66.3˚ F), while in the higher elevations it ranges from -6.2˚ C (21.0˚ F) to 10.9˚ C (51.4˚ F). Annual mean snowfall and rainfall in the bottom of LSRC, as recorded at Riggins, is 18.8 cm (7.4") and 42.7 cm (16.8"), respectively. In comparison, Cottonwood receives an average 85.9 cm (33.8") of snowfall and 57.1 cm (22.5") of rainfall annually (Davis 2001a: 47).

Snowmelt in the mountains is the main factor controlling the flow of the Lower Salmon River, as well as other rivers on the Plateau. During the freshet, or peak snowmelt, between May and June, the river experiences the highest discharge. The rate and volume of flow declines through the summer and reaches the lowest point in September. The reduced flow continues through the fall and winter. Over the past two millennia, the river has generally been downcutting through accumulated floodplain sediment. This is in contrast to the aggrading, storage dominant system that was active before 2,000 BP (Davis 2003). Alluvial deposition occurs seasonally in the form of beaches and bars followed by intervals of degradation associated with periods of high discharge.

The canyon cuts through a variety of bedrock lithologies that influence geomorphological processes shaping the landscape. The segment of the canyon extending from the Snake River upstream to the town of Whitebird bisects volcanic and metavolcanic rocks produced by terrestrial lava flows during the Miocene epoch and the docking of an oceanic island arc against the ancient continental margin of North American 100 million years ago (Alt and Hyndman 1989). From Whitebird to Riggins, the canyon flows along the edge of Columbia River Plateau basalts and exposes limestone formed from reefs that had encircled some of the ancient islands, and passes through the metasedimentary and metavolcanic rock of the Seven Devils complex and Riggins Group. At Riggins, the canyon jogs to the east and continues through the Riggins group, assumed to be the heavily metamorphosed version of the Seven Devils complex (Alt and Hyndman 1989). A few miles west of French Creek, the canyon bisects the granite of the Idaho Batholith, which is interrupted upstream of French Creek by metamorphic rock consisting primarily of gneisses and schists.

The effect of bedrock lithology on the physiography of the canyon is clearly visible when different stretches are compared. Much of the lower section (Figure 3) is generally open in cross-section, with relatively gently sloping walls and active alluvial deposition along the river, comprised of sandy beaches and bars, as well as preserved depositional features in the form of tiered terraces.

The upper section, in stark contrast, is typically narrow in profile with steep side slopes that terminate directly at the river (Figure 4). Sedimentation is much more limited,

Figure 3. Photo taken in summer 2005, downstream of China Creek in lower sample section. View toward northeast. Note wide canyon profile, relatively gentle angle of slope repose, and alluvial deposition in the form of beaches, bars, and terraces.

with beach and bar development and preservation of terraces restricted to certain stretches. The middle section is transitional between the upper and lower sections, featuring extremely steep terrain and limited alluvial deposition in some areas and more gently sloping topography and greater development of surficial landforms in other stretches. Davis (2001a) attributes this physiographic variation throughout the canyon in large part to the differential resistance of bedrock to erosion by the river.

Figure 4. Photo taken in summer 2005, upstream of Allison Creek in upper sample section. View toward east. Note narrow canyon profile, steep side slopes that terminate at the river, and minimal alluvium.

Many factors, including elevation, climate, geology, and aspect, influence the distribution, type, and structure of vegetation within the canyon. The canyon can be longitudinally divided into two general vegetation zones. From the confluence of the lower Salmon with the Snake River upstream to RM 93, grasses dominate the canyon landscape. Primary native plant species covering the open slopes include bluebunch wheatgrass (*Agropyron spicatum*), arrowleaf balsamroot (*Basalmorhiza sagittata*), and yarrow (*Achillea millefolium*). These are in direct competition with exotic annual bromes and weeds that have become well-established as a result of intensive livestock grazing (USDA 1972). Aggregations of native shrubs and trees, such as hackberry (*Celtis douglasii*), mountain mahogany (*Cercocarpus ledifolius*), hawthorn (*Crataegus douglasii*), ponderosa pine (*Pinus ponderosa*), and Douglas-fir (*Pseuduotsuga menzieseii*), are largely restricted to comparatively cool and moist tributary drainages and alluvial fans (Davis 2001a).

Upstream of RM 93, the canyon walls feature subalpine forest. Dispersed ponderosa pines, xeric grasses, and shrubs occupy southern exposures, while Douglas-fir and mesic grasses and shrubs dominate the northern exposures. Historic and modern livestock grazing has also impacted native species in this stretch of the canyon, although not to the degree seen downstream (USDA 1972).

Hunter-gatherers living along the lower Salmon River during the last 2,000 years had a range of plant and animal species at their disposal. These resources are differentially distributed between the bottom and top of the canyon and can be divided into two general zones of availability, as shown in Figure 5. The lower zone (Zone 1) contains the river and adjacent riparian habitat that support species of mussel, anadromous and residential fish, terrestrial and aquatic birds, and small mammals. Vegetation along the river was (and is) generally sparse, supporting relatively low secondary productivity (Davis 2001a: 252).

The walls of the canyon comprise the upper zone (Zone 2) and feature an array of useable plant resources, including arrowleaf balsamroot (*Basalmorhiza sagittata*), hawthorn (*Crataegus douglasii*), serviceberry (*Amelanchier alnifolia*), chokecherry (*Prunus virginiana*), raspberry (*Rubus spp.*), gooseberry (*Ribes gooddingii*), and blue elderberry (*Sambucus cerulea*) (Scrimsher 1967; USDA 1972). Camas (*Camassia quamash*) could be expected in limited quantities in some of the comparatively moist tributary drainages (ethnographically it was collected from Rocky Canyon in the middle study section according to Sisson (1984)). There is the potential for cous (*Lomatium cous*) as well, which grows in rocky dry soil "on the brows of steep hills" (Sisson 1984: 24).

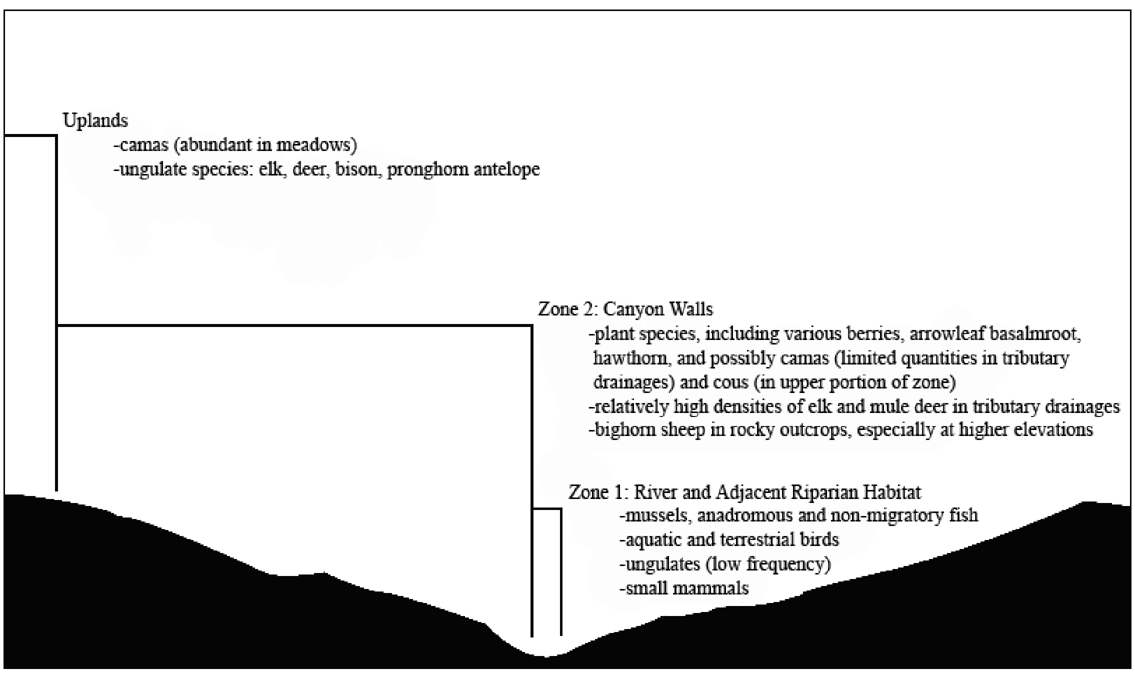

Figure 5. Schematic cross-section of the LSRC showing vertical zonation of available food resources

Valuable animal species in the upper zone include Rocky Mountain elk (*Cervus elaphus)*, mule deer (*Odocoileus hemionus*), and bighorn sheep (*Ovis canadensis*). Tributary drainages bisecting the walls of the canyon provide critical deer and elk habitat in the form of shrub and tree cover for protection against the elements and predators, sources of fresh water (streams and springs), and forage. In the upper study section, protective cover also occurs in the interfluvial areas, but is denser in stream drainages. Elk and deer also can be found near the river, but generally do not linger there due to the lack of sufficient cover. Bighorn sheep are not as dependent on vegetation for cover, using instead rough steep terrain to escape predators (Wilson and Ruff 1999). They live in rocky outcrops throughout this zone, although more typically are found along ridges or escarpments (Davis 2001a).

Additional economically important plant and animal species are found in the uplands outside of the canyon. Those of particular value to hunter-gatherers include camas, deer, elk, and, prehistorically, antelope and bison (Davis 2001a).

The LSRC is located within the traditional territory of the Nez Perce. Multiple Nez Perce groups, collectively known as the White Bird band, are known to have lived along the lower Salmon River (Chalfant 1974). Their main village was located at what is now the town of White Bird. Several villages were also located along White Bird Creek and more were positioned on the river between White Bird Creek and the Snake River; another village was positioned just downstream of Slate Creek (Chalfant 1974: 64). Additional Nez Perce camps and winter villages (which may include those just listed) have been identified ethnographically within the canyon. These include camps located at the mouth of Allison Creek, the mouth of the Little Salmon River (and including the modern town of Riggins), and at the town of Lucile (Schwede 1966: 47). Winter villages are recorded where the Salmon and Snake rivers meet (Tamanma), at the mouth of Rock Creek (Nipeheme), the mouth of White Bird Creek (Lamtama), and the mouth of Slate Creek (Ayaspa) (Schwede 1966: 46-47).

The subsistence-settlement strategy documented for the Nez Perce is very similar to those observed for ethnographic cultures throughout the Plateau and which are collectively termed the winter village pattern. The Nez Perce utilized a diverse array of food resources throughout the year. The staples consisted of anadromous fish, especially salmon; certain root species such as camas, kouse, bitterroot, wild carrot, and wild celery; and game foods, primarily elk, mule deer, and white-tailed deer (Chalfant 1974; Anastasio 1972; Marshall 1977). It is estimated that up to 50% of the Nez Perce diet was comprised of salmonids, 30-50% by plants, and 15-30% by game (Anastasio 1972; Marshall 1977).

Food resources were procured at different times of the year in often spatially disparate locations. The Nez Perce organized procurement of resources through a combined forager and collector strategy. During the summer and fall, the most productive seasons, groups focused on procuring and storing food for consumption in the winter. In the summer, groups were highly mobile, moving from camp to camp to fish, hunt, and collect plants. Camas harvest was an especially important activity at this time. Gathered during June and July in moist upland meadows (Chatters 1998), camas bulbs were then taken back to the winter village sites for processing and storage. Fall was marked by intense food acquisition and preparation activities with an emphasis on individual and group hunting in the mountains and lower river valleys, as well as fishing.

During the winter, groups aggregated in villages along the bottom of river canyons, which experienced warmer temperatures and less snowfall. Villages served as the "anchor in the yearly habitation pattern" and were re-occupied every year by the same group, although perhaps in different locations (Chalfant 1974: 105). Throughout the low environmental productivity winter months, villagers subsisted on cached food supplies supplemented with fresh game. Hunting, in fact, was a very important activity in the winter, and was conducted individually as well as in groups, usually near the villages (Chalfant 1974; Marshall 1977). Following the introduction of the horse between AD 1700-1750, some hunting parties spent winters in Montana in pursuit of bison. Generally, use of the horse is suggested to have caused minimal disruption to the established subsistence-settlement system of the Nez Perce in the sense that traditional camps and hunting and gathering locations continued to be utilized (Chalfant 1974, Walker 1967). Economic activities, like hunting, may have intensified and additional areas exploited since the horse would have increased the speed and range of travel, as well as allowed transportation of greater amounts of material (Anastasio 1972).

By the late winter and early spring, stored food supplies were typically significantly depleted, as well as moldy or rotten, forcing the Nez Perce to utilize emergency foods, such as spawning non-anadromous fish species (Marshall 1977). Later in the spring, village populations dispersed, with smaller groups moving elsewhere to take advantage of the first plant crops and salmon runs. Hunting continued at this time at the individual level.

The winter village pattern is represented archaeologically as well as ethnographically in the LSRC. The primary material indicators are features associated with the construction and use of winter village semi-subterranean pithouses. These features include burnt structural remains and compacted floors exposed during excavations of four sites (Davis 2001b and 2003) and circular depressions identified during various surveys. The earliest pithouse features excavated thus far in the canyon are those at the Double House site, which date to 2,040 ± 190 BP (Butler 1968). Excavations of pithouse features at other sites have generated dates of 1,370 ± 40 BP, 920 ± 40 BP, 460 ± 70 BP, and 300 ± 70 BP (Davis 2001b). The location of circular depressions on late Holocene alluvial terraces indicates that these features date sometime within the last 2,000 years (Davis 2001b). Excavations at a fifth site uncovered "dense cultural scatters of formed artifacts, FCR (fire-cracked rock), and faunal materials associated with dark, greasy sediments" (Davis 2003: 12) dating between 1,780 ± 50 BP that are indicative of semi-sedentary settlement (Davis 2001b).

Significantly greater quantities of fire-cracked rock found in the late Holocene components of LSRC sites indicate a much higher level of food processing activity during the last 2,000 years that possibly was associated with preparation of winter stores (Davis 2003). The relatively lower frequency of mammal bones, mussel shell, and snail shell recovered from these contexts, as compared to earlier levels, suggest the importance of other food resources such as roots and salmon at this time (Davis 2003).

Evidence of late Holocene salmon fishing, absent in pre-2,000 BP components, has been recovered that consists of a net weight (Davis 2003), a possible toggling harpoon head, and a few salmon bones (Davis personal communication 5/30/2007). The minimal amount of salmon remains discovered is not surprising given the “many factors that may restrict (them) from entering and/or remaining in the archaeological record including modes and location of processing, dietary choices and culinary behaviors, and disposal practices” (Davis 2001b: 241).

Archaeological indicators of the winter village pattern appear later in the LSRC than elsewhere in the Columbia River Plateau. It is generally accepted that the winter village pattern was widely established on the Plateau by 2,500 years B.P. (Ames et al. 1998; Chatters 1998) and appeared in some areas as early as 4,000 to 4,500 years B.P. (Chatters and Pokotylo 1998; Schalk and Cleveland 1983). The delayed onset of the winter village pattern in the LSRC is attributed to the “reorganization of the lower Salmon River alluvial system” that occurred around 2,000 years ago and created conditions conducive to salmonid spawning and rearing (Davis 2003: 59). Paleoenvironmental evidence indicates that prior to 2,000 years ago, warm and arid climatic conditions in the LSRC led to increased erosion of side slopes and higher input of sediment to the river, as well reduced the flow of the river. These factors, combined with a lower channel gradient created by remnant debris from a massive landslide, caused the river to store sediment and aggrade over time. With the shifting of a local fault 2,000 years ago, bedrock in the area of the slide debris was uplifted, prompting the river to downcut through the established floodplain and the slide remnant (Davis 2003: 58). The resulting increase in gradient, along with cooler temperatures and greater rates of precipitation, created a higher energy depositional environment and correspondingly higher quality anadromous fish habitat (Davis 2001a: 240).

Chapter 3. Methodology

I described in the introductory chapter how GIS has been productively applied in settlement pattern studies examining the relationship between site distribution and environmental variables. Clearly, GIS is extremely useful in solving questions dealing with spatial patterning. It is for this reason that I use GIS in my analysis to examine the placement of winter village relative to ungulate productivity in the LSRC landscape. In this chapter, I briefly summarize how spatial data is organized within a geographic information system, in particular ArcGIS, and describe the datasets collected for my analysis.

Spatial Data in GIS

In my analysis, I used the GIS software package ArcINFO 9.1, which is comprised of three applications, ArcCatalog, ArcMap, and ArcToolbox, that allow the user to browse, manage, manipulate, edit, and analyze spatial and associated descriptive data, as well as create maps (Ormsby et al. 2004: 11). To a lesser extent, I also utilized the GIS software ArcView 3.3.

Fundamental to ArcGIS and any geographic information system are data models that simplify the complexity of real geographic phenomena in order to facilitate the analysis and interpretation of spatial data. ArcGIS employs three basic data models: vector, raster, and TIN. The latter data model is not used in my analysis and will not be discussed further.

In the vector data model, discrete geographic features, such as archaeological site locations or streams, are represented as points, lines, and polygons. Integral to this model is the "numerical description of the relationship among geographic features, as encoded by adjacency, linkage, inclusion, or proximity," which is also known as topology (Clarke 2003: 326).

In the raster data model, continuous geographic phenomena such as elevation and vegetation distribution are represented as a matrix of cells. Each cell, or pixel, has an assigned value that describes the nature of the phenomenon in the location represented by that cell. The size of the pixels varies according to the resolution of the raster (Conolly and Lake 2006). Rasters are also used to represent images, such as scanned maps or photographs.

These conceptualizations of actual geographic features are implemented in a GIS by data structures. In ArcGIS, coverages and shapefiles operationalize the "object view" inherent to the vector data model, whereas grids (also called rasters) operationalize the "field view" of the raster data model. A coverage is an older vector data structure that permanently stores the topology associated with each feature, making data manipulation and querying relatively cumbersome. The more recently developed shapefile, in contrast, computes the topology on demand. All three structures are geo-relational, as each object or grid cell corresponds to a record in an associated attribute table. This record contains fields of information that describe different characteristics of the feature. Thus, in a GIS spatial and descriptive data are linked.

The data that I used in my analysis came in a variety of formats, not all of which could be brought directly into ArcINFO. The steps that I took to convert particular datasets to shapefiles or rasters are described in the following section. Because of the higher processing speed, I chose to work with shapefiles instead of coverages whenever possible.

Data Collection

To generate the layers in GIS necessary for my analysis, I collected a variety of datasets from a range of sources. In cases where data that I required were either not available for my study area or were too coarse-grained for the scale of my analysis, I created the desired data from existing datasets.

Measures were taken to obtain the highest possible degree of accuracy in the data collected. This is critical as error in a dataset is compounded through use of that data. The results of any analysis involving flawed data are obviously questionable, rendering suspect any conclusions or interpretations based on those results. To guard against this, I obtained data only from reputable sources (government agencies and universities), reviewed the metadata (when available) to assess quality of lineage**,** and compared datasets to ensure spatial correspondence. To maintain consistency, I selected the North American Datum 1983 Universal Transverse Mercator Zone 11N (NAD 1983 UTM Zone 11N) coordinate system as the projection for all spatial data used in my analysis. Some of the datasets I collected did not utilize this spatial reference and had to be re-projected.

A summary of the source, format, and spatial reference (i.e. coordinate system, datum, scale/resolution) of the data collected is presented in Appendix A.

Topographic Data

The Bureau of Land Management (BLM), Cottonwood Field Office provided most of the topographic data in the form of digital raster graphics for the three sections of my study area. A digital raster graphic is the projected geo-referenced image of a scanned USGS topographic map. I downloaded additional digital raster graphics from the Interactive Numeric and Spatial Information Data Engine (INSIDE) Idaho website, then used the Global Mapper software to convert the projected coordinate system to NAD 1983 UTM Zone 11N.

