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ABSTRACT

A Predictive Model Of Paleo-Indian Subsistence And Settlement

by

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Multi-criteria/multi-objective predictive models constructed within a Geographic Information System (GIS) have been used successfully to predict the location of archaeological sites. However, such models often lack explanatory power and are unable to identify the range of behaviors occurring at the archaeological sites they locate. Making use of the multi-criteria/multi-objective decision support tools found within the GIS environment, this research presents a model for simulating behaviors resulting from the decisions hunter/gatherers make about resource use and settlement placement. Thus, the model is able to predict what types of sites or activity areas should be expected within a region based on a hypothesized hunter/gatherer adaptive strategy. Because the model is rooted in an anthropological decision-based behavioral model, the approach is able to accommodate human decision-making process.

The behavioral model outlined within this research is subsequently used to simulate regions suitable for early Paleo-Indian resource use and settlement across Lower Michigan. Simulations were generated for three primary hypotheses with detailed paleoenvironmental models of key floral and faunal species habitats as input. The resultant models were compared with the distribution of archeological remains located throughout Lower Michigan to predict which strategy, or strategies, was most likely utilized by early hunter/gatherers occupying the region. The results of these simulations demonstrate that early Paleo-Indians utilized a settlement strategy that incorporated

characteristics of both logistical and residential mobility. The distribution of activity areas also indicates that early hunter/gatherers engaged in both a focal and diffuse economy.

In Memory of Stanley A. Herdus and Dr. Jerome A. Voss
For Leslie and my family, thanks for always being there!

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Chapter I

INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION

A rapidly changing environment of glaciers, immense melt-water channels, huge waterfalls, and a wide variety of animal species, including mammoths and mastodons, occupying a patchwork of boreal and deciduous forests, characterized the surroundings of Paleo-Indian peoples residing in eastern North America (Kelly and Todd 1988). Throughout North America during the late Pleistocene, plant and animal communities were typified by a greater diversity and number of species along with larger individuals such as the extinct giant beaver, mammoth, and mastodon (Guthrie 1984, Kelly and Todd 1988). Despite this diversity of vegetation, however, Pleistocene boreal forests contained mostly inedible vegetation. As Paleo-Indian peoples began their initial occupation of the Great Lakes ca 11,000 BP, the diverse patchwork of plant and animal species was becoming more allopatric due to the pronounced differences in seasons (Kelly and Todd 1988). By the Paleo-Indian period (11,000-10,000 BP), nearly thirty-five mammalian genera had become extinct in North America (Holman 1995, Kelly and Todd 1988, Meltzer and Mead 1983).

Despite a much harsher climate and a level of material culture far simpler than that of Europeans, Paleo-Indians were able to permanently occupy much of North America within three centuries or less (Shott and Wright 1999). While this makes Paleo-Indians an interesting group to study, it also makes them a challenging culture to investigate. This is due in part to the rapidly changing environment that required Paleo-Indians to develop an adaptive strategy unlike that of any modern hunter/gatherers (Kelly and Todd 1988). In addition to confronting the adaptive challenges of a rapidly changing landscape, Paleo-Indian groups dealt with periodic resource stress. Unlike modern hunter/gatherers, Paleo-Indians frequently moved into new territories utilizing unfamiliar tracts of land. According to Kelly and Todd (1988), this resulted in a Paleo-Indian adaptive strategy relatively undifferentiated throughout a particular region, such as the Great Lakes. In other words, Paleo-Indian peoples did not stay in a single defined economic territory long enough to selectively utilize the landscape's resources. Kelly and Todd (1988) also suggest that Paleo-Indian groups entering unexplored and unpopulated terrain relied heavily on faunal resources, although not exclusively megafauna. They base this assertion on the assumption that with a general knowledge of animal behavior, in previously unexplored regions it is easier to locate, procure, and process faunal resources than plant resources. Kelly and Todd argue that this is due to the fact that animals are generally available throughout the year and that meat and hide processing are relatively constant among various faunal species. This may not have been the case across the Great Lakes region, however, where seasonally available migratory caribou likely played a significant role in early Paleo-Indian subsistence.

According to Kelly and Todd (1988), the adaptive strategy of early hunter/gatherers was relatively consistent throughout North America with a similarity between Paleo-Indian lithic assemblages. This strategy had characteristics of both forager and collector strategies with no evident modern analogs. Paleo-Indians, like foragers, were highly mobile and engaged in similar activities from place to place. The hypothesis that Paleo-Indians primarily used search-and-encounter hunting techniques without storing surplus resources, if correct, also supports the notion that early hunter/gatherers were foragers. The frequent use of logistical forays and the presence of a complex technology, including the exchange of lithic raw materials, suggest that the Paleo-Indian adaptive strategy was also similar to collector systems. Rather than arguing for a single Paleo-Indian adaptive strategy, Meltzer and Smith (1986) illustrate that two distinctly different strategies were likely employed by hunter/gatherers occupying Eastern North America. The first strategy takes advantage of the diverse resource base found within the complex mosaic of boreal/deciduous forests that occupied much of eastern North America. In the northern reaches of Eastern North America, the utilization of a specialized hunting strategy occurred in the tundra/tundra forest ecotone that contained a low diversity of highly rich species. The hypotheses that Kelly and Todd (1988) and Meltzer and Smith (1986) put forward remain relatively untested (Jackson and McKillop 1991) because there have been few regional studies of early Paleo-Indian period site distributions in the Great Lakes and eastern North America.

1.2 PRINCIPAL OBJECTIVES AND PROBLEM TO BE ADDRESSED

Thus far much of the archaeological and ethnographic analysis preformed in Paleo-Indian studies has been inadequate. Traditionally, in both Eastern and Western North America, Paleo-Indian period studies have been influenced by archaeological data gathered from large sites, which often include the remains of large game (Bamforth 1988). An overemphasis on large Eastern sites, such as Debert, Parkhill, and Holcombe led to a wide acceptance that Paleo-Indian groups engaged in a caribou-based subsistence strategy (Jackson and McKillop 1991). Despite the emphasis on caribou, there have been few studies utilizing detailed environmental reconstructions to adequately test this hypothesis.

Ethnographic data are often used to interpret archaeological evidence from the Paleo-Indian period (Kelly and Todd 1988, Peers 1986, Simons 1997). Utilizing relatively recent ethnographic accounts for direct explanatory analogs and comparisons to the archaeological record is problematic, however, because Paleo-Indian period groups coped with a rapidly changing landscape requiring a subsistence strategy unlike that of any modern hunter/gatherers (Kelly and Todd 1988). In general, the use of ethnographic analysis for interpretations may be problematic, leading to biases in the interpretation of the archaeological record. According to Wobst (1978), using ethnographic data to decipher the past places a perceived ethnographic reality or construct into the interpretation of past hunter/gatherer lifeways.

This study examines some of the assumptions Paleo-Indian research has been constructed around within eastern North America. In addition to guiding research strategies these assumptions have created an idyllic view of Paleo-Indian lifeways within the Great Lakes region. By testing these assumptions this research will go beyond preconceived notions presenting new interpretations of early hunter/gatherer subsistence and settlement strategies. To accomplish this goal, three alternate hypotheses of Paleo-Indian resource use and settlement strategies within the Great Lakes region will be tested. The first two hypotheses suggest that Paleo-Indians were highly mobile foragers utilizing an adaptive strategy focused on large game, in particular migratory caribou (*Rangifer tarandus*) and mastodon (*Mammut americanum*) (Deller and Ellis 1992, Fisher 1981, 1984, 1987, Jackson 1997, Kelly and Todd 1988, Overstreet 1998, Storck and Spiess

1994, Simons 1997). Because of the current debate over the role of these large game species in Paleo-Indian subsistence, a strategy reliant on caribou is examined in the first hypothesis and a strategy reliant on both caribou and mastodon examined in the second hypothesis. The third hypothesis tests the assumption that Paleo-Indians were highly mobile generalized foragers subsisting on a variety of both large and small game and plant resources (Kuehn 1998, Meltzer and Smith 1986).

The specific objectives of this research are:

(1) To develop an approach with the ability to simulate the behavior of hunter/gatherers based on the decisions or adaptive strategy they choose in various real world settings.

(2) To use the preceding approach to generate a series of models that simulate the behavior of Paleo-Indian period peoples in the lower Great Lakes based on the three alternate hypotheses about Paleo-Indian resource use and settlement strategies presented in this research.

(3) To compare the resultant models of Paleo-Indian period adaptive strategies with the spatial distribution of archaeological remains to determine which strategy or strategies were most likely utilized by early hunter/gatherers in the lower Great Lakes, a best-fit test of derived models with observable archaeological data.

Unlike other approaches, the research design provides an efficient means for interpreting the settlement systems of hunter/gatherers without a reliance on direct comparisons between specific ethnographic and archaeological data sets (Binford 1980, Keene 1981, Kelly 1995). Rather, this approach, following the lead of Jochim (1976), considers hunter/gatherer subsistence and settlement behaviors the result of an adaptive strategy with a series of embedded decisions, chosen for its ability to resolve problems, while meeting various objectives/goals (Figure 1.1). Therefore, this approach provides a way to simulate the adaptive responses, or behaviors, of hunter/gather groups resulting from the utilization of a particular strategy, or strategies, in a particular "real world" setting, or settings. Bettinger (1980) forcefully argues that traditional hunter/gatherer models have been unsuccessful in this area. In addition, the proposed model's ability to provide a detailed understanding of Late-Pleistocene/Early Holocene environments allows the determination of how the environment may have influenced the adaptations of Paleo-Indian period groups (Storck and Spiess 1994).

This research is applicable to general hunter/gatherer studies in several ways. First, the approach provides an alternative to more traditional models of hunter/gatherer adaptive strategies dependent on archaeological or ethnographic data (Bettinger 1991). Due to site formation processes and data recovery methods, models constructed solely from archaeological data may contain biases or inaccuracies as a consequence of regional and local taphonomic processes (Keene 1981, Raab and Goodyear 1984). For example, due to leaching and natural disturbances, such as root and rodent activity, features including fire/refuse pits or post molds are rare at Paleo-Indian period sites (Deller and Ellis 1992). Using cartographic reconstructions of physiographic features or landforms, floral and faunal habitats, the goals/objectives of hunter/gatherers and their adaptive strategies as inputs into the model, predictions about early Paleo-Indian behavior can be inferred without relying solely on either ethnographic analogies or a direct comparison between the ethnographic and archaeological record. Rather than taking comparisons between the ethnographic and archaeological record at face value, an effective model enables the archaeologist to test hypotheses about past human behaviors even in regions with a poor archaeological record or few excavated sites. Second, the approach is dynamic, with the ability to simulate hunter/gatherer behaviors for any given time. Third, the model presented is flexible, accommodating a wide range of hunter/gatherer

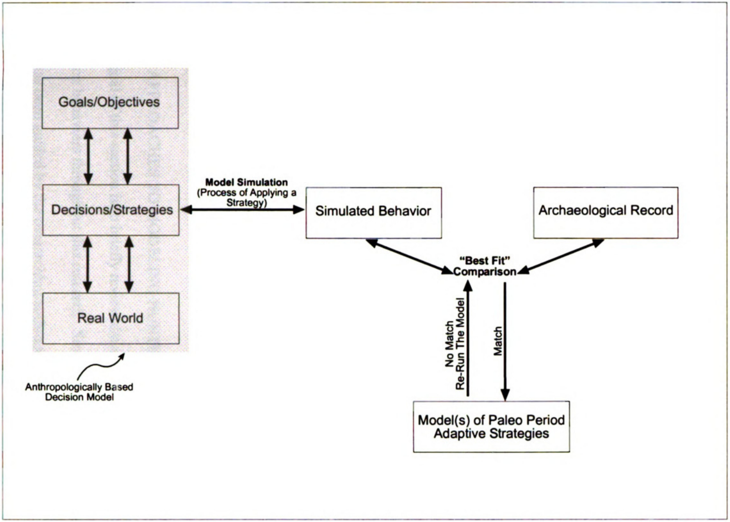

Figure 1.1. The Approach Advocated In This Research, Which Simulates The Behavior Of Hunter/Gatherers

adaptive strategies and goals/objectives. By varying the dominant resource(s), goals/objectives, and adaptive strategies that are entered into the model, different cartographic simulations of settlement patterns can be generated for comparison with the spatial distribution of archaeological sites. The researcher may then test hypotheses about past human behaviors, such as the assumption that Paleo-Indian peoples relied primarily on faunal resources that are easier to locate and procure than floral resources with their limited distributions and higher processing costs (Kelly and Todd 1988). The model is particularly useful for the study of Paleo-Indian period societies in which adaptive strategies may have differed significantly from modern groups on which Binford (1980) and others have based their models of hunter/gatherer adaptive strategies (Kelly and Todd 1988). Fourth, the systematic methodology employed here makes the model easy to use and the results replicable. Fifth, the research provides an alternate approach for determining settlement/subsistence strategies undertaken during the Paleo-Indian period, a time for which archaeological remains are limited (Storck and Spiess 1994). Lastly, this study demonstrates the utility of Geographic Information Systems (GIS) for generating decision-based models of hunter/gatherer adaptive behaviors.

1.3 MAJOR APPROACHES TO MODELING HUNTER/GATHERER BEHAVIOR

The goal of this section is to briefly review the major approaches used to model hunter/gatherer behaviors throughout this research. Since the development of these approaches has been guided by the overarching anthropological theories in place since the Man the Hunter Conference in 1968, a brief discussion of hunter/gatherer theory is in order. In addition to the original works, much of this discussion is drawn from Kelly's seminal work in hunter/gatherer studies *The Foraging Spectrum: Diversity in Hunter/Gatherer Lifeways* (1995).

Steward's cultural ecological approach, which first appeared during the 1950s, and Smith's behavioral ecology of the 1970s provided the theoretical backdrops that influenced the study of hunter/gatherers since the Man the Hunter Conference (Kelly 1995). Steward's (1955) cultural ecology, developed from a desire to better explain Kroeber's (1939) multilineal evolutionary culture area approach, in which different lines of cultural development resulted from occupation of dissimilar environments (e.g. different cultures often occupy different geographic areas). Unlike Kroeber, Steward felt he could explain how and why individual cultures evolve along parallel or divergent lines due to their surrounding environmental conditions. Steward focused on the "culture core", those behaviors interacting directly with the environment, such as tool making and hunting, which play a role in the construction of social behaviors such as ideology and kinship. Although cultural ecology began in the early 1950s, it was not until the 1960s that anthropologists developed a wide range of research strategies and theoretical approaches based on the assumptions subsumed under cultural ecology.

Cultural ecology is built on several major assumptions (Kelly 1995, Lee and DeVore 1968). First, hunter/gatherer adaptive strategies (culture core behaviors) are based on the goal that behaviors will produce an optimal result maximizing reproductive fitness. Secondly, an entire hunter/gather society is the level at which reproductive fitness will be maximized. In other words, individuals within a society are willing to sacrifice their reproductive interests, with practices such as infanticide and geronticide, to keep populations below the carrying capacity of the environment and thereby enabling the entire society to maintain itself. Third, cultural ecology is based on a group-selectionist perspective in which societies that "...remain in homeostatic balance with the environment..." will be selected for by evolutionary processes (Kelly 1995). Fourth, only behaviors within the culture core directly interact with the environment. Lastly, cultural ecology assumes hunter/gatherer societies have not been greatly affected by surrounding cultures.