Elevation Data

I downloaded two National Elevation Dataset digital elevation model tiles from the INSIDE Idaho website that cover the LSRC as well as most of northern Idaho at approximately 10 meter horizontal resolution. A digital elevation model is an array of surface elevations stored in pixel form. The tiles were spatially referenced with a geographic coordinate system, which I projected to NAD 1983 UTM Zone 11N in ArcMap. I generated slope rasters from the projected tiles.

Hydrographic Data

I downloaded 1:24,000 resolution shapefiles for the LSRC and the immediately surrounding area from the USGS National Hydrography Dataset. These shapefiles contain lines that represent the networks of tributary streams feeding into the river. Each stream exists as a discrete object and can be manipulated independently of the others. The lengths of the individual streams are provided in the attribute data, as are their local names (if applicable). I projected each shapefile in ArcMap using NAD 1983 UTM Zone 11N.

Vegetation Cover Data

At the time that I was collecting data, no high resolution data were available that described the distribution of vegetation cover in the LSRC. However, I was able to derive these data from already collected digital raster graphics using Adobe Photoshop and ArcMap. I began this procedure by opening a copied digital raster graphic in Photoshop and isolating (green) forest and (white) grassland/meadow by color. To remove the contour lines, text labels, and township/range lines, I filled these areas with additional color. I then created a path (red) around the filled green areas to represent the ecotone between forest and grassland (Figure 6).

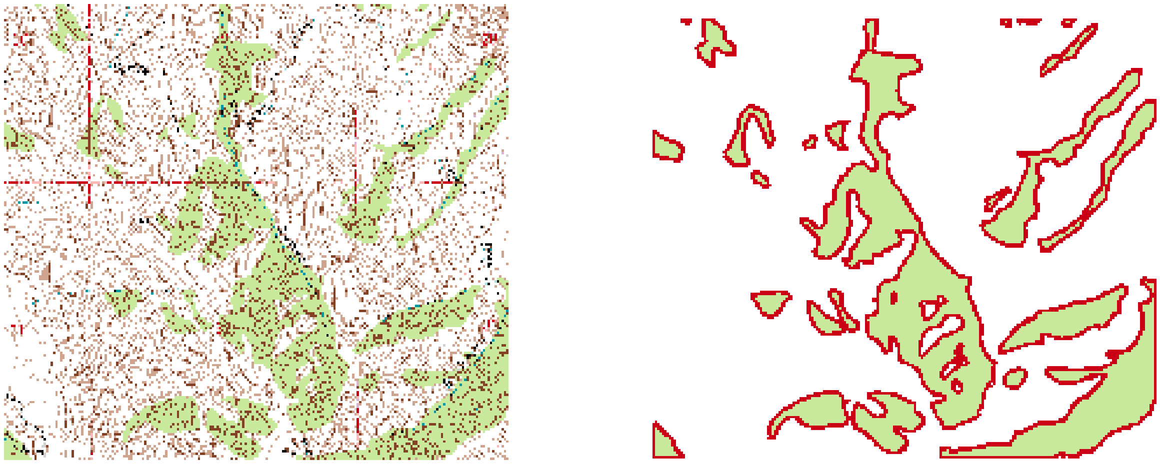

Figure 6. The image on the left is a portion of a DRG before it was modified in Photoshop. The image on the right shows the same area after removal of the contour lines, text labels, and township/range lines and demarcation of the ecotone, shown in red, between forest (green) and grassland (white).

I then opened the modified digital raster graphic in ArcMap and extracted the forest, grassland, and forest/grassland ecotone by gridcode value to create three separate rasters. For the purposes of analysis, I set the width of the ecotone to 100 meters by converting the ecotone raster to a polygon shapefile, then buffering the polygon boundary.

It should be noted that in some portions of my sample sections, the distribution of ecotone was somewhat overrepresented. This is an unexpected byproduct of modifying the DRGs in Photoshop. On some DRGs, the forest cover extends to the edge of the map image. The edge of the map effectively defined a boundary to the forest that Photoshop marked as ecotone. It is easy to identify "false" ecotone as it appears as a straight line bisecting forested area, as shown in Figure 7.

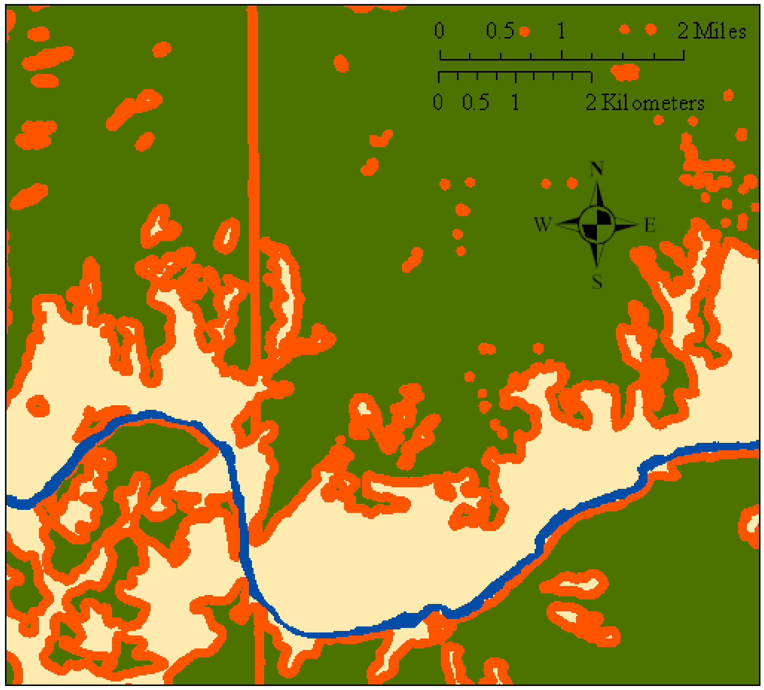

Figure 7. An example of "false" ecotone (straight orange line bisecting the green forested area) in the upper study section.

Land Stewardship Data

The Landscape Dynamics Lab at the University of Idaho, Moscow provided a GIS coverage representing the distribution of land ownership and management categories throughout the state. The coverage was generated as part of the Idaho GAP (Geographic Approach to Planning) Analysis Project, a component of the national Gap Analysis Program, which seeks to "prevent conservation crises by providing policy makers and managers with conservation assessments of biotic elements (plant communities and native animal species) and to facilitate the application of this information by land management agencies" (Scott et al. 2002: 2). After projecting the coverage to NAD 1983

UTM Zone 11N in ArcMap, I created a land stewardship shapefile for each of my sample sections by exporting the geographically corresponding coverage data.

Archaeological Data

As described in first chapter, the LSRC features extremely variable topography, which undoubtedly influenced how prehistoric populations utilized the landscape. In order to examine prehistoric settlement patterns across the range of topographic variability, I defined three study sections in the lower, middle, and upper portions of the canyon (Figure 8). The lower section stretches from RM 5 (downstream of Wapshilla Creek) to RM 13 (just below Eagle Creek) and ranges in elevation from 968 to 1043 fasl (ca. 295 to 318 masl), as measured at the bottom of the canyon. The middle section extends from RM 35 (downstream of Rock Creek) to RM 53 (just upstream of Hammer Creek) and ranges in elevation from 1272 to 1410 fasl (ca. 388 to 430 masl). The upper section begins at RM 91 (immediately upstream of Berg Creek) and ends at RM 113 (upstream of Wind River) and ranges in elevation from 1725 to 1968 fasl (ca. 526 to 600 masl). Technically, the upper section extends eight river miles upstream of the recognized beginning of the LSRC, into the main Salmon River basin. Together, the three sections total 47 river miles or roughly 45% of the total length of the lower Salmon River. This is a non-random sample intended to represent the range in topographic variability within the canyon that prehistoric populations would have encountered.

Within each study section, I examined only those prehistoric sites located on land under the jurisdiction of the BLM and the USFS. This decision stems from the logistical

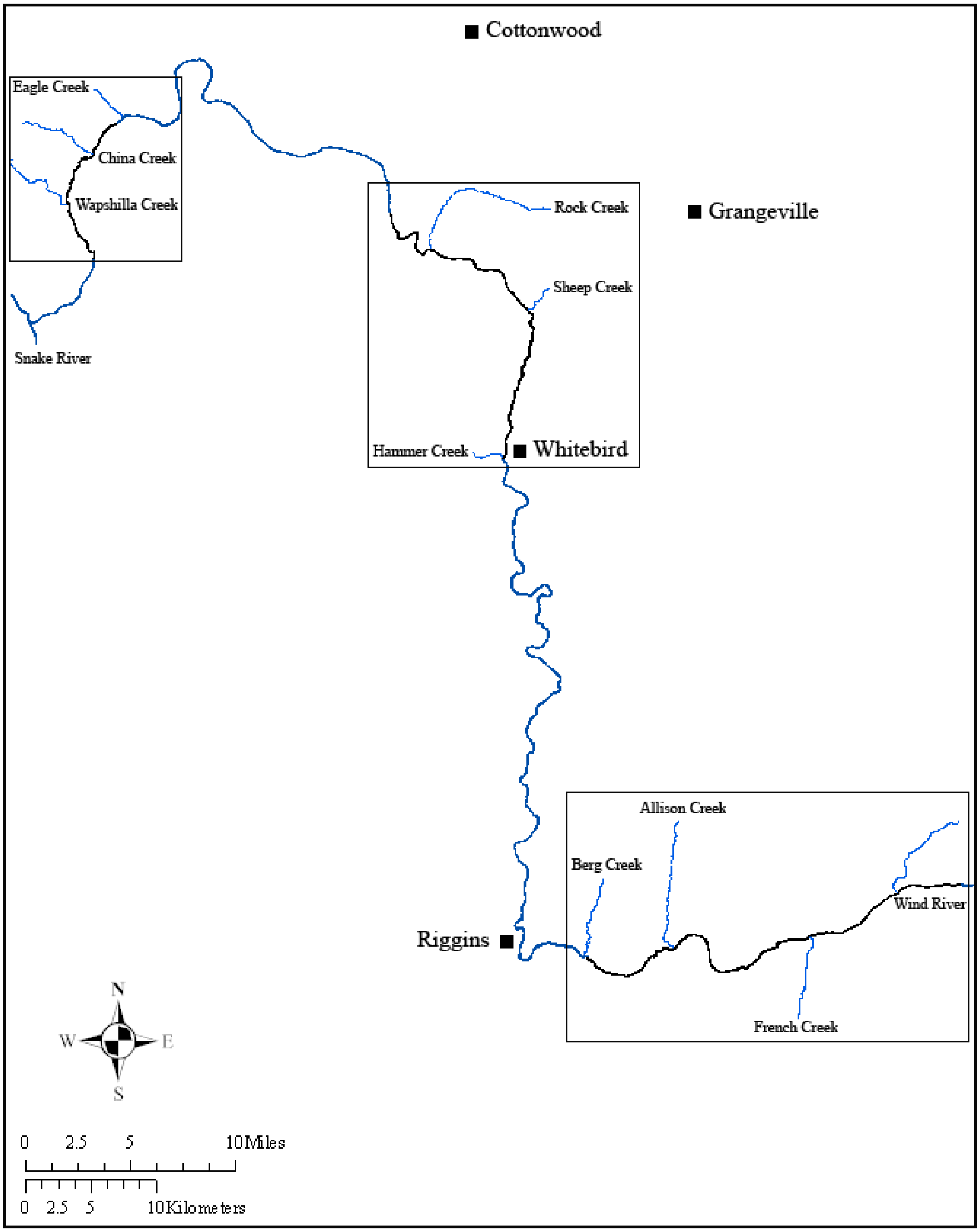

Figure 8. Map of the lower Salmon River showing lower, middle, and upper study sections in black and enclosed in squares. Selected tributary streams and towns provided for reference.

difficulty of gaining access to records for sites on private property, the abundance of sites recorded on federal land as a result of past reconnaissance work, and the cooperative relationships in place between my major professor at Oregon State University and the archaeologists at the BLM Cottonwood Field Office and Nez Perce National Forest. Due to the configuration of land ownership in the canyon, federally initiated and coordinated archaeological work has been largely limited to a narrow corridor along the river. Thus, the distribution of sites included in my analysis is also restricted vertically to the lower elevations of the canyon.

The Cottonwood Field Office of the BLM and the Nez Perce National Forest retain archaeological site information for the federal landholdings in the sample sections of my study area. This information, in the form of Microsoft Access database records and scanned and photocopied site recordation forms, was provided for use in my analysis under the terms of a confidentiality agreement.

Most federally managed sites located in my sample sections were recorded during reconnaissance projects undertaken for compliance and inventory as required by the 1968 Wild and Scenic Rivers Act, the 1956-1958 Federal Aid Highway acts, and sections 106 and 110 of the 1966 National Historic Preservation Act (Sisson 1984; Lucas 2004). Sites were also recorded during surveys of areas where reservoir construction was planned (Sisson 1984). The projects differed with regard to methodology and geographic focus, resulting in variable survey coverage of the canyon landscape.

I selected a total of 96 prehistoric sites to include in my analysis using the following criteria:

1. land ownership (only those sites recorded on federal lands)
2. location (only those sites located within my defined study sections)
3. at least one of the following:
   (a) presence of one or more prehistoric artifacts;
   (b) presence of probable prehistoric feature(s) <u>and</u> one or more prehistoric artifacts in close proximity (i.e. less than 5 meters away), suggesting probable association;
   (c) postulated prehistoric origin or use assigned by the field recorder to the entire site or site component.

The low threshold used for criterion 3a is necessary since surface visibility in the LSRC is generally low due to extensive vegetation cover. While a single artifact may be considered an isolate in other environments, it may be the only observable indicator of a site in this region of Idaho. In fact, a single artifact is the minimum requirement for designating a prehistoric site in the Coeur d' Alene district of the BLM (David Sisson personal communication 12/7/2005). I implemented 3b in an attempt to exclude sites that only include historic archaeological components. Exceptions were made for two sites (10IH96, 10NP232) that feature talus depressions and have no associated prehistoric artifacts, but lack surficial evidence of a historic or modern component. Probable prehistoric features include the following (definitions are taken or adapted from Sisson (1984) unless otherwise indicated):

Talus Depression Depressions "excavated in a stable portion of a talus field," typically found in groups with no associated artifacts; possibly

	are “remnants of Indian hunting blinds, collapsed burials, caches, or are related to vision quest activities” (Sisson 1984: 51)
Lithic Scatter	A “group of stone artifacts or fragments of artifacts observed on the surface or in exposed subsurface deposits” (Sisson 1984: 50); includes use-modified as well as intentionally flaked or ground stone artifacts
Midden	Defined by Waters (1992: 33) as the “combination of chemically altered natural sediments, accumulated organic and inorganic refuse, and sediment brought onto the site on the soles of feet and clothing”
Rock Art	May be pictographs or petroglyphs
Rockshelter	“Outcrop of rock with sufficient overhang to provide shelter from sun, rain, etc.” (Sisson 1984: 42) and associated prehistoric artifacts or rock art
Faunal Remains	Includes bone and shellfish fragments in conspicuous quantity and of apparent antiquity; frequently in association with other features
Cairn	An organized pile of stones with no associated artifacts
Depression	May be circular or rectangular with varying dimensions; Butler (1978: 75) identifies a variety of possible prehistoric functions for depressions, including semi-subterranean house, communal

> lodge, sweat lodge, menstrual lodge, and storage cache; depressions also were used historically as livestock wallows and mine prospect pits and may have a purely natural origin, e.g. slumping.

Because my study concerns the distribution of winter villages, which included residential structures such as semi-subterranean pithouses, it was necessary to differentiate between probable pithouse depressions and non-pithouse depressions. To this end, I selected diameter (for circular depressions) and length (for rectangular depressions) as the distinguishing attribute. According to Hackenberger (1989: 134), the late prehistoric inhabitants of central Idaho "constructed circular-to-oval and rectangular semi-subterranean houses that ranged between 4 and 15 m in diameter or width." Diameters as small as 2 meters have also been recorded outside of the LSRC, although a Northern Paiute or Shoshone, rather than Nez Perce, cultural affiliation has been suggested for these pithouses (Hackenberger 1989: 136). Within the LSRC specifically, the minimum average pithouse diameter is approximately 3 meters (David Sisson personal communication 12/7/2005). Accordingly, I designated any depression with a minimum diameter of 3 meters that had one or more prehistoric artifacts in association (see criteria 3b above) as a probable pithouse feature, along with any depression identified on site records as a possible or likely pithouse. Depressions for which the dimensions are not known but were observed in close proximity to prehistoric artifacts, were designated as non-pithouse depressions.

It should be noted that this classification is as refined as I thought feasible given the interpretive limitations of surficial archaeological material. It is reasonable to assume that natural and cultural post-depositional processes have worked to obscure or destroy pithouse features and associated artifacts, skewing the data to some degree. Thus, the classification scheme is potentially problematic in the sense of under or over-representing pithouse or non-pithouse sites.

I divided the sites selected for my analysis according to the presence/absence of probable pithouse depressions. This distinction is significant as pithouse sites can be assumed to represent winter villages, which fulfilled a specific function within the postulated late Holocene subsistence-settlement pattern in the LSRC. The locational requirements for a winter village would presumably have been different or more extensive than those for a non-village site, such as a camp or resource procurement and/or processing location. By assessing independently the distribution of pithouse sites and non-pithouse sites relative to the same environmental variables, consistent or disparate spatial trends may be identified and evaluated.

After distinguishing pithouse sites from non-pithouse sites, I created database tables for each sample section in Microsoft Access that included locational and descriptive information for the sites in each category (Table 2).

It was necessary to convert the UTM coordinates provided for the archaeological sites on USFS land to NAD 1983 UTM Zone 11N, as the originals were based on USGS topographic maps that had been projected with a datum different than the one I selected for my analysis. I converted the coordinates using the Corpscon 6.0 software provided by the U.S. Army Corps of Engineers.

Table 2. Example of a database table created for pithouse sites in the lower section. UTM information not included here for security reasons.

Site #	UTM	Quad	Prehistoric Feature or Artifact	Comments
10NP0112	xxxxx	WAPSHILLA CREEK	lithics	"probable village site"…
10NP0117	xxxxx	RATTLESNAKE RIDGE	pithouse (2)	two circular pithouses…
10NP0120	xxxxx	RATTLESNAKE RIDGE	pithouse (3)	located on a gently…
10NP0122	xxxxx	RATTLESNAKE RIDGE	depression (3)	"midden"
10NP0125	xxxxx	RATTLESNAKE RIDGE	pithouse (2)	possible pithouses & …

Finally, I imported the database tables into ArcMap and generated shapefiles to show the locations of the pithouse sites and non-pithouse sites in each of my sample sections. To check the accuracy of the converted UTM coordinates, I compared the location of each archaeological site on USFS land as represented in the shapefiles to the sketched location and written description (when provided by the recorder) on the photocopied site records. Discrepancies between the locations indicated by the converted UTM coordinates and photocopied site record information were typically large enough to suggest that the either the original coordinates or sketch map were incorrect. In these cases, I chose to re-position the site in ArcMap to correspond as closely as possible to the location indicated on the sketch map. To maintain consistency, I updated the UTM coordinates associated with the re-positioned site in the attribute table. As a safety measure, sensitive site location information, in the form of maps and text, are not included in the general access copy of my thesis.

The sites analyzed in this thesis comprise a somewhat biased sample of the extant archaeological record in the LRSC, which in turn, is an incomplete representation of prehistoric human activity across the entire canyon landscape. This is a function of the manner in which sites were selected for analysis as previously described, as well as the methodology of the original surveys, the nature of land ownership, and the influence of cultural and natural processes acting on the landscape that differentially destroy, modify, and obscure the physical evidence of prehistoric human activity.

Past archaeological surveys differed with regard to methodology and geographic focus, resulting in variable coverage of the canyon landscape. For example, Sisson's (1984) cultural inventory focused on BLM lands in the river corridor that were adversely affected by recreational use, livestock activity, and fluvial erosion with the goal of assessing damage to known and potential sites. Like a survey procedure, specific methods used for site recordation can influence density or frequency of sites. This is illustrated at site 10-IH-377 in the upper section where numerous "spatially distinct" groups of features were recorded as a single site (Lucas 2004: 3). If each group had been recorded separately, the site count would have increased dramatically for that part of the river corridor.

The distribution of known prehistoric sites is clearly influenced by land ownership in the canyon. An example of this can be seen in the lower section where more than half of the land bordering the east side of the river is privately owned and might have high site potential given its large expanses of low relief terrain, western aspect, and multiple tributary streams; however, site information for this side of the river is limited. Comparatively, a high number of sites are recorded on adjacent land managed by the BLM that feature the same physical conditions. Lucas (2004: 3) provides another example from the upper section between RM 92-96, where he attributes an "anomalous drop in site density" in part to the private ownership of a large amount of land in the area.

Finally, natural and cultural processes acting on the landscape undoubtedly have altered the archaeological record in the canyon. Among these are historical and modern activities, such as hydraulic mining, ranching, road construction, and recreation, that have disturbed many of the alluvial fans, terraces, and beaches in the LSRC (Sisson 1984: 28-32, 34; Lucas 2004: 2). Because post-depositional processes obscure and obliterate surficial evidence, even the most rigorous random sample "is not a sample of all the archaeological sites ever left, but a sample of those sites that remain accessible for selection" (Drennan 1996: 94).

In order to address these uncertainties and other aforementioned limitations, I do not consider the assembled pithouse feature dataset to indicate the absolute distribution of all pithouses in my LSRC study sections. Instead, I distinguish between the utility of the dataset at the individual and aggregate levels. At the individual level, the dataset can be assumed to reflect the contextual relation of different pithouse features to their physical surroundings. Thus, spatial analysis at the individual site level is meaningful on a case-by-case basis. Problems inherent in the way pithouse features were differentially recorded in the LSRC greatly limit how analyses of the dataset are to be interpreted at the aggregate level. Thus, we cannot know if particular spatial patterns along the length of the LSRC (e.g. gaps, clusters, densities) indicate meaningful cultural aspects of settlement or the consequences of sampling bias. That stated, considerations of spatial data at the aggregate level will be considered tentative.

Despite these factors that shape the known archaeological record, I consider the sites that I include in my thesis to comprise, in terms of quantity and geographic distribution, a representative sample of late prehistoric activity along the lower Salmon River. At least half of the river corridor in my lower study section and most of the land bordering the river in my middle and upper study sections is under federal management. These areas have been the focus of multiple surveys since the 1950s that have identified numerous sites. In the chapters that follow, I analyze a large number of these sites deliberately selected from different reaches of the river corridor in order to capture the range of human settlement in varying environmental contexts.

Chapter 4. Analysis and Results

In this chapter, I describe the procedure and results of the analysis that I conducted in order to a) determine whether winter villages were positioned in the LSRC with concern for the proximity to the distribution of large game animals, specifically elk and mule deer, and b) model how hunters based at winter villages would move under a central place foraging strategy to variously optimize hunting success in different environmental settings.

I begin by examining site density and distribution relative to exposure, topography, and distance to the nearest tributary stream in each of my study sections. These are some of the basic environmental attributes that would have been considered by prehistoric hunter-gatherers utilizing a landscape. By establishing such first order spatial relationships, the groundwork is laid for more advanced theory-based investigation of site location.

Preliminary Assessment of Site Density and Distribution

To examine site location in relation to exposure and topography, I draped the pithouse and non-pithouse site shapefiles over digital raster graphics in ArcMap. I then added hydrography shapefiles and measured the distance between each site and the nearest tributary stream. The resulting observations are summarized below according to section. For the purposes of this analysis, site density refers to the number of sites per river mile. This is an arbitrary measurement intended to facilitate pattern recognition.

Lower Section

The lower section of the study area contains nine pithouse sites and 14 non-pithouse sites, for a total of 23 sites. The minimum and maximum densities of pithouse sites per river mile are zero and three, respectively. For non-pithouse sites, the minimum and maximum densities are zero and five, respectively. See Figure 9 for a graphical representation of site density per river mile.

All pithouse sites are located on the right side of the river (if facing downstream), which is characterized by northeastern to southeastern exposures. Most non-pithouse sites (11 of 14) are also located on the right side of the river (oriented in a downstream-looking view). The remaining three, situated on the left side, feature western to northwestern aspects.

Five pithouse sites and seven non-pithouse sites are clustered in RM 9 and 10. This represents approximately half of the known sites in this section. Most of these sites (10 of 12) occur along the right side of the river where the topography is primarily flat to gently sloping and several streams empty into the river. The other two sites are located in close proximity on the only relatively flat ground available along the left side of the river for that two-mile segment. These two sites are also located near a tributary stream.

As illustrated below in Figure 10, most pithouse sites are located within 200 meters of the nearest tributary stream. There is greater variation in the proximity of non-pithouse sites and the nearest streams, but generally, site frequency decreases as distance increases.

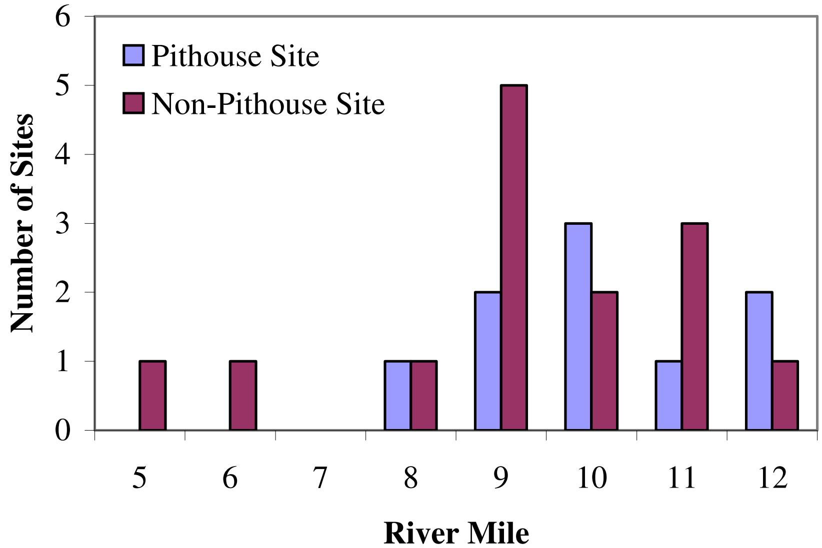

Figure 9. Site density per river mile (lower section).

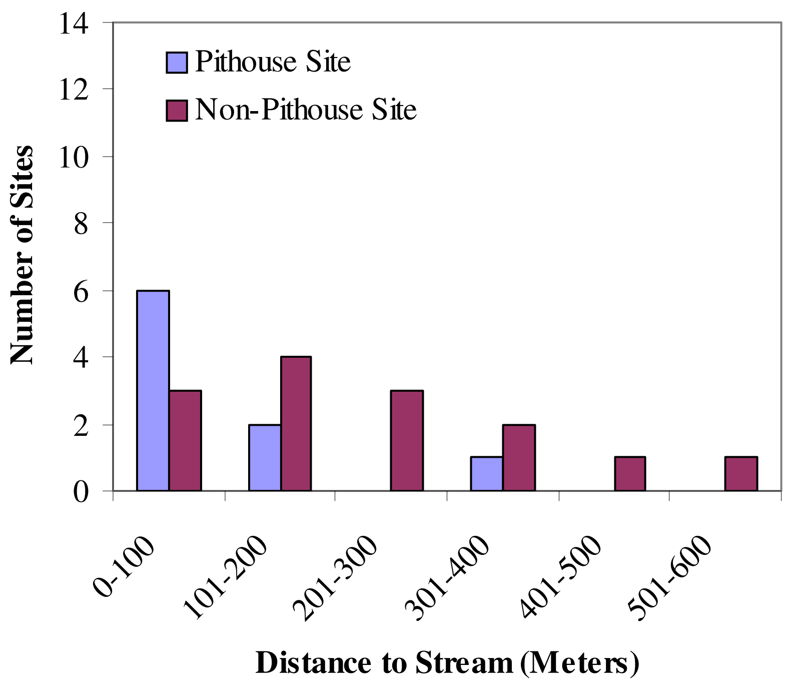

Figure 10. Distance between site and nearest stream (lower section).

Middle Section

The middle section of the study area contains 16 pithouse sites and 33 non-pithouse sites, for a total of 49 sites. The minimum and maximum densities of pithouse sites per river mile are zero and three, respectively. For non-pithouse sites, the minimum and maximum densities are zero and five, respectively. See Figure 11 for a graphical representation of site density per river mile.

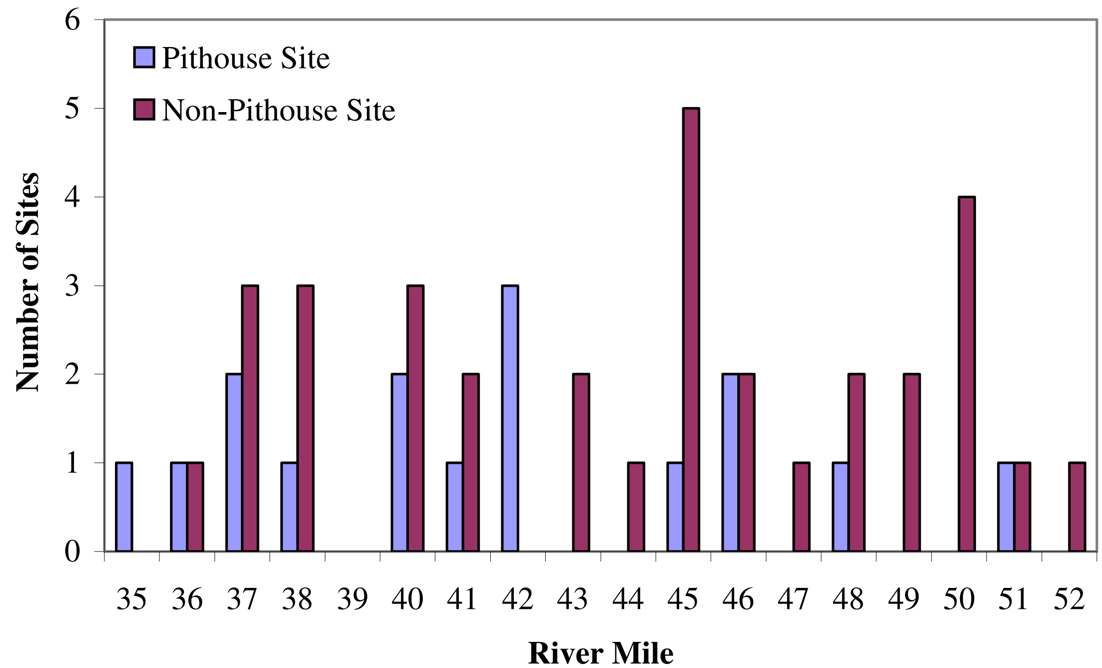

Figure 11. Site density per river mile (middle section).

Most pithouse sites (12 of 16) are located on the right side of the river, which is characterized by western to southern exposures. In contrast, approximately half of the non-pithouse sites (15 of 33) are located on the right side of the river. For non-pithouse site location, then, there is considerable variation in exposure with western to southern aspects on the right side of the river and eastern to northern on the left side.

As illustrated below in Figure 12, just over half of the pithouse sites are located less than 200 meters from the nearest stream, while 80% are less than 500 meters from the nearest tributary. Approximately 20% pithouse sites are located 600 to 900 meters from the nearest tributary stream. This distribution is also characteristic of non-pithouse sites. Approximately 90% of the non-pithouse sites are located less than 500 meters from the nearest stream, while the remaining 10% are 600 to 800 meters from the nearest tributary.

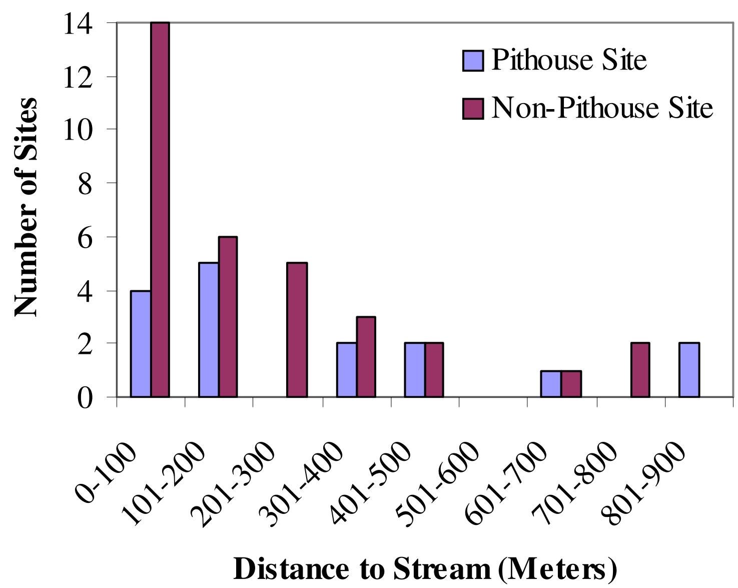

Figure 12. Distance between site and nearest stream (middle section).

Upper Section

The upper section of the study area contains five pithouse sites and 19 non-pithouse sites, for a total of 24 sites. The minimum and maximum densities of pithouse sites per river mile are zero and one, respectively. For non-pithouse sites, the minimum and maximum densities are zero and four, respectively. See Figure 13 for a graphical representation of site density per river mile.

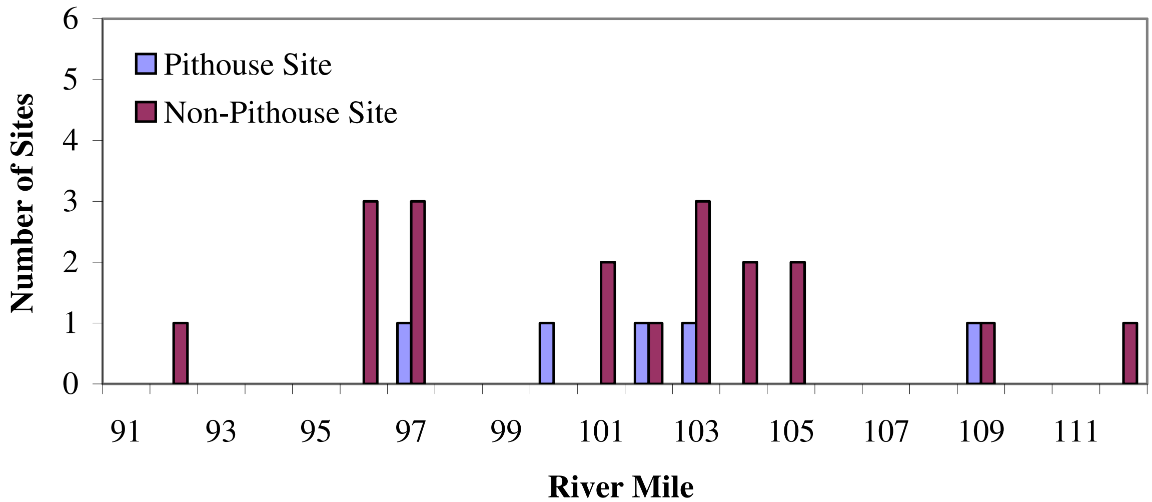

Figure 13. Site density per river mile (upper section).

All pithouse sites in this section are located on the right side of the river, which is characterized by a southern exposure and a higher number of depositional landforms, i.e. beaches and alluvial fans, than the left side. Most non-pithouse sites (17 of 19) are also located on the right side of the river.

In this section, the known pithouse sites are consistently situated at the confluences of tributary streams and the river. As illustrated below in Figure 14, almost 75% of the non-pithouse sites are also located in close proximity, within 100 meters, to the nearest stream. The remaining 25% of non-pithouse sites are located between 200 and 700 meters from the nearest stream.

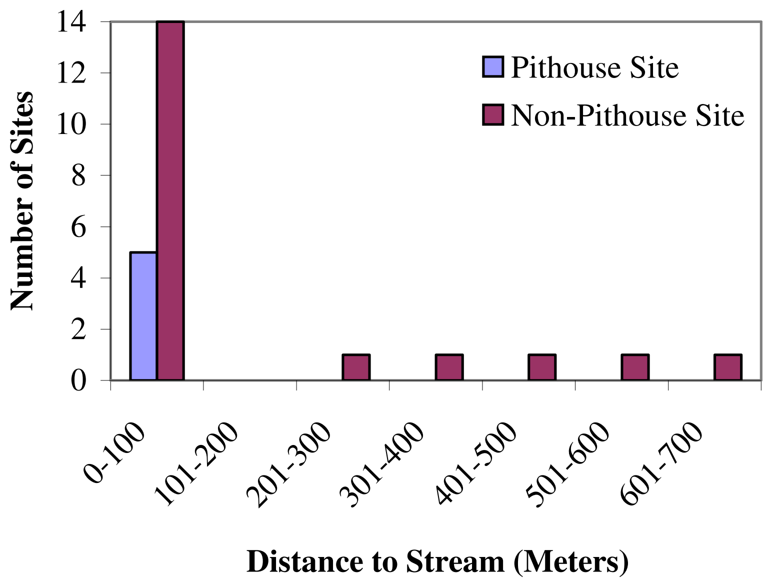

Figure 14. Distance between site and nearest stream (upper section).

The trend in distance between site and the nearest stream that emerges when the data from all sections are combined amplifies the patterns observed for the individual sections. As illustrated below in Figure 15, approximately 73% of pithouse sites and 62% of non-pithouse sites are located within 200 meters of the nearest stream. Approximately 90% of pithouse sites and non-pithouse sites occur within 500 meters of the nearest stream, with overall site frequency decreasing as distance to the nearest stream increases. The remaining 10% of pithouse sites are located 600 to 900 meters from the nearest stream, while the remaining 10% of non-pithouse sites occur between 500 and 800 meters.

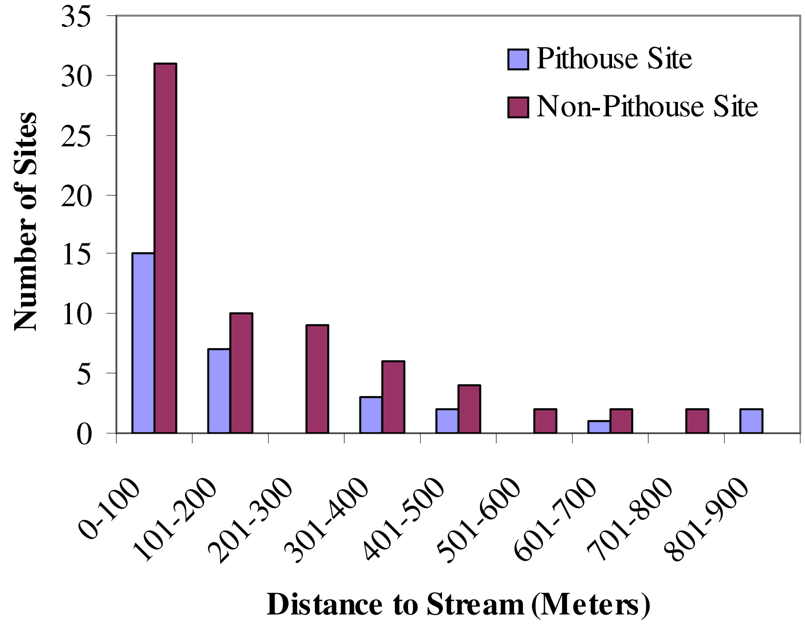

Figure 15. Distance between site and nearest stream (all sections).