There are several key weaknesses inherent in a cultural ecological approach. First, Steward's limited definition of the culture core made it difficult for anthropologists to identify and study core behaviors among hunter/gatherers. His definition was open to a wide range of interpretations and approaches to the study of hunter/gatherer adaptive strategies. This has been beneficial to hunter/gatherer research in many ways. Second, the assumption that evolutionary forces act primarily at the group level has limited the range of behaviors that anthropologists can use to explain the choices hunter/gatherers make. Lastly, the goals guiding or constraining decision-making are limited in scope by the assumption that hunter/gatherer adaptive strategies were oriented toward maximization of energy and resource returns.

Despite its limitations, cultural ecology has inspired and guided numerous field studies of hunter/gathers, such as the work in the Kalahari of Lee and DeVore (1979). These works have provided a wealth of information on hunter/gatherer settlement and subsistence. Cultural ecology also inspired the development of numerous methodological approaches, such as optimal foraging theory and ethnoarchaeology, used by anthropologists to explain and model hunter/gatherer behavior. Smith's behavioral ecology, developed in the 1970s and 1980s, is based on and resembles cultural ecology

(Kelly 1995, Smith 1991). Behavioral ecology is based on many of the same assumptions as cultural ecology and has strengthened cultural ecology. Unlike cultural ecology, the selective forces of evolution are assumed to act at the individual rather than group level. Therefore, personal decisions are the driving force behind hunter/gatherer decisions. Although behavioral ecology assumes that hunter/gatherer behaviors are based on a desire to produce an optimal result, behavioral ecology also recognizes that maximization can take on many forms and occur in a wide range of situations relating to individual fitness, dependent on the goals of the individual. For example, an individual may minimize time spent gathering, while maximizing time spent with children. The primary benefit of behavioral ecology is the ability to explain individual human behaviors under many circumstances.

1.3.1 ETHNOARCHAEOLOGICAL APPROACHES

While studying the settlement patterns of hunter/gatherers within the Kalahari, Yellen (1976) realized that ethnographic facts could aid archaeologists in the reconstruction of the past. Ethnographic data can be used in archaeology for hypothesis generation, as specific analogies, and may serve as a basis for further research. Yellen also pointed out that ethnographic data helps archaeologists devise methodologies for the recovery of cultural materials by preparing them for what to expect during excavation. For example, information such as site size, amount of remains, and the spatial arrangement of activities can be gleaned from the ethnographic record. Binford's *Nunamiut Ethnoarchaeology* (1978) formalized the utilization of ethnographic facts for archaeological interpretation by producing a set of guidelines for the use of ethnographic information in archeological models. By directly examining the behaviors of the Inuit and the remains these behaviors left behind, Binford generated "...concrete descriptions of the dynamics of behavior resulting in static patterning in the archaeological record." The guidelines Binford set forth greatly helped the development of, and brought credibility to, ethnoarchaeology. Ethnoarchaeology is a means through which ethnographically recorded behaviors are used to interpret archaeological data. For example, Binford recorded, among other things, the butchering techniques and refuse disposal patterns of the Nunamiut from which he formed opinions about what might be found in the archaeological record at a site utilized in a similar manner. By examining the spatial patterns left at a modern activity areas, archaeologists can construct models of past behavior that help give meaning to the archaeological record (Legge and Rowley-Conwy 1987).

The primary assumption of ethnoarchaeology is that human behaviors are uniformitarian, especially in areas where there is evidence of historical continuity between past and present. The modern culture being studied and the subsequent behaviors found within it are relicts of or similar to those which occurred in the past (Wobst 1978). As a result, the main weakness of ethnoarchaeology is that the ethnographic observations may not necessarily provide an accurate reflection of past activities. In many areas, surrounding cultures have severely compromised modern hunter/gatherer behavior (Myers 1987, Wilmsen and Denbow 1990, Woodburn 1978). Compounding the effects of modern cultures, the interviewer and the informant can both bias the ethnographic record (Wobst 1978). In addition, some archaeologists argue that the ethnoarchaeological approach focuses on only small and perhaps idiosyncratic singular events, without considering other social factors affecting what is seen ethnographically (Hodder 1986). Despite these minor limitations, if used with caution, an ethnoarchaeological approach provides an excellent means by which to generate hypotheses regarding the archaeological record from which interpretations or models of past behaviors may be constructed. Some anthropologists have adopted an ethnohistorical approach in which hunter/gatherers are located within history, deconstructing biases (Myers 1987). An ethnohistorical approach can, therefore, alleviate the limitations of ethnographic data has for the interpretation of archaeological data.

1.3.2 OPTIMAL FORAGING APPROACHES

Optimal forager models were first developed by ecologists during the 1960s to understand nonhuman foraging behavior (MacArthur and Piank 1966, Winterhalder and Smith 1981). These biological approaches explained the assumptions at work when organisms forage for food. Although these biological and ecological models were based on information from insects and animals, anthropologists adapted these approaches for the study of hunter/gatherer foraging behavior (Bettinger 1991, Kelly 1995). As optimal foraging theory developed, anthropologists borrowed other approaches from the biological sciences, such as Weins's (1976) patch choice model, to help strengthen the optimal foraging approach they were utilizing.

Optimal foraging theory is based on the assumption that hunter/gatherer foraging decisions are guided by the desire, or goal, to maximize energy intake while minimizing energy expenditures (Kelly 1995). To model this goal, resources are usually ranked based on their potential caloric value, with calories acting as a form of currency, or post-encounter return rate. The post-encounter return rate of a resource is the amount of energy gathered per unit time after encountering a resource. Binford (1978) outlined several problems with this approach. First, how much did past hunter/gatherers know, or think, about the environment in economic terms of costs and gains? Surely, past peoples were aware that the utilization of some resources over others would be advantageous to their survival. However, hunter/gatherers are unable to specifically count calories. In addition, calculating accurate post-encounter return rates is difficult for anthropologists, particularly for past societies for which little is often known about resource distributions and hunter/gatherer technologies (Jochim 1998). As a result, the caloric measures generated from optimal forager models should be used with caution because they may not be as accurate as their quantitative precision would suggest. Second, Binford illustrated that optimal foraging theory is inherently flawed, because it does not consider cultural values or how other cultures may have influenced human behavior (1978). A third shortcoming of optimal foraging theory is the assumption that maximization was the primary goal of hunter/gatherers while foraging. In reality, hunter/gatherers probably have set aspirations they attempt to satisfy, such as the attainment of a secure level of food (Jochim 1976).

Several types of optimal foraging models have been developed to help anthropologists determine how resources are utilized by hunter/gatherers (Bettinger 1991, Kelly 1995). These models are used singularly, or in conjunction with one another, as long as the underlying assumptions do not conflict with one another. The diet breadth model predicts whether a resource encountered by a forager will be utilized (Hawks and

Hill 1982, Kelly 1995, Smith 1991). In order to do this, the diet breadth model considers the caloric value for each potential food source in conjunction with the search and handling costs of that resource. The density of resources affects search costs, while handling costs are based on the amount of processing necessary, such as shelling nuts, needed to make a resource edible. Unfortunately, this model does not consider problems encountered while obtaining a resource. For example, how would foragers react if the deer they were tracking got away? Would foragers in this example turn to other resources? These types of questions may be addressed utilizing the patch choice model.