Discussion

The results of the first phase of analysis indicate that most pithouse sites feature a southern to western exposure. Although exposures for non-pithouse sites seem to be more variable, the overall pattern is similar to that of pithouse sites. These observations corroborate Sisson's (1984: 77) finding that most prehistoric sites have a southern exposure. This suggests that maximizing solar insolation was a consideration when selecting settlement location.

Both pithouse and non-pithouse sites in my sample sections tend to be located in stretches of the canyon with flat to gently sloping topography. This undoubtedly reflects a cultural preference. It also likely reflects the absence, or limited expanse, of habitable landforms such as beaches, alluvial fans, and terraces in other parts of the canyon where the bedrock exhibits greater resistance to erosion. According to Davis (2001a: 45), "canyon width appears to be directly related to the resistance of bedrock units to the erosional action of the river." The narrowing of the canyon through more resistant bedrock serves to funnel the river, increasing the energy of the current and the ability of the river to transport sediment particles, thus limiting formation of depositional landforms. An extreme example of this is found in the upper section between RM 98 and 100, where the river has cut a very narrow steep-sided channel, known as "The Crevice," through the bedrock. The geology of this area is marked by a change from plutonic rock of the suture zone to the metasedimentary rock of the Riggins Group (Lucas 2004: 3). The physiography of the eastern end of the upper section seems to be similarly, though less dramatically, influenced by bedrock geology. From RM 106 through 112, located in plutonic rock, the terrain is extremely steep on both sides of the river. Only three sites are recorded in this seven-mile corridor. The basaltic lower section offers a sharp contrast, featuring broad terraces and less severe side slopes.

Close proximity to tributary streams seems to be a characteristic of both pithouse and non-pithouse site locations. The majority of pithouse sites, approximately 73%, and over half of non-pithouse sites are located within 200 meters of the nearest stream. Approximately 90% of pithouse sites and non-pithouse sites occur within 500 meters of the nearest stream, with overall site frequency decreasing as distance to the nearest stream increases. These results augment those produced by Sisson (1984: 80), who determined that the mean distance between sites with prehistoric features and the nearest perennial stream is 3,802 feet, or 1,159 meters. He identified an average distance of 4,661 feet, or 1,421 meters, between possible pithouse sites and the nearest perennial stream (1984: 80). Proximity to streams, and specifically confluences, would have facilitated access to a number of useful resources including fresh water, spawning anadromous and resident fish, wood for fuel, and game.

It should be pointed out that these proximity measurements refer to the Euclidean distance between site and stream. Given that humans tend to modify their routes to avoid or minimize the cost of traversing obstacles and barriers, such as steep terrain, when traveling through the landscape, this method of measurement may, in some cases, yield results inconsistent with past hunter-gatherer behavior.

Analysis Procedure and Results

This section begins with a discussion of the approach taken in my analysis and the GIS procedures used, and concludes with a description of the results. In order to test the idea that proximity to elk and deer factored into winter village placement, it is necessary to first define the foraging radius within which elk and deer could be expected to be procured, then identify how these animals are distributed in the landscape. Traveling across a landscape requires the expenditure of energy, the amount of which, or cost, is a function of time and distance and varies according to the nature of the terrain, vegetation, weather, the size of the load carried, and other factors. Prehistorically, the cost of travel limited how much of the surrounding area hunter-gatherers “habitually exploited from a single site” (Bailey and Davidson 1983: 88). The extent of this area, which is called the site exploitation territory, may be estimated by using a time-distance factor, which is the “maximum radius of travel from a given site to a given area of resource exploitation such that the energy expended in travel and extraction does not exceed the energy acquired as food” (Bailey and Davidson 1983: 91).

For my analysis, I used a time-distance factor of 10 km/2 hours to delimit the site exploitation territory for each pithouse site. This represents the maximum amount of time and distance typically traveled, in the dry season, by !Kung San hunter-gatherers from base camp during daily foraging activities. Originally documented by Lee in 1969, this ethnographically-based daily foraging radius is used frequently in archaeological site catchment studies (e.g. Vita-Finzi and Higgs 1970; Bailey and Davidson 1983; Jochim 1976). Ethnographic studies of other cultures have observed comparable travel distances (Madsen et al. 2000: 21).

Using Lee’s daily foraging radius when calculating site exploitation territories for pithouse sites in the LSRC is justified for a couple reasons. First, it has been documented that the Nez Perce typically hunted for game during the winter in the hills near the villages (Chalfant 1974: 84). Ethnographic information for other hunter-gatherer cultures on the Plateau suggests that hunting excursions ranged in duration from one day to multiple days (Miller 1998: 257; Ross 1998: 272). Modeling the distance that hunters could travel roundtrip in a day from the villages serves as a starting point. Second, the settlement systems of the !Kung and Nez Perce share a crucial similarity. During the dry season, the !Kung have limited mobility as their settlements must be tethered to perennial water holes (Dennell 1980: 4). The Nez Perce led a similarly sedentary lifestyle in the winter, with groups aggregating in villages located at or near food caches. Thus, in both instances, "it is appropriate to envisage a catchment area extending uniformly in terms of time-distance around a (settlement)…" (Dennell 1980: 5).

It should be noted that the walking rate of the !Kung is facilitated by the relatively flat terrain of the Kalahari desert. In comparison, much of the topography of the LSRC is extremely rugged. To model the effect of variable terrain on travel time and distance, I used a friction surface to generate the site exploitation territories in GIS. The resulting mobility polygons represent the work equivalent of a two-hour daily foraging radius for each pithouse site. Figure 16 illustrates the difference in size and shape of a site exploitation territory defined by a fixed radius and calculated with the friction surface.

The procedure that I used to generate the site exploitation territories in GIS is as follows:

1) *Creating the friction surface.* First, I generated a slope raster in ArcMap from the re-projected digital elevation models. Opening the raster calculator under Spatial Analyst, I then entered the following formula to calculate the cost of travel per grid cell based on slope:

(((slopegrid/45)*3.168)+1)

In the formula, "slope is divided by 45 to convert from degrees to proportional vertical gain per cell width" [1]. This value is then multiplied by an ascent cost factor of 3.168, taken from conventional backpacking computations (van Leusen 1998: 3), and increased by a value of one to represent the effort required to traverse the horizontal distance of the cell. The resulting raster is an isotropic friction surface that

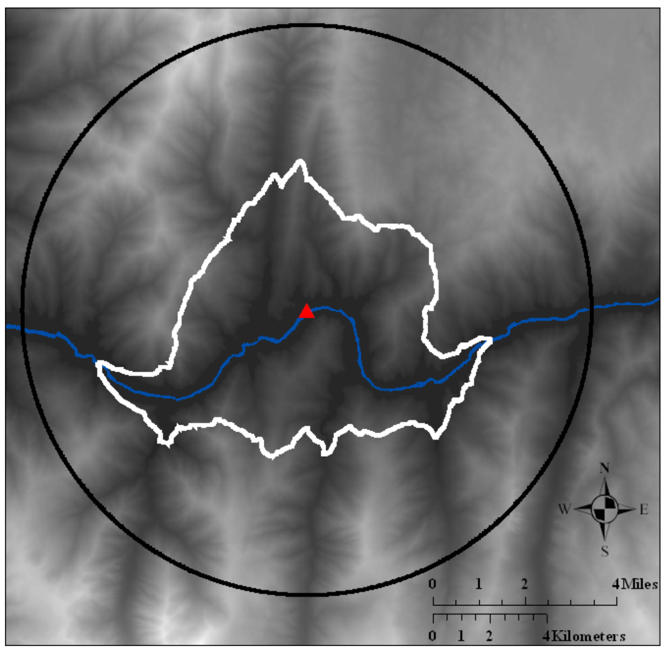

Figure 16. Extent of a 10 km fixed radius site exploitation territory (outer black circle) and 10 km work equivalent site exploitation territory (inner white polygon) generated for a pithouse site (red triangle) in the upper study section. Note how the site exploitation territory generated with the friction surface extends further across relatively low relief terrain (the darker portions of the underlying digital elevation model) than in high relief terrain (the lighter portions of the digital elevation model) and overall is much smaller than the fixed radius site exploitation territory.

[1] This formula was originally used in a lab exercise at Arizona State University and can be seen at www.public.asu.edu/~peterm/courses/asb591/lab_7.htm. Van Leusen (1998) describes a variation of the formula in his discussion of cost surface analysis.

uses slope to determine the relative energetic cost of moving across the landscape.

In order to ensure the accuracy of the slope grid and derived friction surface raster, I examined the source digital elevation model tiles for possible errors. I draped the digital elevation models over digital raster graphics comprising the same geographic extent, then compared the pixel values of the digital elevation models with the mapped elevation values in the digital raster graphics at randomly selected points. I also overlaid the friction surface and slope rasters over the digital raster graphics to corroborate values.

2) *Converting individual site points to grids.* I created a separate shapefile for each pithouse site in ArcMap by opening the pithouse site shapefile and exporting each site point individually. Next, I read the friction surface and all 30 pithouse site shapefiles into ArcView 3.3. Using the friction surface to set the parameters for geographic extent and cell size, I then converted each site shapefile to a grid.

3) *Calculating site exploitation territory grids.* Opening the map calculator in ArcView, I applied the following cost distance formula to each site grid to generate the site exploitation territory[2]:

[site grid].costdistance([friction surface], nil, “name of output”.asfilename,10000)

[2] The original version of this formula was used in a lab exercise at Arizona State University and is available at www.public.asu.edu/~peterm/courses/asb591/lab_7.htm. It has been modified here for use in my analysis.

This instructed ArcView to calculate the work equivalent of 10,000 meters extending from the site in all directions along the least accumulative cost path. It should be emphasized that the least-cost path in this case is determined by differences in slope gradient and does not model cost-reducing behavior such as contouring. To assess the accuracy of the formula and input datasets, I calculated the exploitation territory for a randomly selected site using a no-cost friction surface raster[3]. I compared the size and shape of the resulting site exploitation territory to a 10 km circular buffer that I generated for the site to determine if the polygons corresponded. Using the regular slope-based friction surface raster, I then calculated smaller site exploitation territories, representing the work equivalent of 1000 meters, for a few selected sites. Draping the site exploitation territories over base digital raster graphics, I examined the site exploitation territory polygons relative to the mapped topography to confirm that they extended farther across terrain with low relief and truncated in areas with high relief.

4) *Converting site exploitation territory grids to vector shapefiles.* I opened each site exploitation territory grid in ArcMap and converted the raster from floating point to integer using the trigonometric function in the Spatial Analyst toolbox. Then, I converted each grid to a shapefile by selecting the raster to polygon function under Conversion Tools. The resulting object consisted of a multitude of tiny data points that I joined into one continuous polygon using the dissolve function in the Data Management toolbox.

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[3] Technically, each pixel in the friction surface would have a value of one, as this is the cost of traversing the horizontal extent of the cell.

The next step after generating the pithouse site exploitation territories was identifying the spatial distribution of elk and deer. Elk and deer share basic survival needs that determine where they are found in a landscape (Wallmo 1981; Toweill and Thomas 2002). Two of these, food and cover, dictate a range of suitable habitat according to type, structure, and distribution of vegetation. The diets of elk and deer change seasonally with the fluctuating availability and quality of various plant species. In winter, elk subsist primarily on grass or woody plants, according to the dominant locally available forage and snow depth (Toweill and Thomas 2002: 281), while deer consume primarily browse (Capp 1968: 33, 39). Where shrubs are limited, deer turn to grasses and forbs (Wallmo 1981: 495).

In addition to providing sustenance, dense vegetation serves as an important source of shelter. Elk and deer use forest cover for protection against wind, precipitation, and temperature extremes, as well as concealment from predators (Wallmo 1981; Toweill and Thomas 2002). Generally, forest with greater overstory stand and crown density functions as thermal and protective cover, while forest with lower stand density and more open canopy, and thus greater understory biomass, serves as a feeding area (Toweill and Thomas 2002: 540-541).

Given these dietary and cover requirements, it follows that both elk and deer prefer to live near the interface between forest and non-forest, especially grassland or meadow, communities (Toweill and Thomas 2002: 542; Capp 1968: 57). Plants in this edge area, or ecotone, are especially diverse and abundant due to the intermixing of vegetation from adjacent plant communities (Toweill and Thomas 2002: 542), providing both cover vegetation and a prime selection of forage in close proximity. From the cover of the forest, elk and deer can also venture into the nearby grassland or meadow to take advantage of additional grazing and browsing opportunities.

Using these preferred habitat characteristics, the landscape of the LSRC can subdivided according to a hypothetical model of relative elk and deer habitat productivity. Areas with the highest habitat productivity for these game animals are found near the ecotone between a forest and open grassy slope or meadow clearing. Forested areas, providing cover but less diverse and abundant forage than the open-forest ecotone, have the next highest level of productivity. The riparian corridor along the river offers water as well as forage, but limited cover, except in stretches with adjacent forest, and so typically has a low level of game productivity. Grassy clearings and slopes have the lowest game productivity due to the absence of cover.

As described in the second chapter, forest cover in the lower and middle study sections of the LSRC tends to be restricted to tributary drainages that bisect the walls of the canyon. Forest cover is widely distributed in the upper study section, but tends to be denser in tributary drainages. Given their preference for forest cover and open-forest ecotone, elk and deer can therefore be expected to generally occur in greater numbers in tributary drainages rather than in the interfluvial areas. Game might also be more concentrated in landscapes with heterogeneous vegetation cover and broadly distributed in areas with homogeneous vegetation cover.

Areas of high elk and deer productivity would have offered hunters an increased chance of success by virtue of a) greater numbers of elk and deer, serving to increase the likelihood of hunters encountering their targeted prey, and b) vegetation cover behind which hunters could conceal themselves as they moved within bow and arrow range of an elk or deer. Generally, the chances of killing an elk or deer are significantly reduced in open areas, where the animals typically range for only brief periods of time in order to forage and therefore are less frequently encountered, and where they are very difficult to stalk due to the lack of places to hide. Notable exceptions include the use of hunting blinds and pits in talus slopes positioned next to game trails. These site types are limited to special places in the landscape and are not considered here. The riparian corridor along the river offers hunters somewhat better odds as they could conceal themselves and wait for an elk or deer to come drink from the river. Alternatively, hunters could drive the animals into the river, where they can more easily dispatch them. The latter method is documented ethnographically elsewhere on the Plateau (Miller 1998: 257; Walker 1998: 421).

Because differences in the productivity and structure of ungulate habitat in the LSRC probably affected a hunter's chances of encountering and successfully killing an elk or deer, economically-motivated hunters are expected to have preferentially accessed those areas that offered higher chances of success and generally avoided or minimized travel in areas like open grassland that offered lower chances of hunting success. Given the rugged terrain in the canyon, hunters might have adjusted their search route to mitigate the energetic cost of moving through the varied topography of the landscape. This was probably of secondary importance and may not have applied in situations where a greater expenditure of energy contributed to the potential success of the hunt (e.g.

climbing straight up a steep slope to take the shortest path to a meadow, or to approach an elk or deer undetected).

Thus, variation in game habitat type and to a lesser degree topographic relief might have influenced where economically-motivated hunters seeking to maximize their chances of hunting success would have traveled in the canyon. The presence of low "success" habitat and steep terrain would have served to discourage movement through the landscape by offering low economic payoff and high frictional resistance. Conversely, high "success" habitat and low relief terrain would have encouraged movement by offering high economic payoff and low frictional resistance.

In my analysis, I modeled the relative influence of habitat type and topographic relief on payoff-related movement within pithouse site exploitation territories to examine the quality of hunting grounds in the nearby landscape. I began by combining habitat type and slope data in a weighted overlay cost surface for each study section. High success habitat and gently sloping or low relief terrain received low "cost" values, whereas low success habitat and steep terrain received high "cost" values. In the context of this analysis, "cost" is a relative measure of resistance that is a function of potential hunting success (dependent on habitat type) and topographic relief. Here, I assume that hunters seek to minimize time and energy expended in their attempt to acquire game. On this basis, a least-cost solution analysis will reveal the direction and distance game hunters should go to most efficiently meet their goal.

Using the cost surface, I then performed a cost distance operation on each pithouse site to a) calculate the total accumulative "cost" of moving from the site to the boundary of the exploitation territory along the least-cost (highest payoff) route, and b) generate an optimal exploitation polygon showing the least-cost (highest payoff) direction(s) of travel from the site within the daily foraging radius. For comparison, I conducted cost distance functions on 15 non-site points.

I evaluated the results of the operations in two stages. First, to measure the relative payoff afforded by site location, I compared the total accumulative travel "costs" (based on habitat type and slope gradient) for the pithouse sites and non-site points. I expected generally lower accumulative "costs" for pithouse sites if villages were indeed placed to optimize access to high success areas. Next, I examined the shapes of optimal exploitation polygons for a sample of pithouse sites selected from each section to see how the local environmental structure and topography affected payoff-related movement. The spatial configuration of high productivity habitat differs between the three study sections. In the lower and middle sections, high productivity habitat is generally patchy and oriented perpendicular to the river, whereas in the upper section it is relatively homogeneous and oriented parallel to river. Thus, I expected the polygons to be irregularly shaped in the lower and middle sections and more uniform in the upper section.

Analysis Procedure

To create the weighted overlay cost surface described above, I first had to generate the component habitat and slope datasets. As no small-scale vegetation cover datasets were available for the LSRC, I created forest, grassland, and forest/grassland ecotone rasters from digital raster graphics using the procedure described Chapter 3. The river itself and adjacent riparian corridor also offer a certain level of potential success for hunters. Therefore, I converted the river shapefile to a raster, which I then combined with the vegetation cover rasters. I reclassified the pixels in the output raster according to relative probability of hunting success, assigning forest/grassland ecotone a score of 90; forest cover, 60; the river and adjacent riparian zone, 40; and open grassland, 20. It should be emphasized that these numbers are for heuristic purposes only and do not represent a probability in the absolute sense (i.e. out of 100%).

Historic and modern activities in the canyon, such as mining, logging, and grazing, undoubtedly have affected the extent of non-forested and forested areas at a local level. Based on paleoenvironmental research conducted in the LSRC, however, I assume the modern distribution of open and forested areas, and associated ecotone, as shown on the digital raster graphics is reasonably characteristic of the last two millennia. The climatic conditions extrapolated for this period closely resemble those of the present day (Davis 2001a: 252); the fluvial behavior of the river, and thus the extent of the riparian zone, has been largely consistent (Davis 2001a: 240); and it is reasonable to expect that other influential abiotic factors, such as aspect, bedrock geology, and elevation, have remained relatively unchanged over the last 2,000 years.

Because I had already produced slope rasters for all my study sections when calculating the site exploitation territories, I did not need to repeat the process for this analysis. However, in preparation for input into the weighted overlay function, I reclassified the continuous floating point slope values using an integer scale of 1 to 10 (where 10 represents highest slope gradient).

In a weighted overlay, multiple raster datasets with different value scales (i.e. meters, dollars, elevation) are combined and reclassified according to a common scale of measurement. Depending on the relative importance of the factors being assessed, each input raster is assigned a percentage of influence. To calculate the final cost raster, the GIS multiplies the reclassified values of each input raster by the assigned percentage, then adds the pixel values from the resulting weighted datasets.