The patch choice model assumes that hunter/gatherers continue to evaluate choices while in pursuit of a resource, such as the lost deer in the example above. If the costs of obtaining the original resource become too high, that is if the pursuit costs for the deer are too high, an individual may decide to select another resource(s) to utilize (Hawkes et al. 1982). The primary objective of the patch choice model is to determine where and from what resource patch hunter/gatherers will obtain their resources. The Marginal-Value Theorem (MVT) is used to predict when a hunter/gatherer should abandon one area or patch for another (Kelly 1995). MVT indicates foragers leave a resource patch when the rate of harvest falls below the average for the entire environment.

Orians and Pearson's (1979) central place foraging model suggests that the focus guiding hunter/gatherer settlement placement was the proximity of economic resources. Central place foraging is based on the gravity model, that states peoples will move or gravitate to locations allowing better access to resources. This model assumes hunter/gatherers attempted to maximize their gains, while minimizing their caloric expenditures through the placement of settlements in locations that allow access to the greatest amount of available resources. The model considers the diversity and richness of resources when determining the costs of harvesting potentially available resources from a central location. The central place forager model also provides a means for anthropologists to simulate the potential locations of hunter/gatherer base camps. This type of model, however, has limited effectiveness because it assumes hunter/gatherers always placed their settlements centrally in relation to resources to maximize harvests.

Lastly, linear programming approaches, which utilize a series of linear equations, provide an efficient method to evaluate a complex set of dietary goals and criterion (food X contains Y amount of calories) in intricate detail (Keene 1981, Reidhead 1980). With the advent of computers, this approach has proved particularly useful when analyzing an array of dietary elements. Linear programming is more advantageous than other optimal foraging models because it accommodates caloric measures as well as other dietary information, such as the nutritional requirements of humans, to predict subsistence behavior. The output determines exactly how much of each resource is needed to meet a human's dietary requirements. However, with specific data on the dietary requirements of past societies often lacking and with only a minimal understanding of past environments, the actual precision of quantitative models such as linear programming is in question (Jochim 1998).

1.3.3 SATISFICER APPROACHES

The satisficer approach provides another means to model hunter/gatherer adaptive choices. Unlike optimal foraging theory, which assumes that economic maximization is a primary objective guiding hunter/gatherer behavior, satisficer models are based on the premise that hunter/gatherers make decisions to satisfy a desired aspiration(s) level (Jochim 1976). Satisfaction comes in many forms and may in fact include maximization of energy. However, more often, satisfaction comes from obtaining only what is needed. Satisficer models allow the anthropologist to evaluate resources based on their non-economic characteristics, such as taste, unlike optimal foraging models that focus on the costs and benefits of resources (Egan 1993, Jochim 1976). To date, the satisficer approach provides one of the best frameworks for the anthropologist to model hunter/gatherer decision making regarding what to eat and when and where to reside.

1.3.4 POLITICAL ECONOMY AND HISTORICAL REVISIONIST APPROACHES

Political economy and historical revisionist approaches have recently appeared in hunter/gatherer studies due to the realization that modern hunter/gatherers are not pristine isolates. Rather they are societies that have been affected by the cultures and political systems they encounter (Wilmsen and Denbow 1990). In other words, political economy and revisionism address concerns about the role outside cultures have played in changing the lifeway of modern hunter/gatherers. This approach calls for the careful examination of both social and political processes that have occurred historically and are occurring today, that may alter the adaptive strategies of hunter/gatherers. For example, there is continuing debate over the effects on the Kung! of European colonization and subsequent trading. This is of considerable concern to archaeologists utilizing these ethnographic data to interpret the archaeological record. The effects of European cultures can clearly give the wrong impression of hunter/gatherer life. Currently, an attempt is being made to determine the degree to which contact with other societies has had an impact on the "pristineness" of many hunter/gatherer cultures that have been studied ethnographically (Wilmsen and Denbow 1990). A clear understanding of a culture's historical developmental process, how the hunter/gatherer group of study arrived at its present stage of cultural "development", and determination if that stage is one that was present in the past, is of particular importance when attempting to evaluate the archaeological record with ethnographic data.

1.4 CROSS-CULTURAL REGULARITIES IN HUNTER/GATHERER BEHAVIOR

The Man the Hunter Conference held in Chicago 1968, was significant for anthropology because it dispelled misconceptions about hunter/gatherer lifeways held by both the public and researchers alike (Kelly 1995, Lee and DeVore 1968). Hunter/gatherers were no longer viewed as simple societies lacking the time to "build culture" (Feit 1994, Kelly 1995). Instead, hunter/gatherers were seen as affluent, often in equilibrium with their environments and no longer viewed as just hunters because of greater emphasis on the role of gathering (Sahlins 1968, 1972). This view of hunter/gatherer lifeways was known as the generalized foraging model (Kelly 1995).

As mentioned previously, the overarching theoretical framework in place at the time, Steward's (1955) cultural ecological approach guided new ideas from the Man the Hunter Conference, (Kelly 1995). Cultural ecology, which first appeared during the 1950s (Steward 1955), provided a guide for many hunter/gatherer studies of the 1960s and 1970s and still influences research today. This approach inspired field studies of hunter/gatherers, such as the work of Lee, DeVore, Yellen and others in the Kalahari

(Lee and DeVore 1976). The ethnographic work conducted within the Kalahari was aimed at developing a holistic view of hunter/gatherer lifeways before hunting and gathering as a way of life disappeared. These ethnographic data provided a wealth of information on hunter/gatherer settlement, subsistence, and social structure from which cross-cultural regularities and differences could be codified (Yellen 1976, Lee and DeVore 1976). The cumulative data suggested that important aspects of modern hunter/gatherer behaviors are highly patterned, allowing archaeologists to build a theoretical model of expected past behaviors (Jochim 1998). Such a theoretical model, if properly used in a deductive framework, enables archaeologists to predict past human behaviors within any single-habitat type.

Soon after the Man the Hunter Conference, anthropologists began challenging the generalized foraging model (Kelly 1995). Researchers discovered that Lee had only accounted for search and pursuit costs when he estimated the amount of work hunter/gatherers did within the Kalahari. Once resource processing was considered, hunter/gatherers were found to often work more than forty hours a week. In addition, Winterhalder (1988) demonstrated that when hunter/gatherers limit the amount of work they did it was not as part of a desire to have very little as Sahlin's (1968, 1972) had suggested, but rather to ensure that resources were not depleted. As a result, hunter/gatherer foraging effort varies from society to society depending on the availability of resources. Researchers were also beginning to find that hunter/gatherers are often undernourished and as a result are prone to contracting infections and diseases (Kelly 1995). Prehistoric data were also demonstrating that hunter/gatherers within a variety of regions were faced with seasonal food shortages (Kelly 1995, Yesner 1994).

The ability to obtain a minimum amount of food was emerging as very important goal for hunter/gatherer societies. The assumption by the general foraging model that hunter/gatherers relied heavily on plant resources was also demonstrated to be false (Kelly 1995). Typically, meat satisfies at least half of a hunter/gatherer societies caloric needs. Within hunter/gatherer societies occupying the arctic, meat comprises the majority of the diet (Binford 1978, Spiess 1979). Lastly, anthropologists began to realize that modern hunter/gatherers were not isolated from the affects of the world system that had surrounded and invaded their societies (Wilmsen and Denbow 1990). As a result, anthropologists are beginning to consider the history of hunter/gatherer societies prior to developing broad assumptions.

The ethnographic work that followed the Man the Hunter Conference in Chicago has enabled anthropologists to better understand the hunter/gatherer decision making process and to identify a broad set of cross-cultural goals and objectives that guide decision making. These goals are outlined within the next section.

1.4.1 BEHAVIORIAL CONSTRAINTS: GOALS AND OBJECTIVES

Since most human behaviors are the result of conscious decisions and traditions, a theoretical framework pinpointing the motives or goals guiding (constraining) decisions is critical for modeling past hunter/gatherer behavior (Jochim 1998). This section is a review of the cross-cultural goals, which guide modern hunter/gatherer decisions regarding what to eat, where to camp, and when to move. The cross-cultural goals or motives identified by Jochim (1976, 1998) likely guided decisions made by late

Pleistocene/early Holocene hunter/gatherers and will be utilized as a point of departure for this research.

In his seminal work, *Hunter/Gatherer Subsistence And Settlement: A Predictive Model* (1976), Jochim suggests that past hunter/gatherer adaptive strategies could be successfully predicted based on the characteristics and distribution of resources. Jochim's use of quantitative algorithms allowed his predictions to be independently evaluated and set his approach apart from the cultural ecological perspectives of Steward and his followers (Bettinger 1998). Based on a plethora of ethnographic data, Jochim (1976) summarized and codified cross-cultural regularities in goals and behavior found among hunter/gatherers. This portion of Jochim's work will be examined here.

Jochim organized the goals of hunter/gatherers into three domains: resource use schedule, site placement, and demographic arrangement. This organization assumes subsistence/settlement patterns are the result of decisions made to solve problems, such as site placement. Another assumption is that the decisions are simultaneously guided and constrained by the goals of hunter/gatherers. Problem areas, identified by Jochim, are presented in causative priority in which resource use patterns directly affect settlement placement and demographic arrangement.

Based on the ethnographic data, two major and four secondary goals guiding hunter/gatherer resource procurement were identified by Jochim. First, hunter/gatherers attempt to attain a minimum amount of food and non-food materials, such as hides for clothes and building materials for shelter. These nutritional and non-food requirements of individuals limit the choices peoples make. However, that is not to say cultural objectives cannot influence decisions about the attainment of a secure level of resources.

Second, hunter/gatherers limit the amount of effort expended while procuring food and non-food items. The timing of resource exploitation, distances traveled, and relative ease of exploitation are some major factors hunter/gatherers consider when attempting effort minimization. When procuring food resources, hunter/gatherers also consider taste and variety in their diet. Such secondary goals insure that the group obtains the quantity and quality of food needed to insure biological viability while avoiding monotony. Fifth, the attainment of prestige is often a factor guiding resource procurement. Prestige varies among different groups, however, its importance seems to be universal. Lastly, the fact that there is often a differentiation of gender roles within hunter/gatherer society is also a guiding factor in resource use activities.

According to Jochim (1976), settlement placement is the spatial arrangement of a population of hunter/gatherers in order to satisfy three primary goals. The first goal, proximity to resources, recognizes the influence that resource distributions can have on human settlement or placement in the landscape. In addition, seasonal variations in resource distributions were an important consideration guiding hunter/gatherer settlement decisions. Protection from the elements (shelter) and a concern for the texture and dryness of the ground surface is the second objective of site placement. The third goal behind hunter/gatherer settlement patterning is the necessity to position the group for a view of both game animals and other human populations.

Jochim found that the spatial arrangement of hunter/gatherer populations represents adjustments to the natural environment by means of choices. Five goals guide a group choices about population aggregation. There first must be enough food to accommodate the entire group. Sustaining the group is not based solely on the availability of food resources; regional carrying capacity affects the resource use decisions of a group. In fact, population densities are generally below the carrying capacity of the environment. The second goal, to maintain the size and spatial arrangement of populations, should enable hunter/gatherers to procure resources with a minimal amount of effort. This objective is based on the mobility strategy a group of hunter/gatherers chooses to utilize (see the discussion below). Third, in order to insure that some food is readily available, decisions on group size are made in relation to the spatial distribution and abundance of resources. For example, a large cooperating group will expand the potential resource base, due to the availability of additional persons, which could result in increased area coverage, greater intensity of exploitation, or greater efficiency of exploitation. Increased size can also enable the group to exploit a larger area with greater intensity and or efficiency. Fourth, the desire to be reproductively viable also affects decisions on population aggregation. Hunter/gatherer groups must maintain contacts with sufficient numbers of suitable individuals that can mate. In order to accomplish this at a low cost, population aggregation becomes an important consideration, particularly for groups that are evenly distributed across a landscape and especially in low-density situations. Finally, the desire for social interaction is an important consideration in decisions relating to the arrangement of hunter/gatherer populations.

Of the goals outlined above, Jochim (1998) suggests efficiency and risk minimization are the most important underlying factors guiding hunter/gatherer decisions about what to eat, and when and where to move. The importance of these goals in understanding hunter/gatherer behavior requires further consideration. Since

"...efficiency varies qualitatively among resources depending on both their yields (edible/inedible, calories/nutrients, food/nonfood) and their costs (according to technology and tactics of procurement)..." developing an exact measure of efficiency requires complex quantitative models. Although a variety of optimal foraging models (Bettinger 1991, Kelly 1995, Winterhalder and Smith 1981) attempt to do this, accurately measuring efficiency is a daunting task for archaeologists, since there are a wide variety of unknowns about human costs and resource yields of past societies and ecosystems respectively (Jochim 1998). Given that archaeologists know little about past resource structure and the cost and effectiveness of adaptive strategies, utilizing a general measure (high/low or rankings) of efficiency rather than a quantitative one, may be a better alternative. For example, the ethnographic record demonstrates that prey size is closely related to procurement efficiency. Large game is considered very cost-efficient. Plant gathering and fishing, when these resources are highly concentrated, reliable, and predictable, can also be a efficient means of obtaining food resources. As models develop and until new archaeological data are obtained, ranking resources may provide a more robust alternative to quantitative approaches that require precise measures as input. Given the unknowns about the structure of past ecosystems and societies, relying on precise quantitative resource measures is unrealistic for most archaeological models (Jochim 1998). Drawing inferences from general rankings and relationships among factors that affected hunter/gatherer behavior is likely a more robust process under a wide range of assumptions than depending on models that seek quantitative precision. In addition, optimal foraging models such as linear programming and central place foraging, that utilize highly precise inputs assume that hunter/gatherers had an extensive knowledge of the environment that would have enabled them to estimate caloric intakes (Kelly 1995).

Risk-minimization as a goal enables humans to avoid life-threatening situations by encouraging them to consider the reliability of a resource and the efficiency at which a resource can be procured and processed (Jochim 1998). Since the intensity, frequency, spatial extent, and predictability of resources vary, and because hunter/gatherers rarely have perfect information about the environment, they face situations with variable risk on a seasonal or even daily basis (Kelly 1995). To minimize risk, hunter/gatherers diversify their resource base, store food, or share knowledge and or resources with other groups (Hayden 1981, Jochim 1998, Kelly 1995, Winterhalder 1981a). Risk-minimization strategies vary among groups and individuals. For example, women, the elderly, and the very young provide the most reliable resources, while men pursue high-risk resources to obtain prestige. The wide range of strategies and variability among them, compounded with the fact that archaeologists know little or nothing about variations in past resources, make risk extremely challenging to model. As a result, Jochim (1998) recommends archaeologists seek a general understanding of risk, utilizing simple logical models focusing on the structure of subsistence variability rather than highly detailed quantitative approaches. Kelly (1995) points out that examining resource intensity, frequency, spatial extent, and predictability provides a useful means for assessing the risk a hunter/gatherer society may have faced.