I reclassified my input datasets, as necessary, according to a common cost scale of what I term "resistance values." The scale ranges from 1 to 10, where 1 represents the lowest impediment to movement and 10 the highest. The reclassified habitat raster values are shown in Table 3.

Table 3. Weighted overlay reclassification table for elk and deer habitat

	Success Probability Score	**Resistance Value**
Forest/Grassland Ecotone	90	1
Forest	60	3
River/Riparian Corridor	40	6
Grassland	20	10

I next assigned the reclassified habitat raster a weight of 70% and the slope raster a weight of 30% to reflect the relative influence of these factors on hunter mobility, which is based on the assumption that hunters were less concerned with conserving energy than maximizing payoff, and then ran the function (Figure 17).

The cost distance operation that I performed in this analysis to model payoff-related movement utilizes the following formula:

[site grid].costdistance([friction surface], nil, "name of output".asfilename,#)

At this point, it is useful to clarify how this formula works. The first part of the formula contains the command for the Cost Distance function. The Cost Distance function uses a friction surface (in this case, the weighted overlay cost surface) and source dataset (a pithouse site or non-site point grid) to produce an output raster in which every cell is assigned a value representing the accumulative cost to reach that cell from the source along the least-cost path. The second part of the formula defines the extent of the output raster by specifying a total accumulative cost value for the Cost Distance function.

In this particular analysis, I wanted the output raster (i.e. the optimal exploitation polygon) to extend from the site to the boundary of the site exploitation territory. This would allow identification of the highest payoff directions of travel from the site within the daily foraging radius and provide a relative index (i.e. the total accumulative "cost") of the quality of ungulate habitat and steepness of terrain occurring along these trajectories. Accordingly, I ran the cost distance operation multiple times for each

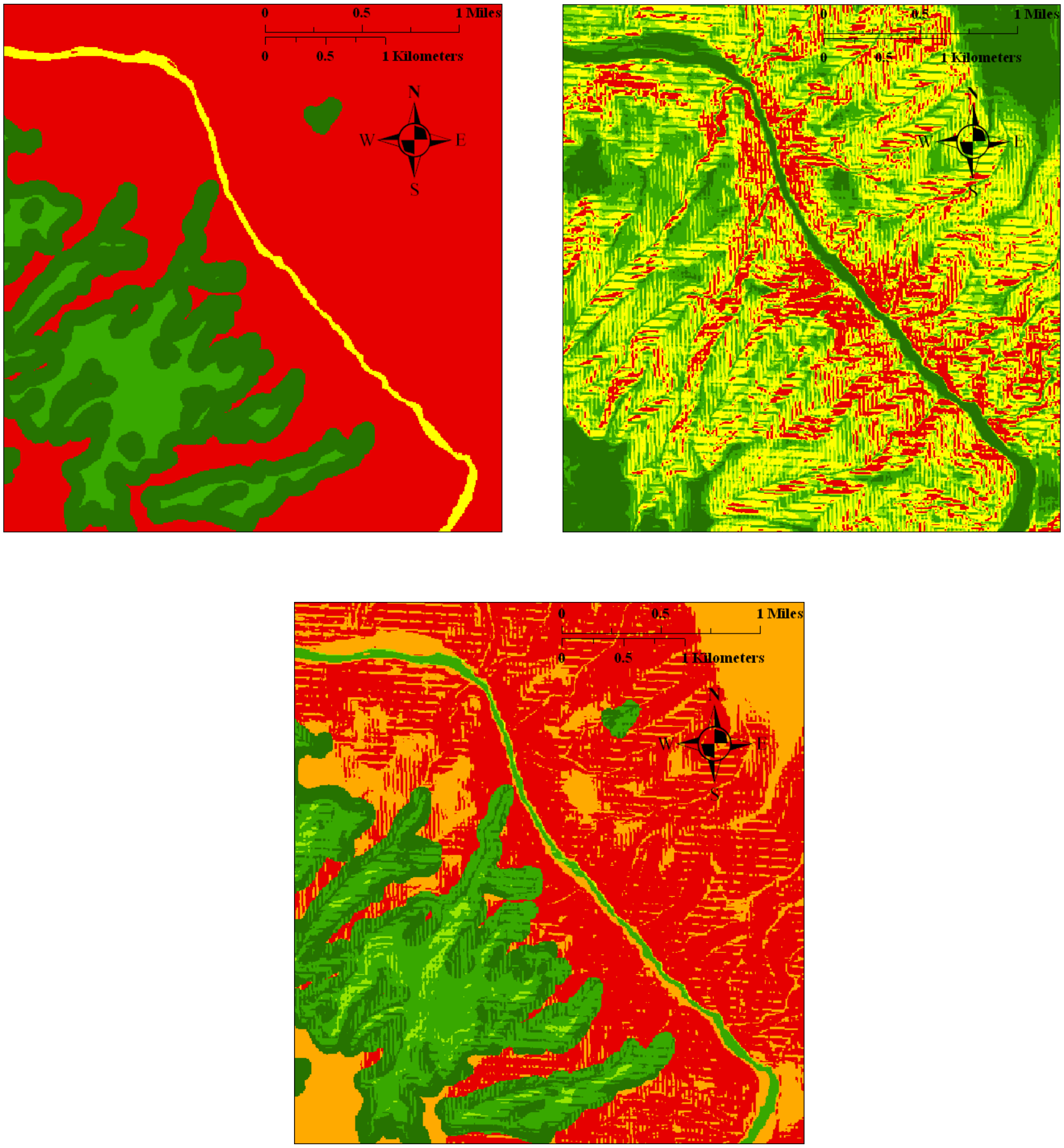

Figure 17. Portion of the two input rasters and final weighted cost surface for the middle study section. Level of resistance is represented by color, with greens reflecting low resistance, yellow as medium, orange as medium-high, and red as high. The habitat cost raster is shown in the upper left, the slope cost raster in the upper right, and the weighted overlay cost raster at the bottom. Horizontal lines running through the images are artifacts of the original digital elevation model datasets.

site, experimenting with different total accumulative "cost" values, until some portion of the optimal exploitation polygon reached a part of the site exploitation territory boundary (Figure 18).

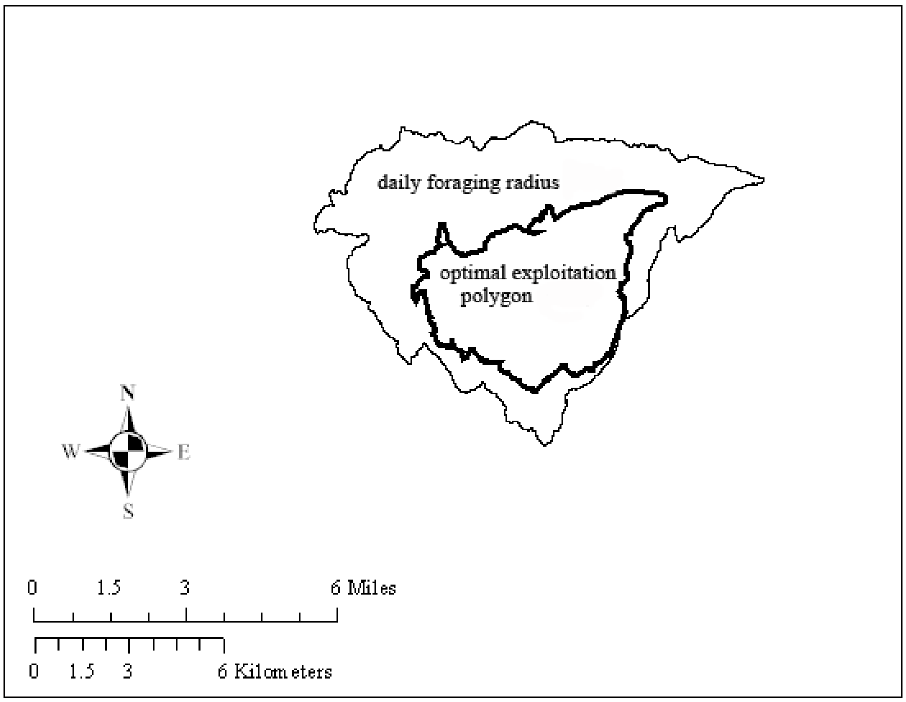

Figure 18. Optimal exploitation polygon and site exploitation territory generated for site 10IH419. Note how the OEP terminates at the boundary of the SET.

I performed the cost distance operation on all 30 pithouse sites in my three study sections as well as 15 arbitrary non-site points that I created (five in each section). The non-site points were intended to serve as a point of comparison for the pithouse sites. I positioned the non-site points on low relief terrain in stretches of river corridor under BLM or USFS jurisdiction that measured over one river mile in length and lacked recorded pithouse sites (Figures 19-21). I chose to not use non-pithouse sites as many of these are in close enough proximity to pithouse sites that no significant difference in total accumulative "cost" would be identified, or are situated in stretches of river corridor with steep terrain where it is unlikely that pithouse sites would have been placed.

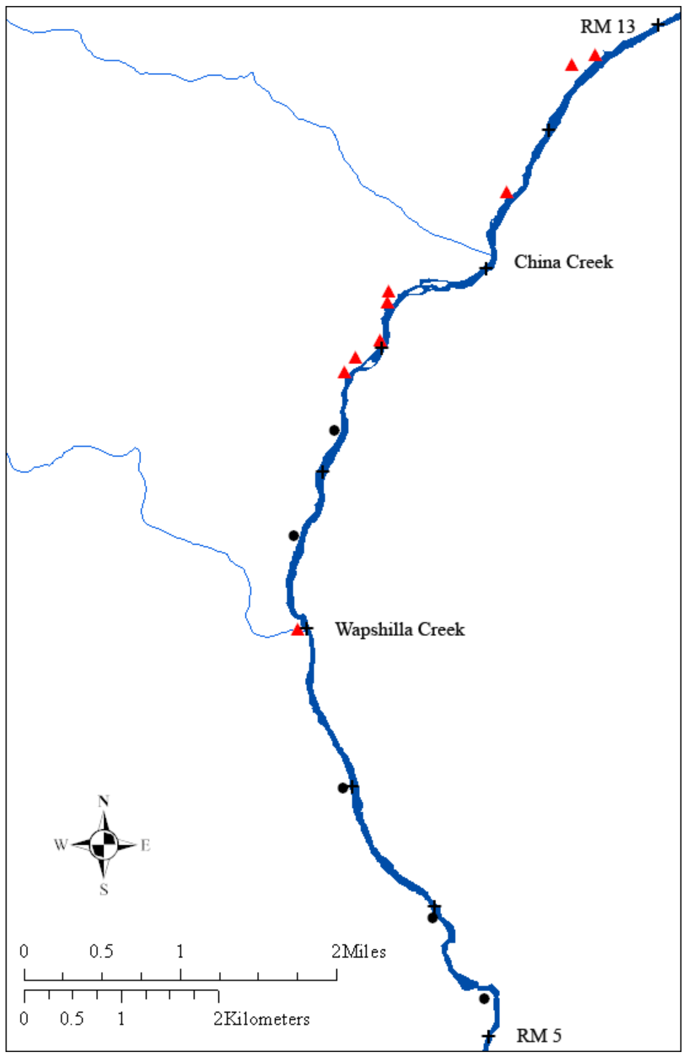

Figure 19. Distribution of non-site points (represented by black circles) and pithouse sites (represented by red triangles) in the lower study section.

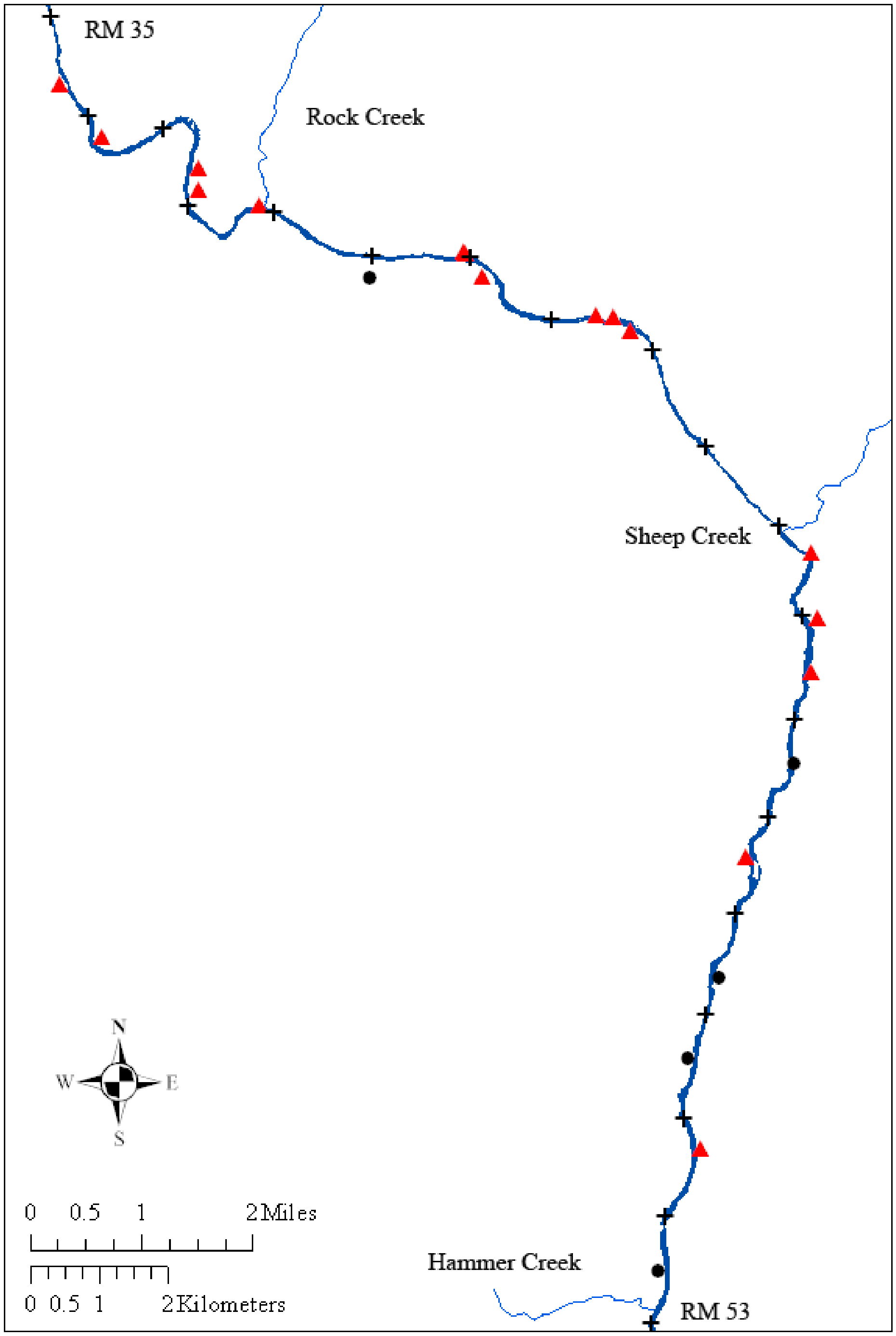

Figure 20. Distribution of non-site points (represented by black circles) and pithouse sites (represented by red triangles) in the middle study section. Non-site points were not placed between RM 43-45 due to the extremely steep terrain bordering both sides of the river in this stretch.

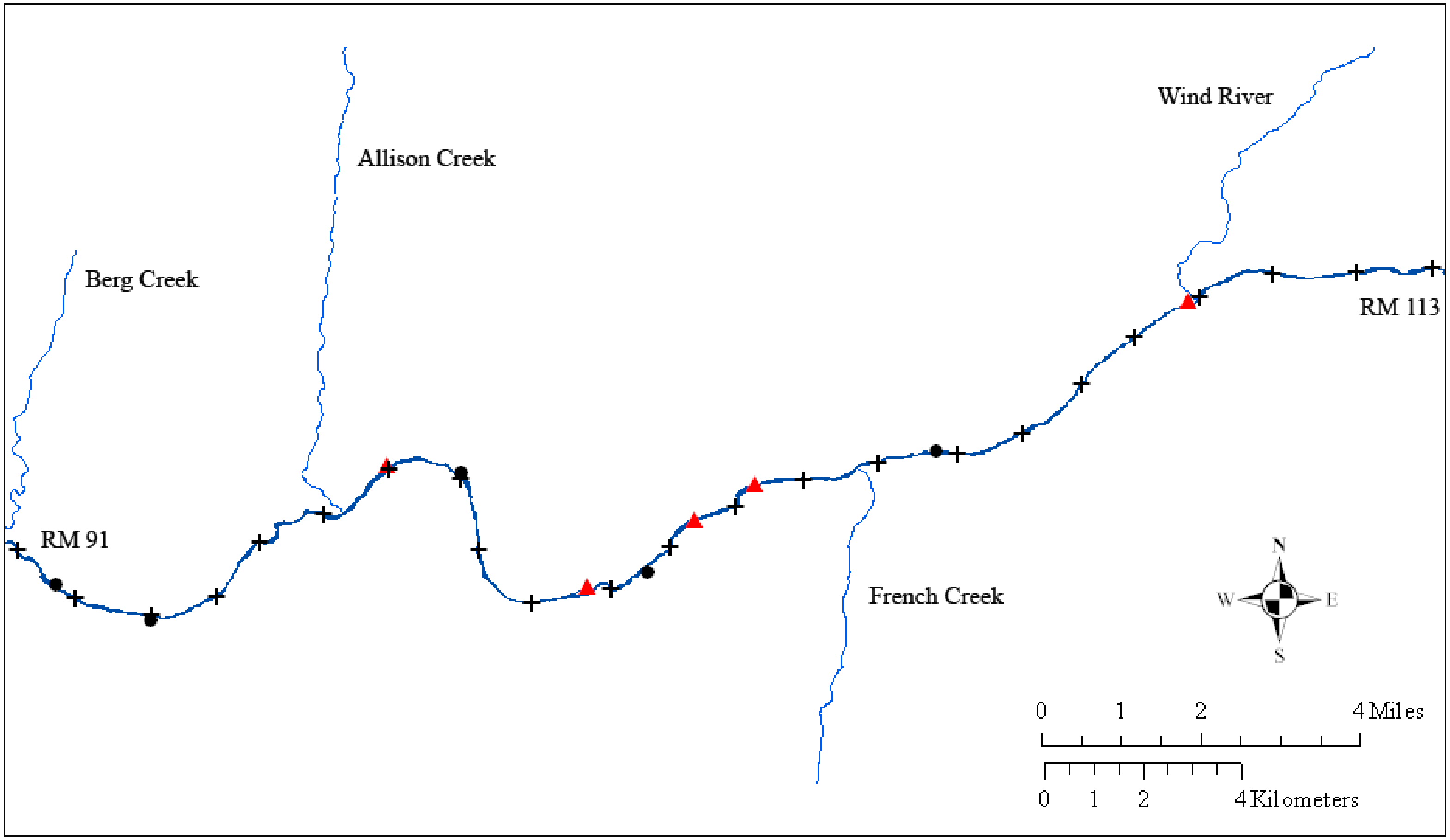

Figure 21. Distribution of non-site points (represented by black circles) and pithouse sites (represented by red triangles) in the upper study section. Non-site points were not placed between RM 93-95, 99-101, and 106-113 due to the predominance of steep terrain bordering both sides of the river in these stretches.