Hunter/gatherer decisions are also guided by the biological constraints and requirements of the human body. The most obvious example is the daily need for water, particularly in desert environments where the movements of hunter/gatherers are restricted or may be tethered to regions with water resources (Kelly 1995). In addition to water, the human body requires base levels of carbohydrates, lipids, proteins, minerals, and vitamins (Keene 1979, 1981). Although the exact quantities of such nutrients needed by human populations are unknown, a deficiency in any or all of these may unconsciously cause persons to seek other food resources. For example, in some plant-dependant societies, hunter/gatherers refer to the lack of meat as a time of "starvation". An unconscious desire to acquire carbohydrates (fat) or energy may account for the fact that fat is a positive component of taste (Egan 1993, Jochim 1976). Also, the desire for variety in the diet helps to ensure that hunter/gatherers get necessary nutrients. In addition, caloric intake can guide the decisions hunter/gatherers make about what and when to eat. On average, the human body requires about 2000 kcal per day. It should be noted that when describing the caloric requirements of the human body, kilocalories are often erroneously referred to as calories. Caloric requirements can vary greatly depending on the size of an individual and the season, winter versus summer (Lee 1979, Wilmsen 1982). Lastly, physical exertion often affects hunter/gatherer decision-making. For example, the maximum round trip distance a group of hunter/gatherers will walk during the span of a day is twenty to thirty kilometers, and during most activities, the distance is less.

1.4.2 MOBILITY STRATEGIES

Variability among hunter/gatherer mobility s was first characterized by Beardsley (1956), who divided mobility strategies into four categories: free wandering, restricted wandering, central-based wandering, and semi-permanent sedentary. Free wandering groups have very low populations and lack territorial boundaries. The movement of restricted wandering groups is confined to territorial boundaries, while central-based wandering groups seasonally reoccupy specific locations within a defined territory. Lastly, semi-permanent sedentary groups occupy a single village throughout the year and move only every few years. The categories initially defined by Beardsley were later redefined into fully nomadic, semi-nomadic, semi-sedentary, and fully sedentary by Murdock (1967).

By demonstrating that Murdock's settlement types are related to the environment, Binford (1980) spurred new interest, especially among archaeologists, in hunter/gatherer mobility (Kelly 1995). Binford proposed a latitudinal variation model in which hunter/gatherers tended to be fully nomadic in the high Arctic and tropical forests, where resources are homogeneously distributed throughout the year. Groups occupying temperate forests and deserts, where the distributions of key resources, such as water, constrain movement, are generally seminomadic or semisedentary (Binford 1980). Using the terms forager and collector as conceptual tools, Binford codified settlement systems based on the amount of residential and logistical movements hunter/gatherers engage in annually (Kelly 1992). Collectors move to key locations, for relatively long periods, from which small groups on logistical forays harvest resources for the entire group. Foragers frequently move the entire group to resources, spending little time on logistical forays.

Binford's model was designed to study camp movements relative to foraging activities enabling researchers to understand the role mobility plays in the generation of archaeological sites (Kelly 1995). However, the terms forager and collector have often been used to pigeonhole both modern and prehistoric settlement systems (Kelly 1995). In actuality, hunter/gatherer mobility should be viewed on a continuum ranging from highly mobile foragers to sedentary collectors (Kelly 1995). Viewed in this way, Binford's settlement model is a useful tool for examining the continuum of settlement forms/mobility strategies found among hunter/gatherers.

By identifying several broad correlations between forager and collector strategies and the environment, Binford demonstrated that subsistence was a primary driving force behind mobility strategies (1980). Binford found that the frequency of movement depends on the resource density and the subsistence items hunter/gatherers choose. Building upon Binford's work, Kelly (1983) further examined the relationship between hunter/gatherer subsistence and mobility in much greater detail. Kelly divided mobility into five separate variables including 1) number of residential moves, 2) average distance moved, 3) total distance moved, 4) total area used during the course of a year, and 5) average length of logistical forays, analyzing each in relation to the abundance and distribution of food. To determine food abundance and distribution, primary biomass, the amount of standing plant material, and the intensity of solar radiation or effective temperature, were measured in environments where modern hunter/gatherers resided. Kelly found the number of residential moves per year rises as primary biomass increases and food accessibility decreases. In regions with a paucity of food resources, logistical search, pursuit, and commuting costs become more critical. As temperature decreases and resources become dispersed, the average distance between residential moves increases. Peoples residing in colder climates depend more on faunal resources, while exploiting a larger total area. While, the length of logistical forays increases as hunter/gatherers become more dependent on faunal resources.

There are several variables affecting hunter/gatherer mobility, with the majority related to subsistence (Kelly 1983, 1995). A primary factor guiding hunter/gatherer movement is the decline in returns and subsequent rise in cost of food as resources around a residential camp are exhausted requiring people to search farther afield. In order to remedy this problem, hunter/gatherers move when daily returns decline to a level that fails to meet the goals or requirements of the group. In addition to returns from resource extraction, hunter/gatherers also evaluate the cost of moving to another camp based on the distance between the camps, the terrain to be covered, available transport technology, and the amount of goods and people that need to be moved. Hunter/gatherers also consider the risk involved in moving or the likelihood and magnitude of an unacceptable event occurring. If moving to another settlement is perceived as too risky, foragers may accept lower return rates and remain in the same location. An alternative to moving an entire group is splitting into smaller social units, each moving on a different schedule, to alleviate diminishing harvests in any single location. Trade also alleviates diminishing returns, enabling hunter/gatherers to reside in locations lacking key resources.

Most discussions of mobility focus on the behavioral component. Since hunter/gatherers occupy a place both physically and conceptually, mobility, therefore, contains a cultural component that should be considered as well (Kelly 1995, Steward 1955). After leaving a locale, hunter/gatherers may feel culturally attached to it due to religious, kinship, trade, and personal obligations. For example, hunter/gatherers often return to a location to visit friends or relatives. Residential mobility also provides a means for alleviating boredom.

The discussion thus far has centered on the forager-collector scheme outlined by Binford (1980). Bettinger and Baumhoff (1982) presented an alternative model of hunter/gatherer mobility. Like Binford's forager-collector model, their work recognizes that mobility strategies are on a continuum from high to low mobility. Travelers, depending on high return resources such as large game, are very mobile; while processors, utilizing a diversity of resources, particularly plant materials. By focusing on high yield resources, travelers often incur greater costs in travel while minimizing expenditures related to resource extraction. Processors engage in a high-cost strategy, utilizing low quality resources, minimum travel costs, but mandating greater extraction and processing time. Since the approach Bettinger and Baumhoff use is rooted in coupled theoretical constructions drawn from microeconomics and anthropological observations, it has the advantage of providing insights into "...relationships between population and resources, on the one hand, and settlement and subsistence patterns, on the other." (Bettinger 1991). As a result, their model has the ability to provide standardized descriptions of subsistence/settlement systems that are particularly useful for comparative studies.

1.5 PROJECT OVERVIEW

Despite the discovery of direct evidence for Paleo-Indian subsistence, kill sites, bones with cut marks, botanical remains, etc., the extent to which early foragers relied on particular resources and how they obtained those resources (adaptive strategies) cannot be determined without a sound anthropological framework and a holistic paleoenvironmental model (Shott 1990). Until these criteria are met, archaeologists are left with general interpretations and characterizations. For example, Paleo-Indian cultures in the Northeast are characterized as a focal economy centered on caribou hunting in the north and a more diffuse economy in the south (Custer and Stewart 1990, Meltzer and Smith 1986). The research presented here provides the anthropological framework necessary, while presenting methods for improved modeling of paleoenvironmental data to a generate model of Paleo-Indian behavior that depicts the extent to which resources were utilized and how these resources are acquired. The model developed is flexible, recognizing that there will be future archaeological discoveries and improved means of modeling the Paleo environmental ecosystems and human behaviors. These new data can be easily entered into the model bringing the results closer to reality.

This research embodies both anthropological and spatial investigations. The study takes a deductive, positivist perspective toward hunter/gatherer adaptive strategies. A series of simulations framed as alternate hypotheses are presented and tested using Paleo-Indian period archaeological site locations and remains to estimate the validity of each. The approach is based on the assumption that hunter/gatherers are limited by what they can get access to in the real world. As a result, many aspects of hunter/gatherer behaviors are better understood with a detailed knowledge of the distribution of environmental variables (Binford 1980, Jochim 1976, Kelly 1995).