Analysis Results and Discussion

Part 1 - Evaluating Total Accumulative Cost Values

The total accumulative "cost" defining the boundary of a mobility polygon is the sum "cost" of traveling from the originating site out to the limit of the site exploitation territory along the path of least resistance. As described earlier, resistance is a function of a) potential hunting success dependent on habitat type and b) topographic relief, with greater success and lower relief offering low resistance. "Cost" accrues quickly over a short distance where the least-cost path extends through areas of high resistance and slowly over a long distance through areas of low resistance. Thus, in a situation where a hunter's route between a village and the limit of the daily foraging radius passes through predominantly low resistance areas, the total accumulative "cost" will be low. Conversely, if the hunter's route passes through primarily high resistance areas, the total accumulative "cost" will be high. Calculating the total accumulative "cost" thus provides a way to model the payoff landscape relative to a starting point in the LSRC.

Table 4. Total accumulative "cost" values for pithouse sites and non-site points in all study sections.

	Pithouse Site or Non-Site Point	**Total Accumulative "Cost" at Site Exploitation Territory Boundary**
Lower Section	Non-Site Point 1	19,400
	Non-Site Point 2	18,600
	Non-Site Point 3	18,000
	Non-Site Point 4	17,600
	Non-Site Point 5	17,100
	10NP112	19,000
	10NP229	15,100

Table 4 continued.

	Site or Non-Site Point	**Total Accumulative "Cost"**
	10NP117	14,800
	10NP224	13,900
	10NP231	13,300
	10NP120	12,700
	10NP125	12,600
	10NP233	12,400
	10NP122	10,600
Middle Section	Non-Site Point 1	18,700
	Non-Site Point 2	18,500
	Non-Site Point 3	16,800
	Non-Site Point 4	13,800
	Non-Site Point 5	10,600
	10IH387	18,300
	10IH789	18,200
	10IH783	17,800
	10IH787	15,900
	10IH796	14,800
	10IH397	14,500
	10IH396	14,400
	10IH1885	13,200
	10IH1163	13,000
	10IH1312	12,400
	10IH760	11,800
	10IH761	11,700
	10IH1217	11,400
	10IH395	10,100
	10IH1220	10,100
	10IH1211	8,700
Upper Section	Non-Site Point 1	12,200
	Non-Site Point 2	11,300
	Non-Site Point 3	10,900
	Non-Site Point 4	10,500
	Non-Site Point 5	8,300
	10IH427	11,500
	10IH425	10,800
	10IH354	10,400
	10IH419	10,100
	10IH360	9,400

On average, the total accumulative “cost” value for pithouse sites (13,822) in the lower section is noticeably lower than that of non-site points (18,140). The average total accumulative “cost” value for pithouse sites (13,519) in the middle section is slightly lower than that of non-site points (15,680). In the upper section, there is little difference between the mean total accumulative “cost” values of pithouse sites and non-site points (10,440 and 10,640, respectively).

To determine whether there is a statistically significant difference between the total accumulative “cost” values of pithouse sites and non-site points, I conducted the Mann-Whitney test (or Wilcoxon Rank-Sum test). This is a nonparametic test that uses the ranks of data from two independent sample populations to assess whether the means of the samples are equal (DeVeaux et al. 2005: 492). The null hypothesis was that the means of the samples are equal, indicating that the samples are drawn from populations with the same distribution and consequently that there is no significant difference in total accumulative “cost” value between pithouse sites and non-site points. The level of significance for rejecting the null hypothesis was 0.05.

I tested the difference between pithouse sites and non-site points for each study section using the interactive Mann-Whitney test available on-line through Vassar College (http://faculty.vassar.edu/lowry/utest.html). The results of these tests are provided in Appendix B. The small P-value obtained for the lower section (0.0164 for a two-tailed test) indicates that there is strong evidence to reject null hypothesis. This suggests that there is a significant difference between the locations of pithouse sites and non-site points with respect to total accumulative “cost”. In the middle section, the P-value (0.1738) is larger than the 0.05 probability threshold, indicating that there is weak evidence to reject the null hypothesis. The P-value obtained for the upper section (0.5287) is even larger, which means that there is no statistical basis for rejecting the null hypothesis. Thus, in these two sections, there does not seem to be a significant difference in the locations of pithouse sites and non-site points (especially in the upper section) in regard to total accumulative "cost".

These results point to a meaningful relationship between the positioning of villages and the spatial distribution of high payoff game habitat in the LSRC, albeit differentially expressed across the spatial scale. In the lower section, where forest and forest/grassland ecotone are extremely heterogeneous, the total accumulative "cost" values of pithouse sites are significantly lower overall than those of non-site points. This supports a hypothesis that winter villages were positioned in the LSRC in order to enhance access to high payoff hunting areas in the landscape. Conversely, the total accumulative "cost" values for pithouse sites and non-site points in the upper section are statistically comparable. This makes sense given that forest is essentially continuous across the landscape in this part of the canyon, thus all locations are roughly equal in terms of proximity to high payoff areas. In the middle section, the distribution of forest and forest/grassland ecotone is transitional between the extreme patchiness of the lower section and relative uniformity of the upper section. The difference between the mean total accumulative "cost" values of pithouse sites and non-site points is similarly transitional as it is less than that observed in the lower section but more than in upper section. The P-value generated for this section is large enough that the difference in total accumulative "cost" values cannot be attributed with a statistically high level of confidence to the positioning of pithouse sites; however, this analysis indicates that there is still an 83% chance that the difference observed between the samples actually does reflect a difference borne out of location rather than the vagaries of sampling (Drennan 1996: 192).

Part 2 - Examining Optimal Exploitation Polygons

Optimal exploitation polygons are abstractions of hunting payoff-related movement that could be expected given the nature of the local topography and distribution of different types of elk and deer habitat. Habitat is modeled according to vegetation cover, which in the LSRC is significantly influenced by physiography and elevation. As can be seen in Figure 22, an optimal exploitation polygon extends further from the site in parts of the landscape where the probability of successful hunting is high and the topography is less steep (indicated by shades of green), and truncates where the chances of success are low and the topography is steep (indicated by orange and red).

Figures 23-25 display the optimal exploitation polygons and site exploitation territories for pithouse sites sampled from the lower, middle, and upper study sections. I selected these polygons to show the range in shape in each section. The shapes of the polygons differ not only within a section, but between sections as well, reflecting relative differences in habitat type distribution and topographic relief. For reference, the river runs through the long axis of the site exploitation territories in all of these figures.

In the lower section, least-cost (highest payoff) routes are typically localized, non-circular, and strongly oriented perpendicular to the river. This form reflects the limited

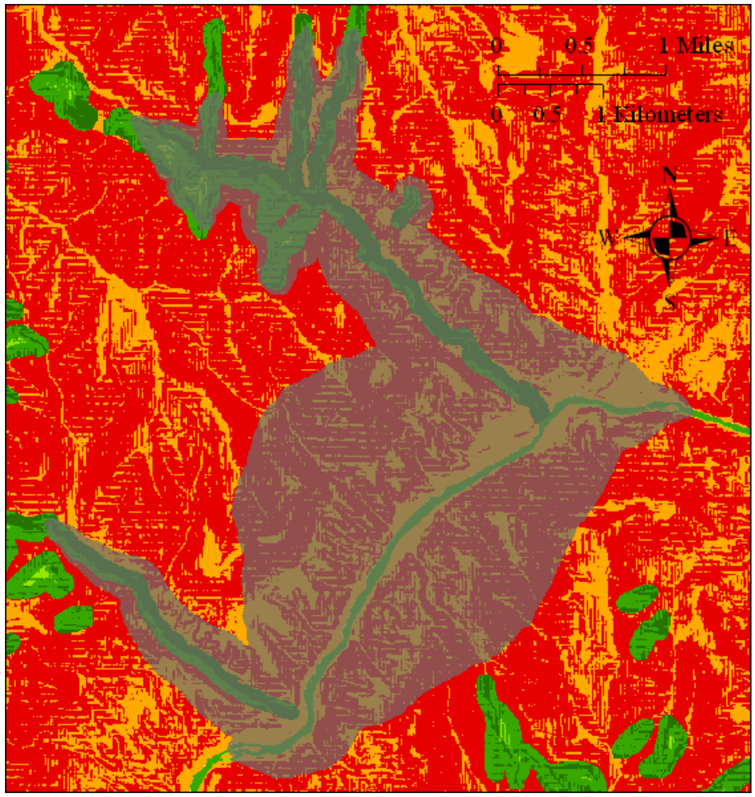

Figure 22. Optimal exploitation polygon (shaded) generated for site 10NP224 in the lower study section. Note how the site is positioned to split the difference between two high payoff areas (Eagle Creek and China Creek).

distribution of high success habitat in particular tributary drainages. The optimal exploitation territory for 10NP112 is not as strongly focused, which is due to the local patchy distribution of nearby high success habitat.

In the middle section, optimal exploitation polygon shapes are more variable than in the lower section and tend to be slightly rounder. The polygon for 10IH789, located in the upstream stretch of the middle section, shows a strong directional preference

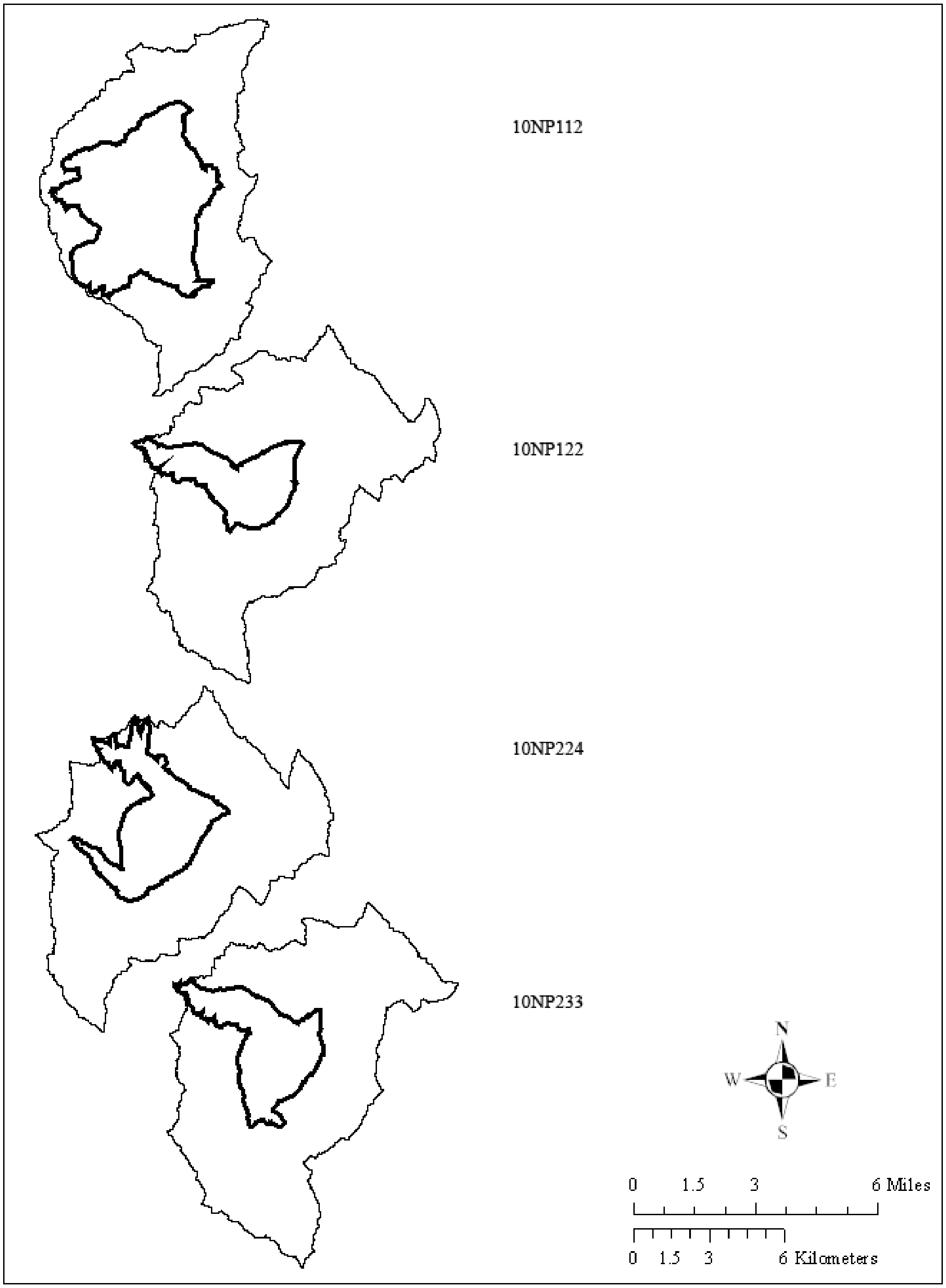

Figure 23. Sampled optimal exploitation polygons (outlined in heavy dark line) and site exploitation territories from the lower study section.

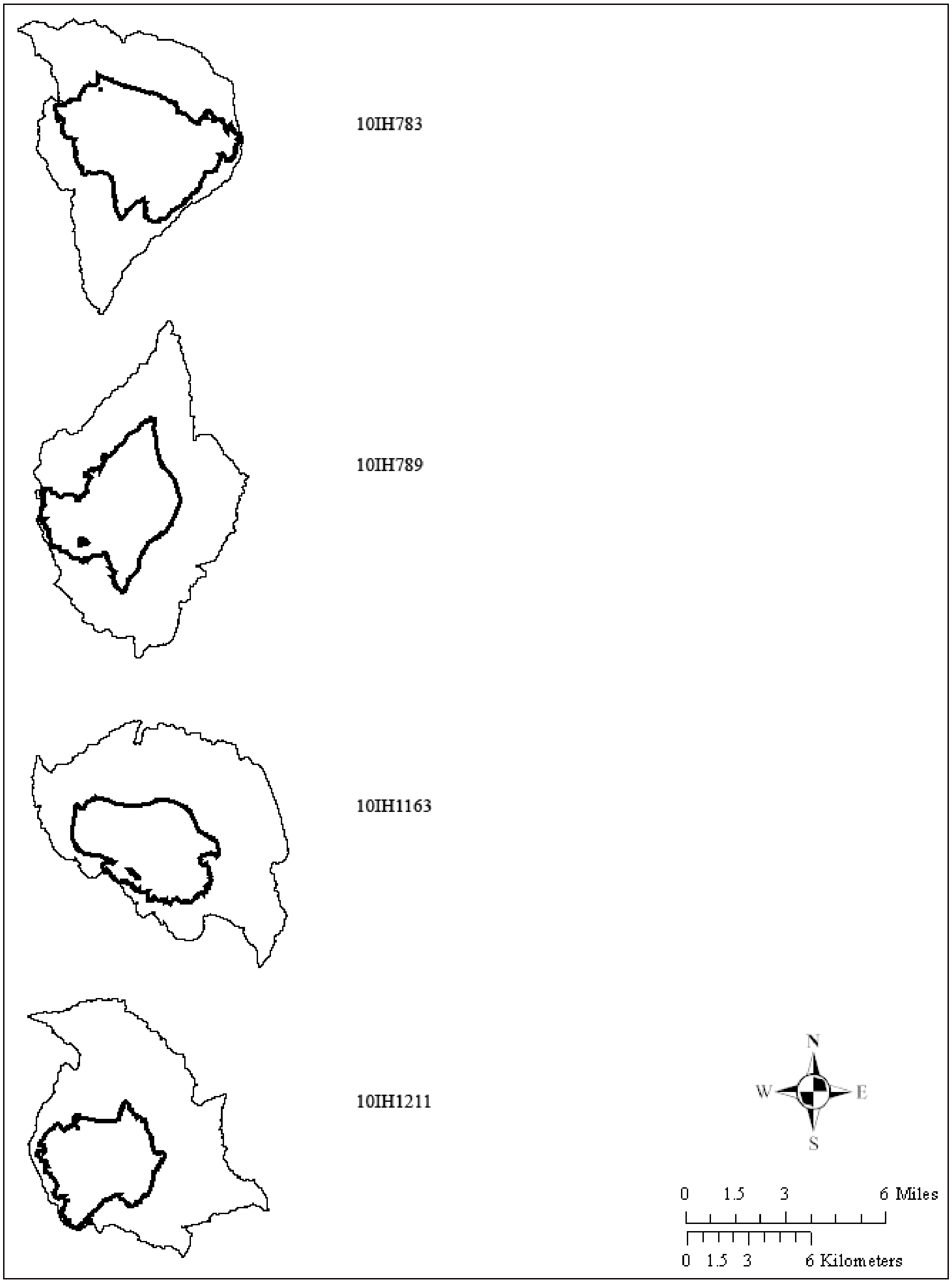

Figure 24. Sampled optimal exploitation polygons (outlined in heavy dark line) and site exploitation territories from the middle study section.

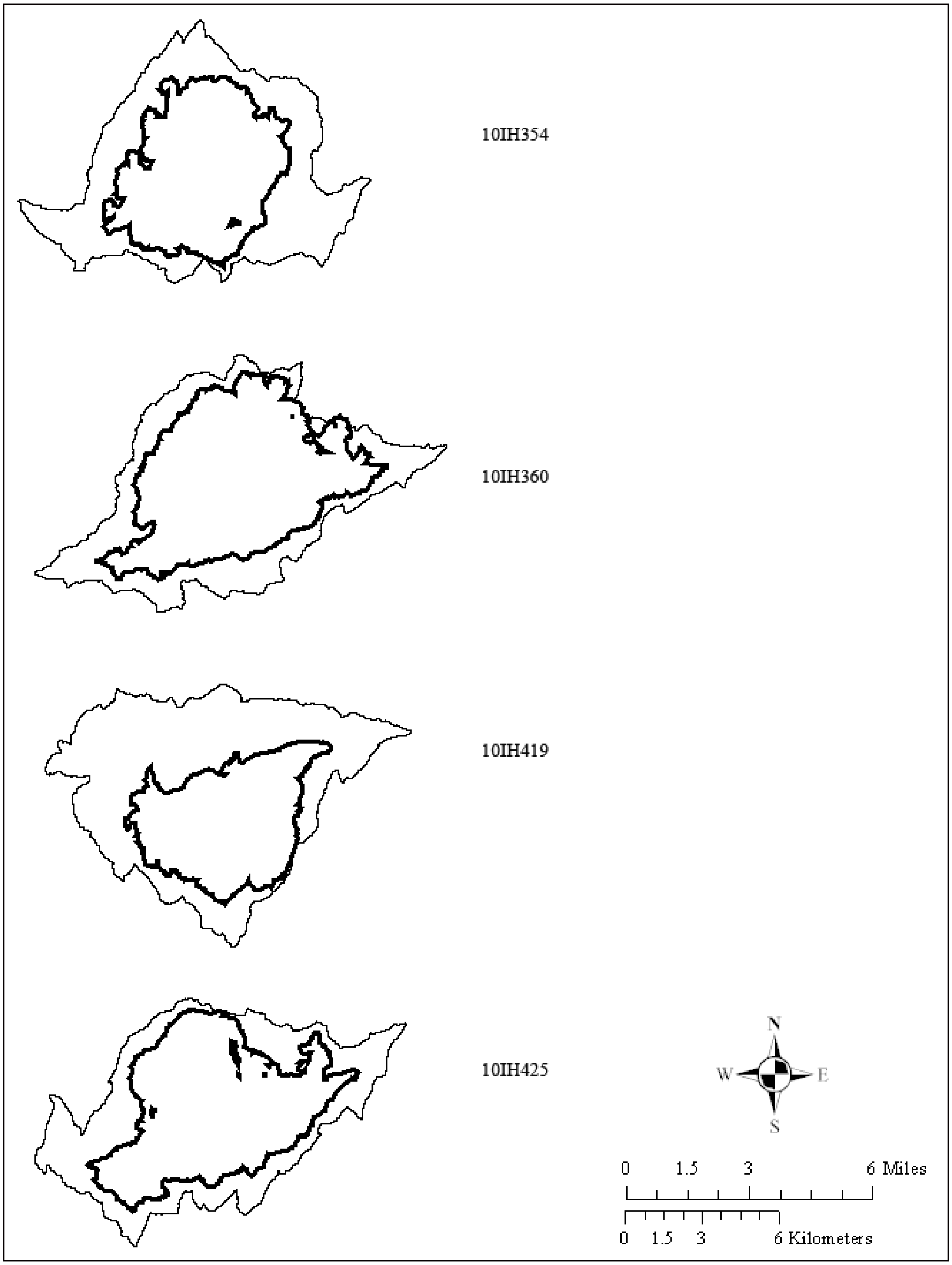

Figure 25. Sampled optimal exploitation polygons (outlined in heavy dark line) and site exploitation territories from the upper study section.

perpendicular to the river on the left side where patches of high success habitat occur in the upper elevations of some tributary drainages. In contrast, the polygon for 10IH783, located in the middle stretch, preferentially extends perpendicular to the river on both side of the canyon. This is because drainages on both sides of the river contain forest cover. Both 10IH1163 and 10IH1211 are located in the lower stretch of the section where high success habitat is distributed relatively continuously along the left side of the river. Accordingly, the polygons for these sites are extremely truncated along the right side of the river and extend uniformly up the left wall of the canyon.

Optimal exploitation polygons in the upper study section are generally larger and more rounded than in the other two sections. This reflects the relatively continuous forest on both sides of canyon. The optimal exploitation polygon for 10IH354 has a very round shape, which is due to the extremely meandering course of the river in this area. Most of the polygons in each study section exhibit elongation along the river, which acts as a corridor of low resistance. This is due in large part to the comparatively flat nature of the terrain along the bottom of the canyon. In reaches where the river is bordered by open grassland, it also reflects the relatively higher level of hunting success associated with the river. Where 10IH354 is situated, however, the river does not flow in a generally straight path, but curves significantly. Thus, the “pulling” effect of the river is absent.

It can be seen that the optimal exploitation polygon for 10IH425 has a bulbous profile north of the river. This is an area where low slope and high success habitat coincide spatially, offering especially low resistance values. This also is the case for the 10IH360 polygon, which bulges to the north of the river. Here, relatively low slope gradients and high payoff forest/grassland ecotone overlap to form extremely low resistance corridors through steeper, low payoff grassland between the site and edge of the site exploitation territory (as illustrated below in Figure 26). This suggests that many different routes may be pursued due to environmental homogeneity. In contrast, the optimal exploitation polygon for 10IH419 is truncated to the north of the river, where there is relatively uninterrupted zone of grassland and steeper terrain.

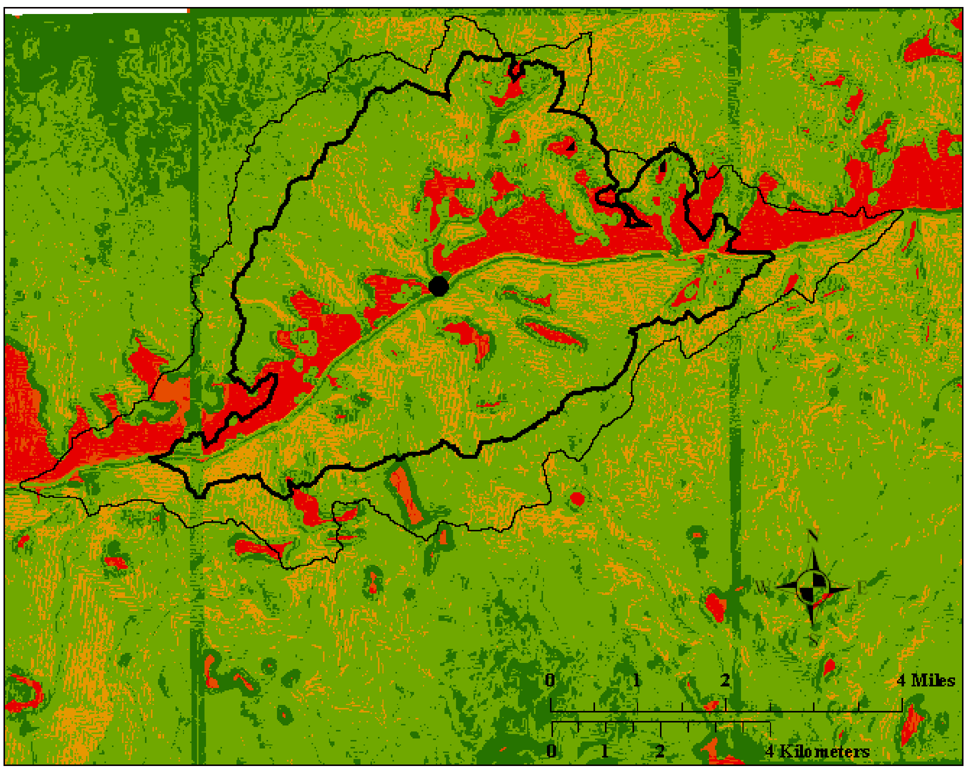

Figure 26. Optimal exploitation polygon (marked by heavy dark line) and site exploitation territory (marked by thin dark line) for 10IH360, shown as a black circle, overlaid on the weighted overlay cost surface generated for the upper study section. Note the low resistance corridors (shown in dark green) consisting of high payoff habitat and low relief terrain north of river.

Chapter 5. Discussion and Conclusions

In this chapter, I discuss the behavioral implications of my analysis results and review the contribution of this thesis toward a greater understanding of the archaeological record in the LSRC and elsewhere on the Plateau. My discussion is organized according to the research questions introduced in the first chapter.

Question 1: Did the local distribution of elk and mule deer influence the siting of winter villages?

The results of the statistical analysis described in the last chapter suggest that in portions of the canyon where the environmental structure creates spatial inconsistency in the type and distribution of game habitat, villages may have been positioned to facilitate easy access to areas in the landscape providing a relatively greater chance of hunting success. Patterning in the clustering and dispersion of pithouse sites in each section relative to high payoff habitat provide tentative corroboration for this conclusion.

The majority of pithouse sites (8 of 9) in the lower study section are located between RM 9 and RM 13. Groups living at these sites would have had easy access to China Creek (in RM 11) and/or Eagle Creek (in RM 13), as illustrated by the shapes of the optimal exploitation polygons (Figure 27). These two drainages contain the most abundant and vertically continuous forest cover in the lower section, connecting the river to forested upland areas and undoubtedly serving as wooded travel corridors for elk and deer. The extremely high payoff potential of this stretch of river is reflected in the low

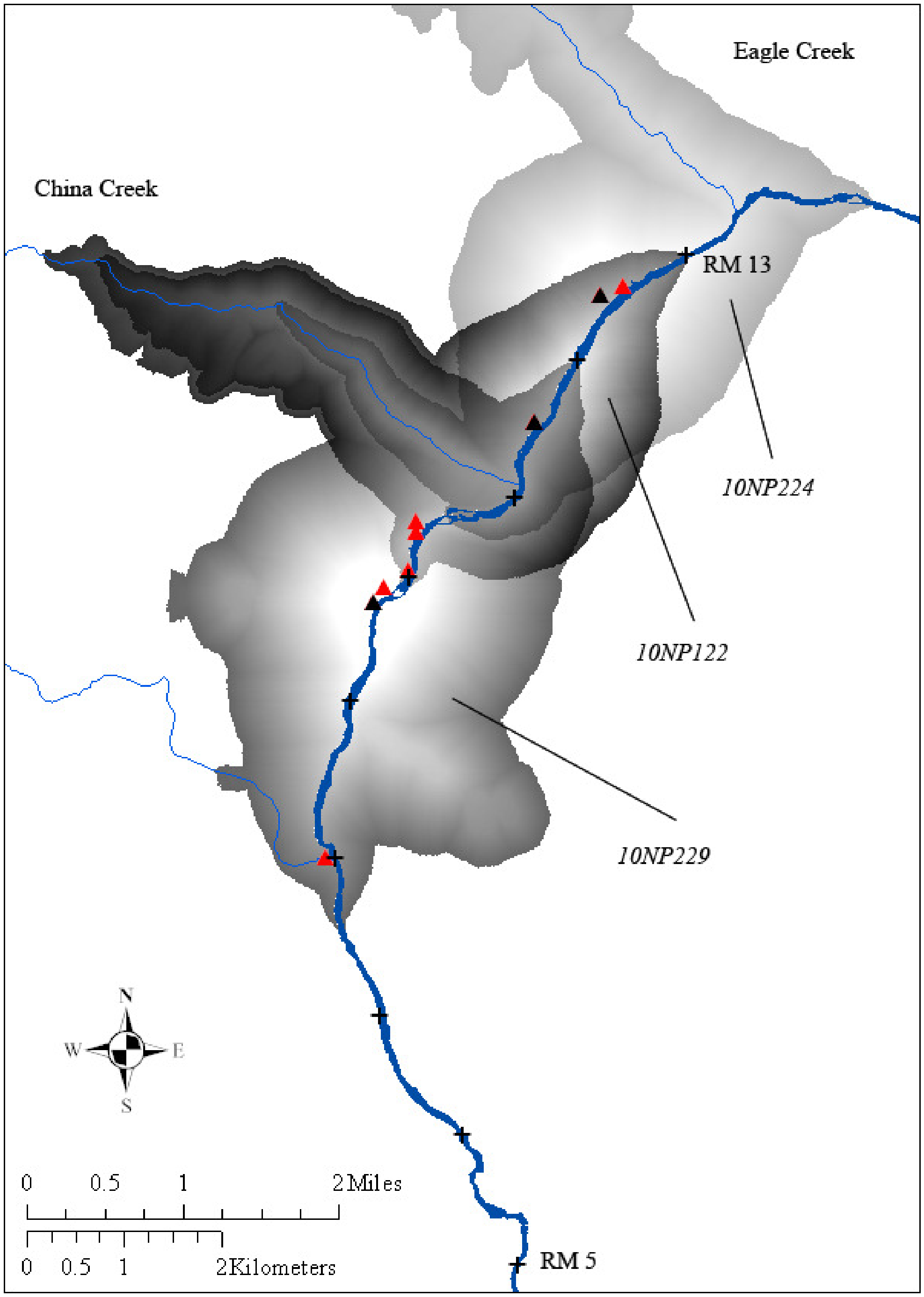

Figure 27. Distribution of pithouse sites (shown as triangles) and selected optimal exploitation polygons in the lower study section. Black triangles represent the originating sites (10NP224, 10NP122, and 10NP229) of the labeled OEPs.

total accumulative "cost" values of the pithouse site optimal exploitation polygons. Comparatively, the non-site optimal exploitation polygons located downstream have high total accumulative "cost" values, indicating low payoff potential.

In the middle study section, well over half of the pithouse sites (11 of 16) are found between RM 35 and 43. Drainages in this stretch feature relatively greater expanses of forest and forest/grassland ecotone, extending closer to river, than anywhere else in the section (Figure 28). The total accumulative "cost" values of pithouse site optimal exploitation polygons in this stretch are the lowest in the entire section, reflecting the relatively higher payoff potential.

The remaining few pithouse sites are located in the lower payoff stretch of the section extending upstream from approximately RM 45. From approximately RM 45 to 48, drainages on both sides of the canyon contain high payoff habitat. However, it is less extensive and is further removed upslope from the river than in the lower stretch. The four sites in this area (10IH796, 10IH783, 10IH787, and 10IH387) have higher total accumulative "cost" values than downstream. The higher total accumulative "cost" values probably also reflect the generally steeper terrain along the river in these river miles. From roughly RM 48 to 53, small patches of high payoff habitat occur in the upper elevations of some drainages on the left side of the river. Unsurprisingly, the site in this stretch, 10IH789, has one of the highest total accumulative "cost" values in the section.

The lack of pithouse sites in RM 39 may be attributed to the steep terrain south of the river and/or private land ownership to the north, while the absence of pithouse sites between RM 43 and 45 is likely due to the steep slopes extending down to the river on both sides.

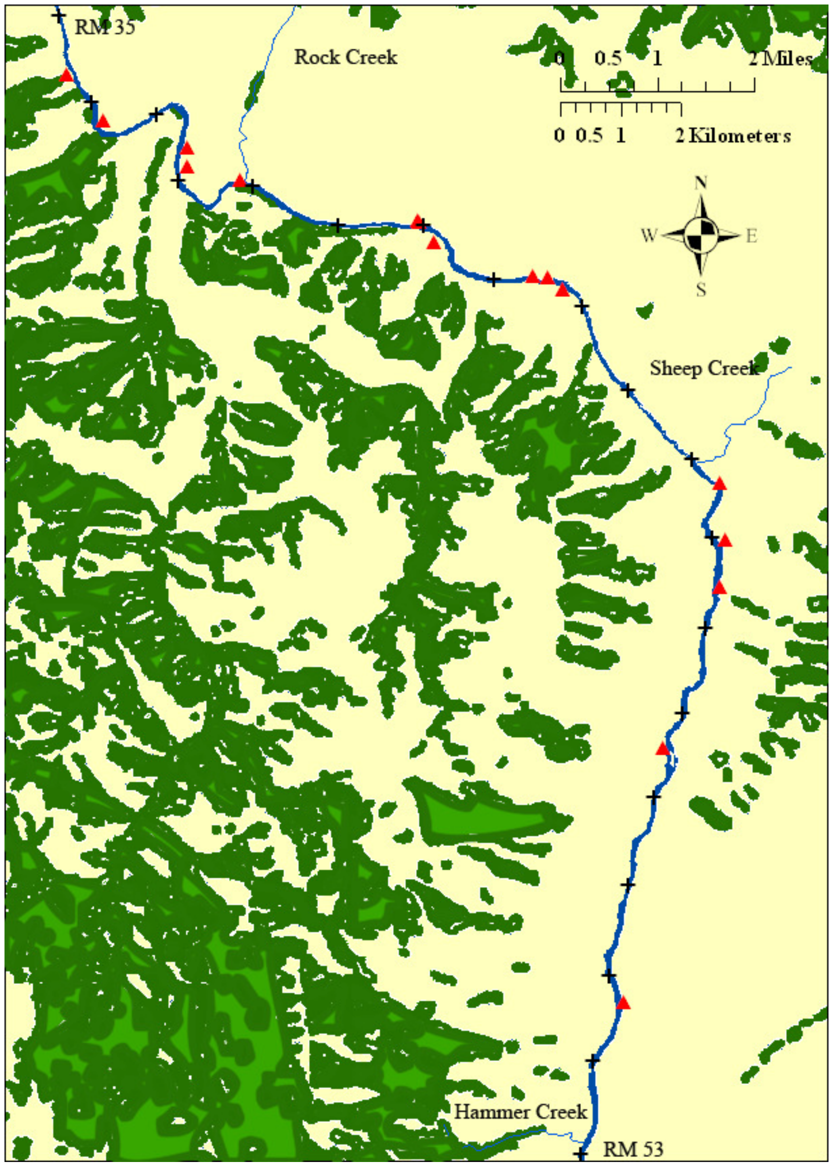

Figure 28. Distribution of pithouse sites (shown as red triangles) relative to forest cover (light green) and forest/grassland ecotone (dark green) in the middle study section.

It is clear that the distribution of forest and forest/grassland ecotone in the middle study section offers different levels of hunting payoff depending on pithouse site location. This being the case, why are not all the pithouse sites restricted to thedownstream, higher payoff stretch? Most, in fact, are located in that higher payoff stretch further supporting the idea that winter village sites were placed to allow optimal access to elk and deer. The positioning of the remaining village sites could be attributed to the desire to reduce resource competition with other villages established in the higher payoff areas. This, of course, assumes contemporaneity of occupation among the various winter village sites in each stretch. It is also possible that access to higher payoff areas was restricted by local villages claiming "ownership" through usufruct, or use-right (Schwede 1970). On the other hand, perhaps villages could be placed in lower payoff locations because sharing or trading between specific villages occurred. Groups at different drainages could have shared access to resources or exchanged resources to mitigate shortfalls associated with the locations of the respective villages. Alternatively, the occupants at lower payoff village sites may not have been concerned with maximizing hunting return and placed greater weight on other positioning factors.

In comparison to the lower and middle sections, the distribution of pithouse sites in the upper section is widely dispersed. This would be expected given the relatively continuous forest cover on both sides of river (Figure 29). There are three gaps where no pithouse sites are recorded: RM 91 to RM 97, RM 98 to RM 100, and RM 104 to approximately RM 110. These may be explained by a combination of factors. The gap between RM 91 and RM 97 appears to be a function of a lack of high payoff habitat,

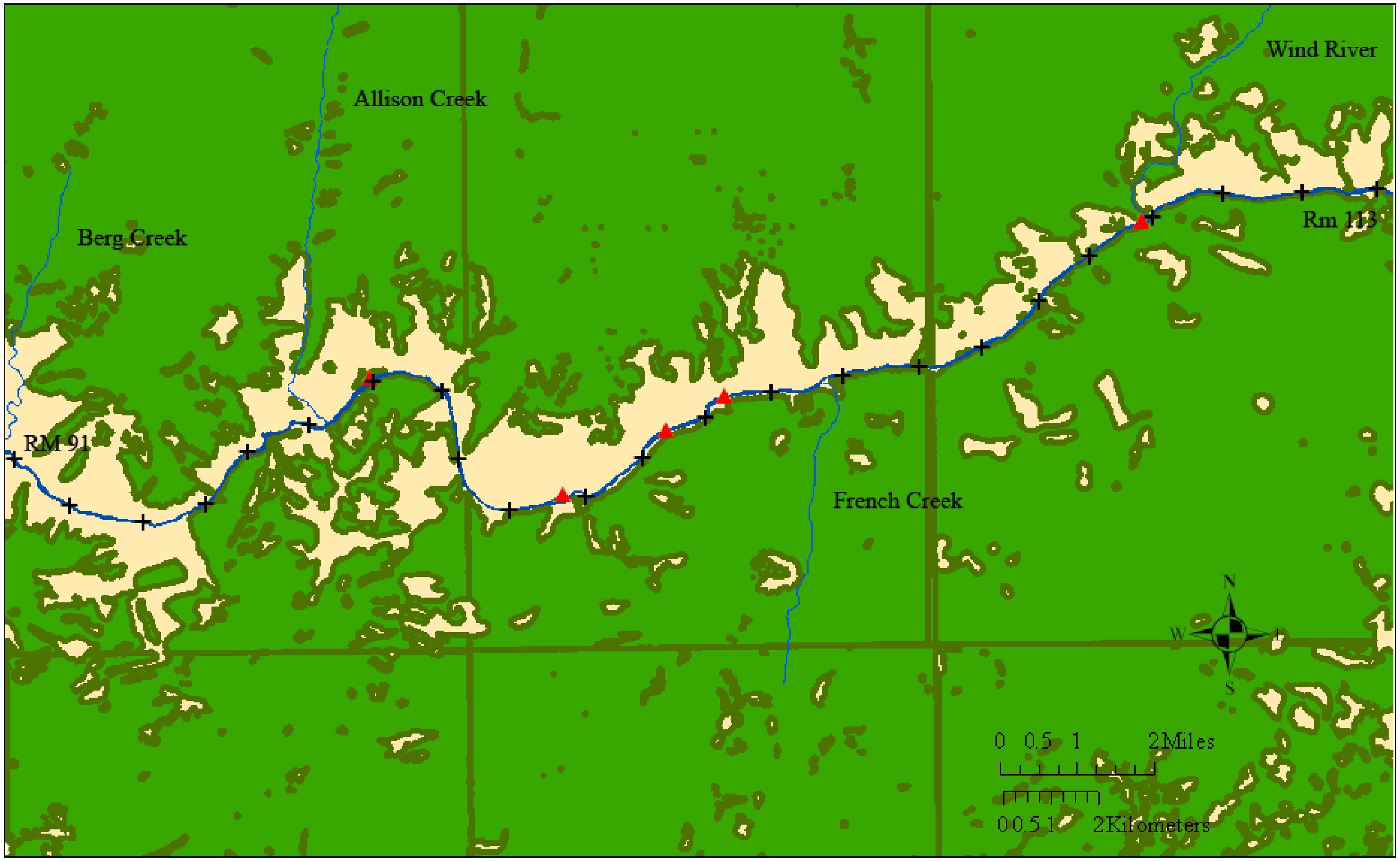

Figure 29. Distribution of pithouse sites (shown as red triangles) and forest cover in the upper study section. Pithouse sites are relatively dispersed in this part of the canyon, presumably because of the more homogeneous distribution of game produced by the continuous forest cover and overall low economic payoff for hunters.

rugged topography, land ownership, and possibly site classification. From RM 91 to almost RM 94, large expanses of open grassland occur on both sides of the river, creating a lower payoff environment. This is reflected in the high total accumulative "cost" value for the non-site optimal exploitation polygon that encompasses this stretch. Just downstream of RM 94 and continuing to immediately downstream of RM 95, forest cover extends to the river on the left side of the canyon. This would appear to be a high payoff area, but the canyon slopes steeply on the left side, and there are limited or no habitable landforms along the river. Broad terraces and beaches are available in RM 95, and lobes of forest cover extend down to the river, creating a high payoff environment where a pithouse site should occur. However, private property extends along both sides of the river in this stretch, and so it is not considered in my analysis. Finally, it is possible that two of the three non-pithouse sites identified in RM 96, featuring depressions and prehistoric material, may actually be pithouse sites. The available site information, though, does not provide the details necessary to satisfy the criteria that I established for classification as a pithouse site.