A raster Geographic Information System (GIS) is used for the project analysis. GIS was chosen for its ability to concurrently analyze an infinite number of spatial variables. In addition, continuous variables (soils, elevation, and activity intensity) can realistically be portrayed within a raster GIS environment. The tools for generating predictions based on a series of behavioral objectives and their subsequent criteria are found within a raster GIS system. Lastly, spatial data can be mathematically manipulated within a GIS, allowing the calculation of factors such as the general estimation of energy/time costs of traveling through a landscape.

Chapter II

REVIEW OF PALEO-INDIAN PERIOD LITERATURE: A VIEW FROM EASTERN NORTH AMERICA

The goal of the first half of this chapter is to provide a broad regional overview of Paleo-Indian archaeology across eastern North America and to discuss some of the major trends in Paleo-Indian research within this same region. Because current research indicates that Paleo-Indian adaptive strategies vary on a continuum from south to north (Meltzer 1988) it is important to place this research within a regional context in order to more accurately develop hypothesis about Paleo-Indian adaptive strategies within the Great Lakes region. Across eastern North America, two major research trends have emerged in Paleo-Indian subsistence studies. The first research trend suggests that Paleo-Indian adaptive strategies were centered around large game hunting while the second places less emphasis on large game indicating that many Paleo-Indian foragers probably utilized a much broader set of resources for subsistence including plant materials.

The latter part of this chapter is a critique of the Paleo-Indian behavioral models that have emerged from research conducted across eastern North America. These models are based on three primary types input: ethnographic data, ecological data, and assemblage data. This critique helps to guide the construction of the Paleo-Indian behavioral model presented in chapter six.

2.1 A VIEW FROM EASTERN NORTH AMERICA

Paleo-Indian subsistence studies in eastern North America resulted from a series of large-scale reconnaissance surveys undertaken during the 1960s (Dent 1995). These surveys studied the regional distribution of fluted points, but little was revealed about specific settlement and subsistence patterns. Beginning with Mason's 1962 paper Paleo-Indian studies began to shift their focus from artifact discovery and site excavation, to a regional concern with adaptation and Paleo landscape use (McNett 1985, Meltzer 1988, Anderson 1990). However, the scarcity of faunal and floral remains and the near absence of features at Paleo-Indian sites, particularly in the East where many sites consist of single point finds, leave much to the imagination. Systematic biases in artifact preservation and site visibility and discovery also impeded Paleo-Indian studies in the east.

Meanwhile, in western North America, the prevalence of buffalo and mammoth remains at Paleo-Indian sites led researchers to conclude Paleo-Indian groups depended nearly exclusively on large game for food (Bamforth 1988). According to this model, Clovis peoples on the Plains predominately hunted mammoth, while later Folsom groups hunted bison. This western model of Paleo-Indian subsistence was quickly adopted and applied to Paleo-Indian groups in the east, where subsistence data were largely lacking. The fragmentary remains of caribou found in excavations in the Northeast supported the conclusion that large migratory game was a primary resource of early peoples (Cleland 1965, Storck 1988).

Such a dependence on larger animals is difficult to demonstrate because the presence of remains of animals, such as caribou, on archaeological sites is easily misinterpreted (Dent 1995). Larger animals leave more remains and are more likely to be preserved. Therefore, the presence of caribou at a few Paleo-Indian sites does not necessarily reflect the extent to which large game resources were utilized. Small animal and or botanical remains may have been more widespread at Paleo-Indian period sites. However, these remains were not preserved as well.

In an attempt to reconcile traditional models based on big game subsistence strategies identified in the West, recent Paleo-Indian studies in the East began relying on paleoenvironmental reconstructions (Curran 1990, Meltzer and Smith 1986, Shott 1990) to supplement the limited amount of floral and faunal remains that were the basis for interpretations of Paleo-Indian lifeways in eastern North America. Recent paleoenvironmental reconstructions indicate that there were several latitudinal variations in biotic communities, ranging from tundra in the north to deciduous forests in the south. This variation appears to have had a significant affect on the subsistence strategies utilized by Paleo-Indians. Recent archaeological research suggests that Paleo-Indians utilized more than one adaptive strategy depending on the paleoenvironment that was being occupied (Meltzer and Smith 1986). In tundra environments, humans were probably caribou specialists, while the deciduous forests contained a wide range of small game and plant foods utilized by early hunter/gatherers (Curran 1990, Meltzer and Smith 1986, Shott 1990).

The following discussion examines recent evidence for the settlement and subsistence patterns of Paleo-Indian period groups in three major regions of northeastern North America: the Northeast, the Southeast, and the Great Lakes. The discussion will also present the new approaches used to examine Paleo-Indian adaptive strategies in eastern North America. In the Northeast, debate has centered on the extent to which early hunter/gatherers hunted caribou. In the Great Lakes, researchers are concerned with the overemphasis placed on Paleo-Indian period settlements along active glacial strandlines and the corresponding neglect of upland settlement areas. In the Southeast, where overall preservation is poor, archaeologists are addressing issues of Paleo-Indian site visibility and distribution.

2.1.1 NORTHEAST

With artifacts that may date to 14,250 BP some of the earliest evidence of human habitation within the Northeast comes from the Meadowcroft Rockshelter in southwestern Pennsylvania (Adovasio et al. 1990, 1992, Meltzer 1993). However, these dates are not without controversy. The incredibly small sample of organic remains from the Pleistocene levels of the rockshelter provides archaeologists with an inadequate sample from which to judge whether the early dates are actually associated with human occupation or are an anomaly (Meltzer 1993). Also, the presence of natural coal deposits within the region may have contaminated the radiocarbon samples, thus inflating their ages (Haynes 1980). In addition to the controversial dates, geologists suggest that the Laurentide ice sheet was within fifty miles of the Meadowcroft Rockshelter at ca 14,000 BP that would have generated a very inhospitable near-glacial climate at the site. As a result, flora and fauna species would have been nearly absent from the site at the time humans are first thought to have inhabited the region.

With few reliable dated Paleo-Indian sites in the Northeast the chronology of the Paleo-Indian period in this region is not fully understood (Custer and Stewart 1990, Dent 1995, Spiess et al. 1998). Sites in the Northeast containing Clovis-like Debert (MacDonald 1968) points were occupied between 10,600 and 10,200 years ago. Debert points are followed by the appearance of Vail and Bull Brook (Custer and Stewart 1990) points in the latter part of the Paleo-Indian period. The social and economic significance of these point types is not well known, however.

Traditional interpretations of Paleo-Indian lifeways have been heavily scrutinized and debated in the Northeast. This is due, in part, to a reevaluation of the paleoenvironmental data from the region (Curran and Grimes 1989, Custer and Stewart 1990, Meltzer 1988). According to older paleoenvironmental reconstructions, a tundra/spruce biotic zone supporting large herds of caribou was present throughout much of the Northeast, while a complex mosaic of grass and deciduous/boreal woodlands occupied southern areas of the region.