The other two gaps in pithouse site distribution appear to the product of land ownership and topography. Locations with high potential for pithouse sites along the left side of the river in RM 98 and RM 104 are excluded from my analysis due to private ownership. The remaining stretches of river corridor bisect extremely steep terrain lacking habitable landforms.

Question 2: How might a central place foraging strategy have worked given the environmental context proximal to villages in different parts of the canyon?

It has been established that within the LSRC physiographic structure (elevation, topography, aspect) influences the type and distribution of vegetation cover, thus conditioning where and in what density elk and deer will be found in the landscape. This has implications for how economically motivated hunters seeking game may have moved within the site exploitation territory to enhance their chances of success and most efficiently secure prey.

The distribution of forest cover and forest/grassland ecotone in the lower section is heterogeneous. Elk and deer under these conditions are concentrated in certain parts of the landscape. Hunters looking to maximize payoff would focus on these areas, in the same manner that task groups in a collector system target specific resources in specific contexts (Binford 1980: 10). The extremely irregular constricted shapes of optimal exploitation polygons modeled in this section illustrate the hypothetically preferential movement of this "collector" mobility strategy.

In the upper section, elk and deer may have been much less concentrated in the landscape because forest cover is fairly uniformly distributed. Generally speaking, most areas of the upper section offer similar chances of encountering an animal, thus homogenizing the potential payoff across space. In this environment, hunters are expected to employ a "forager" mobility strategy and range widely in search of game. The optimal exploitation polygons in this section more closely approximate site exploitation territories (which reflect solely the effect of topography on forager mobility) in size and shape. This is because the structure of resource distribution exerts less influence on hunter movement. Thus, hunters probably had to move over greater distances more often to exploit game.

The distribution of forest cover and forest/grassland ecotone is heterogeneous in middle study section. However, the size and frequency of patches is extremely variable throughout section, more so than in the lower study section. In the lower end of the middle section, forest cover occurs in large adjacent patches, which are restricted to the south side of river. Hunters based out of villages in this stretch could be expected to employ a hybrid "forager/collector" mobility strategy in which they ranged broadly exploiting key areas. Hunter mobility should become increasingly focused and "collector-like" as forest patches become increasingly small and dispersed upstream. This change in strategy is reflected in the variability of optimal exploitation polygon shapes across the study section. Optimal exploitation polygon shapes in the lower end of the section are generally more rounded, while those in the upper end are irregular.

Question 3: What archaeological signatures might have been generated by a central place foraging strategy?

According to Binford's collector-forager model (Binford 1980), several types of sites should be produced in association with hunting under a central place strategy. These include stations, which are used for observing game in order to guide the movement of hunters, and locations, where game is killed and perhaps processed. If enough game is procured that a hunter or hunters are unable to transport it all back to the village at once, the bulk may be stored for later retrieval. This would produce a third type of site, the cache.

Where these auxiliary sites are generated in the landscape is a function of hunter mobility, which is closely related to the distribution of game as described in the previous section. In environments where game is heterogeneously distributed, prompting hunters to preferentially exploit key areas, these sites should occur in a focused pattern in the landscape. This is the signature expected in the lower as well as middle study section. (It may be that in the downstream stretch of the middle section, where hunter movement is not as focused due to the less restricted distribution of game, the sites may exhibit a more dispersed pattern.) Comparatively, in environments where game is homogeneously distributed and hunters range widely in the landscape, hunting-related sites should occur in an essentially random "shotgun" pattern in the landscape.

Question 4: How can this knowledge contribute to a greater understanding of the archaeological record in the LSRC and the larger Columbia River Plateau?

This thesis contributes to a greater understanding of the late Holocene archaeological record in the LSRC by articulating in a testable manner how late prehistoric hunter-gatherers may have selected the locations of their winter villages and strategically used their environment during the winter to satisfy their economic needs.

The models generated in my analysis do not identify how hunter-gatherers in the canyon did behave in the past, but identify how they might have behaved if they were seeking to maximize the return of supplemental foraging activities. Thus, they have heuristic rather than substantiative value. If these models are verified, it can be inferred that prehistoric hunter-gatherers in the LSRC and, by extension, on the Columbia River Plateau were concerned, at least to some degree, with the economics of supplemental foraging when choosing locations for winter villages. This is an idea that has been suggested by other archaeological and ethnographic studies but not demonstrated to any extent until now.

Testing the validity of the optimal exploitation polygons is a task that should be undertaken in the future. This could be accomplished by the following procedure: first, systematically survey portions of the canyon contained within pithouse site exploitation territories to identify the spatial distribution of hunting-related sites; second, use pithouse site optimal exploitation polygons to generate a "sensitivity" map that classifies the canyon landscape in terms of expected concentration of auxiliary hunting sites (Figure 30); finally, compare the spatial variation in relative density of hunting-related sites independently predicted by the map and observed in the field for correlations. The "sensitivity" map would have practical as well as research application. Federal agencies in the LSRC could use the map to guide survey efforts as they inventory cultural resources on their lands or attempt to assess possible impacts to resources by development or natural processes.

There is a range of questions that could be productively addressed in future applications of the optimal exploitation models. For example, is it possible to correlate fixed facilities, such as stations, caches, hunting blinds, and chutes, to heterogeneous environments where hunters are expected to employ a "collector" mobility strategy?

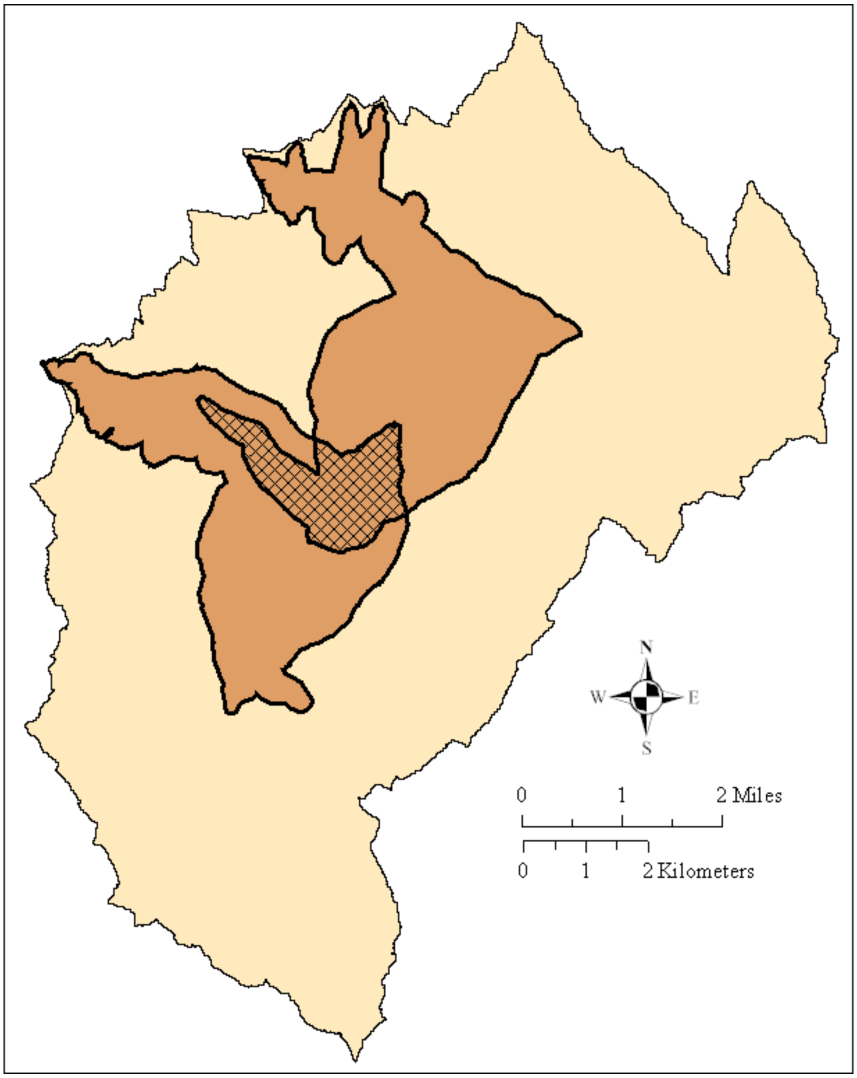

Figure 30. Map showing the expected concentrations of auxiliary hunting sites in part of the lower study section. Although multiple optimal exploitation polygons may overlap in a given area, only two are used here to illustrate the process. The highest concentration of sites would be expected where the two optimal exploitation polygons overlap (shown with cross-hatching) as this would be an area utilized from both villages. A medium concentration of sites would be expected in the non-overlapping portions of the optimal exploitation polygons (shown in brown) since usage in these areas would originate from only one village. The lowest concentration of sites would be expected in the non-optimal areas of the site exploitation territories associated with each site (shown in beige).

This is expected to be the case in areas of the canyon like the lower study section where the distribution of game in the landscape is more predictable.

Another question that could be addressed is how a change in the surface area of different game habitats would change the total accumulative "cost" values and optimal exploitation polygon shapes for pithouse sites. The models generated in my analysis are based on the modern extent of forest cover in the canyon. This has undoubtedly been influenced at the local level by historic and modern activities. It would be worthwhile to identify a range in potential payoff and hunter mobility strategies for each pithouse site as a way to account for the possible variation in vegetative cover over time. This would involve modeling greater and lesser expanses of forest cover in GIS. It is possible, for example, that prehistoric hunter-gatherers regularly burned forested areas in the landscape to create more forest/grassland ecotone, the optimal habitat for elk and deer. If this practice were then curtailed historically, the result would have been an expansion of forest cover at the expense of ecotone. Thus, the current forest/grassland ecotone surface area in the canyon may be less than what was present in the past. This scenario can be modeled in GIS by widening the ecotone buffer in the habitat cost raster (see "Analysis Procedure" in Chapter 4). Increased ecotone surface area could be expected to produce lower total accumulative "cost" values, reflecting the higher potential payoff of the surrounding landscape, and possibly more rounded optimal exploitation polygon shapes, due to the broadening of optimal payoff hunting routes. Conversely, ranching could have caused an increase in the amount of grassland at the expense of forest cover and forest/grassland ecotone in some areas. Reducing the size of forest patches in the habitat cost raster should produce higher total accumulative “cost” values, reflecting the lower potential payoff of the surrounding landscape, and perhaps greater irregularity in the shape of optimal exploitation polygons, due to the greater localization of optimal payoff hunting routes.

The utility of the GIS modeling methodology described in this thesis is not restricted to the LSRC, a specific time period, or a particular resource. It is a tool that can be applied to residential sites of various ages anywhere on the Columbia River Plateau to examine the relationship between hunter-gatherer subsistence and settlement patterns. Some modification will be necessary in cases where sites date to periods when climatic conditions were significantly different than the present, or are located in environments where vegetation cover has been significantly altered through historic or modern land use. In these instances, it would be inappropriate and unproductive to model the distribution of a food resource using data relating to the modern environment. Instead, the paleoenvironmental context must be established. This may be accomplished by analyzing proxy records of past climatic conditions and vegetation types in the form of pollen, phytoliths, stable isotopes (contained in soil carbonate), and sediment grain size (Davis 2001a).

To conclude, this thesis sought to provide insight into the question of how hunter-gatherers utilized the lower Salmon River Canyon (LSRC) in west-central Idaho during the late Holocene. Specifically, it examined whether the positioning of winter villages was related to the relative success of winter hunting in variously structured canyon environments.

The winter village was conceptualized as the central location from which hunting activities could take place to supplement winter food stores. Drawing on optimal foraging theory and site catchment analysis, models were developed in GIS that were used to a) evaluate optimality of village site location in terms of facilitating access to high payoff hunting areas in the surrounding landscape, and b) identify how hunters may have moved within the site exploitation territory to enhance their chances of success and most efficiently secure prey given the spatial distribution of game.

The results of the analysis suggested that in portions of the canyon where the environmental structure creates spatial inconsistency in the type and distribution of game habitat, villages may have been positioned to facilitate easy access to areas in the landscape providing a relatively greater chance of hunting success. Furthermore, a relationship between hunter mobility strategy and local environmental structure was observed based on patterns in the optimal hunting payoff-related movement modeled in GIS. The GIS models supported general predictions for the spatial distribution of hunting-related sites in the landscape surrounding winter village sites, which can easily be tested through archaeological survey, and thus used to evaluate the overall veracity of the models.

This thesis contributes to a greater understanding of the archaeological record in the LSRC as well as elsewhere on the Columbia River Plateau. It clarifies, using testable models, how late prehistoric hunter-gatherers in the canyon may have selected the locations of their winter villages and strategically used their environment during the winter to satisfy their economic needs. It also provides a GIS modeling methodology that can be applied to sites of varying ages throughout the Plateau to examine the relationship between hunter-gatherer subsistence and settlement, and thus enhance archaeologists' ability to reconstruct past lifeways.

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Global Mapper
http://www.globalmapper.com

Interactive Numeric and Spatial Information Data Engine Idaho
http://inside.uidaho.edu/

United States Army Corps of Engineers Coordinate Conversion (Corpscon 6.0)
http://crunch.tec.army.mil/software/corpscon/corpscon.html

United States Geologic Survey, National Elevation Dataset
http://ned.usgs.gov/

United States Geologic Survey, National Hydrography Dataset
http://nhd.usgs.gov/

VassarStats: Website for Statistical Computation, Mann-Whitney Test
http://faculty.vassar.edu/lowry/utest.html

APPENDICES

Appendix A. Data Sources

Topographic Data
Digital raster graphics provided on CD by the BLM, Cottonwood Field Office:
Raster
NAD 1983 UTM Zone 11N
North American Datum of 1983
1:24,000
and downloaded from INSIDE Idaho:
Raster (compressed in .tgz format)
NAD 1927 UTM Zone 11N
North American Datum of 1927
1:24,000

Elevation Data
Digital elevation models downloaded from INSIDE Idaho
(http://insideidaho.org/data/USGS/NED/10m/archive/ned10m_tile03_usgs.tgz)
(http://insideidaho.org/data/USGS/NED/10m/archive/ned10m_tile04_usgs.tgz)
ESRI Grid
GCS North American 1983
North American Datum 1983
~10 meter resolution

Hydrographic Data
Downloaded from the USGS National Hydrographic Dataset (by 7.5' quad)
Shapefile
GCS North American 1983
North American Datum of 1983
1:24,000 (i.e. "high resolution")

Land Stewardship Data
Provided on CD by the Landscape Dynamics Lab, University of Idaho at Moscow
Vector Coverage
Transverse Mercator
North American 1927
1:100,000

Archaeological Site Data
Site records provided by BLM Cottonwood Field Office and Nez Perce National Forest
Digital format (PDF and Microsoft Access database) and photocopies

Appendix B. Results of Mann-Whitney Test

Lower Study Section

VassarStats Printable Report
Mann-Whitney Test: $n_a = 9$; $n_b = 5$
Sun May 20 16:06:40 PDT 2007

Data Entered:

	Ranks for		Raw Data for	
count	Sample A	Sample B	Sample A	Sample B
1	1	9	10600	17100
2	2	10	12400	17600
3	3	11	12600	18000
4	4	12	12700	18600
5	5	14	13300	19400
6	6		13900	
7	7		14800	
8	8		15100	
9	13		19000	

Mean Ranks for	
Sample A	Sample B
5.4	11.2

Note that mean ranks are provided only for descriptive purposes.They are not part of the Mann-Whitney test.

$U_A = 41$ $z = -2.4$ $P_{(1)} = 0.0082$ $P_{(2)} = 0.0164$

Critical Values of U for na=9; nb=5

	Level of Significance for a		
	Directional Test		
	.05	.025	.01
	Non-Directional Test		
	--	.05	.02
lower limit	9	7	5
upper limit	36	38	40

Middle Study Section

VassarStats Printable Report
Mann-Whitney Test: $n_a = 16$; $n_b = 5$
Sun May 20 16:12:19 PDT 2007

Data Entered:

	Ranks for		Raw Data for	
count	Sample A	Sample B	Sample A	Sample B
1	1	4	8700	10600
2	2.5	11	10100	13800
3	2.5	16	10100	16800
4	5	20	11400	18500
5	6	21	11700	18700
6	7		11800	
7	8		12400	
8	9		13000	
9	10		13200	
10	12		14400	
11	13		14500	
12	14		14800	
13	15		15900	
14	17		17800	
15	18		18200	
16	19		18300	

Mean Ranks for	
Sample A	Sample B
9.9	14.4

Note that mean ranks are provided only for descriptive purposes.They are not part of the Mann-Whitney test.

$U_A = 57$ $z = -1.36$ $P_{(1)} = 0.0869$ $P_{(2)} = 0.1738$

Critical Values of U for na=16; nb=5

	Level of Significance for a		
	Directional Test		
	.05	.025	.01
	Non-Directional Test		
	--	.05	.02
lower limit	19	15	12
upper limit	61	65	68

Upper Study Section

VassarStats Printable Report
Mann-Whitney Test: $n_a = 5$; $n_b = 5$
Sun May 20 16:18:06 PDT 2007

Data Entered:

	Ranks for		Raw Data for	
count	Sample A	Sample B	Sample A	Sample B
1	2	1	9400	8300
2	3	5	10100	10500
3	4	7	10400	10900
4	6	8	10800	11300
5	9	10	11500	12200

Mean Ranks for	
Sample A	Sample B
4.8	6.2

Note that mean ranks are provided only for descriptive purposes.They are not part of the Mann-Whitney test.

$U_A = 16$ $z = -0.63$ $P_{(1)} = 0.2643$ $P_{(2)} = 0.5287$

Critical Values of U for na=5; nb=5

	Level of Significance for a		
	Directional Test		
	.05	.025	.01
	Non-Directional Test		
	--	.05	.02
lower limit	4	2	1
upper limit	21	23	24