After a re-examination of northeastern pollen records, Custer and Stewart (1990) suggested that boreal forests had, in fact, replaced tundra and open grasslands by the time of early Paleo-Indians began occupying the Northeast. With the exception of northern Maine, which contained "…a vast sedge-birch dominated open (tundra-like) area…" (Spiess 2001), the Northeast had only small areas of tundra and grasslands left during the Paleo-Indian period. The dense boreal forests occupying regions south of New Hampshire and Vermont, which were dominated by spruce parkland, supported a wide variety of animal species, including mastodon, deer, moose, beaver, and other small mammals. Blueberries, blackberries, cranberries, grapes, and other plant species may have been available to Paleo-Indians residing within the boreal forests as well (Larsen 1980, McNett 1985). Migratory caribou would have occupied the northern edge of the boreal forest during the winter while moving into northern Maine during the summer (Spiess 2001). According to this reconstruction, Paleo-Indian groups in the Northeast could have relied on a diffuse subsistence adaptation (Cleland 1966, 1976) similar to that seen among historic native peoples of the eastern sub-arctic boreal forests.

Recently acquired data has demonstrated that fish may have played a significant role in the lives of early Paleo-Indians (McNett 1985). The use of fish is well established for historic groups in the sub-arctic boreal forests. Remains of fish were discovered at Shawnee-Minisink, a Paleo-Indian period site, along the Delaware River in Pennsylvania (McNett 1985). The site also yielded a wide range of plant remains. The variety of food remains discovered at Shawnee-Minisink is consistent with Custer and Stewart's (1990) re-interpretation of the environment. However, this is the only site in the Northeast that has yielded significant evidence for the use of fish and plant resources. The lack of such food remains may be due, in part, to the absence of excavation techniques geared toward faunal and floral collection at many Paleo-Indian sites (Dent 1995).

Meltzer's alternative paleoenvironmental reconstruction also emphasizes the coexistence of two different environmental regions in the Northeast, each, however, is characterized by a different adaptive strategy (Meltzer 1988). According to Meltzer's model, specialized caribou hunters occupied the tundra/spruce parkland that blanketed the north. Many of the visible sites in this region represent repeated occupation areas along caribou migration routes. Sites in this region have yielded formal tools such as projectile points, scrapers, and drills, and utilized flakes. This lithic evidence is consistent with mobile hunters and short term, task specific occupation.

According to this second model the southern part of Maine, and all of Vermont and New Hampshire were covered with a complex boreal-deciduous forest ecosystem that required a different Paleo-Indian adaptive strategy (Meltzer 1988). In this region, human adaptation represents a dispersed, generalized adaptive strategy, in which reuse of locations was infrequent. Such a strategy resulted in a few highly visible sites. This strategy of land use may have extended into the Southeast as well (Anderson 1990, Meltzer 1988). Movement of early Paleo-Indian peoples appears to have been east-west, particularly within northern Maine (Spiess and Hedden 2000), rather than north-south between the ecological zones Meltzer (1988) and others have identified in the northeast (Curran and Grimes 1989, Spiess 2001).

These two models differ most in the way they view the role of caribou hunting. However, the lack of floral and faunal remains at most Paleo-Indian period sites in the Northeast has made estimating the extent of caribou hunting across North America tenuous at best. Lacking direct evidence of faunal utilization, the best way to develop and test models of Paleo-Indian period adaptive strategies is through detailed paleoenvironmental reconstructions at the local and regional level (Storck and Spiess 1994). The work of Curran and Grimes (1989) and Spiess (2001) has begun to move in this direction.

Curran and Grimes' work focuses on developing improved paleoenvironmental reconstructions and understanding how the environment affected Paleo-Indian peoples (Curran and Grimes 1989). They estimate the resource potential for various physiographic regions, based on the simulated distribution of plant and animal resources, and the accessibility of lithic raw materials. Next, they attempt to reconcile this information with the spatial patterning of known Paleo-Indian period sites. Curran and Grimes suggest that site locations are consistent with expected caribou migration routes and conclude that early hunter/gatherer bands followed and hunted caribou as they moved between the interior and the coastal regions of the Northeast.

Curran and Grimes also suggest that early hunter/gatherers procured cherts only within the range of their seasonal round (Curran and Grimes 1990). This interpretation is in contrast to the views of Spiess and Wilson (1987), who argue that specialized task groups procured lithic resources independently of the seasonal movements of the band. Spiess and Wilson also suggest that the seasonal movements of early hunter/gatherers were not as predictable, nor their subsistence as dependent, on caribou as Curran and Grimes have suggested. Therefore, the role of caribou is important not only in evaluating Paleo-Indian subsistence, but also in evaluating the importance of caribou hunting relative to other activities, such as lithic procurement. A recent work by Spiess and Hedden (2000) contradicts the findings of Curran and Grimes (1989), suggesting the movement of Paleo-Indian peoples, particularly within northern New England was east-west rather than north to south.

2.1.2 SOUTHEAST

The Paleo-Indian period throughout the Southeast is difficult to understand, due to the paucity and small size of sites and the generally poor preservation of plant and animal remains. The Paleo-Indian period of the Southeast is characterized by a wide variety of point forms, divided into three sub periods: Early (12,000 - 11,000 BP), Middle (11,000 - 10,500 BP), and Late Paleo-Indian (10,500 - 9,900) (Anderson 1990, Dent 1995). Clovis projectile points, nearly 12,000 years old, are among the earliest Paleo-Indian materials in eastern North America. However, dates have only been obtained from one Early Paleo-

Indian period site containing Clovis diagnostics. During the Middle Paleo-Indian sub-period, a wide range of fluted and unfluted point forms began replacing Clovis points, most contained broad blades and constricted haft elements.

In the Southeast region, the majority of the datable material comes from the Late Paleo-Indian period; characterized by the appearance of small triangular fluted and unfluted projectile point types known as Dalton points (Anderson et al. 1996). These small projectiles resemble side notched points, such as those seen in the later Archaic. In general, Paleo-Indian materials in the Southeast occur earlier than similar artifacts to the north and west. For example, in the Southeast region, Late Paleo-Indian Dalton points dating to circa 10,500 BP, are contemporaneous with early Paleo-Indian Parkhill (Barnes), and Crowfield points in the north (Anderson et al. 1996, Ellis and Deller 1990).

Most Paleo-Indian sites in the Southeast consist of single point finds (Anderson 1990). The few large Paleo-Indian sites known in the Southeast are generally quarry sites. According to Meltzer (1984, 1988), the small size of early sites resulted from the dispersed settlement pattern of people in a forested environment that extended across the entire Southeast region and into the southern portion of the Northeast region. The Thunderbird site along a fork of the Shenandoah River in Virginia is an exception, however. This site, located on an early Holocene floodplain acted as a central base camp in a game-rich territory (Gardner 1974). Thunderbird, occupied repeatedly by Clovis peoples, contains multiple activity areas that represent tool fabrication and a wide range of residential activities.

The paleoenvironment across the Southeast was a boreal-deciduous complex consisting of oak, oak savanna, hickory, and southern pine biotic communities. Paleo-

Indian groups in the Southeast had access to a variety of dispersed subsistence resources such as seeds, nuts, small mammals, and to a limited extent, deer, bison, giant tortoise, and big game such as mammoth, and mastodon (Anderson 1990, Dunbar and Webb 1996). The Kimmswick site in Kentucky yielded 23 species of mammals including snakes, rodents, turtles, deer, and mastodon (Graham and Kay 1988, Meltzer 1993). Although large game generally did not likely dominate the Paleo-Indian subsistence system, the substantial involvement of Paleo-Indians in the butchering of megafauna including the giant tortoise at several locations within Florida, such as Little Salt Spring, suggests that big game species played a substantial role in Paleo-Indian subsistence within certain regions (Dunbar and Webb 1996). Aside from the remains of the giant land tortoise at Little Salt Springs, the presence of a wood spear that was radiocarbon dated to ca 12,000 is also intriguing (Meltzer 1993). Regions such as Florida may have contained a particularly high population of large herbivores. In addition to evidence of butchery, Dunbar and Webb have identified bone and ivory Paleo-Indian tools made from the remains of large extinct mammals. The location of these artifacts within underwater deposits that are particularly conducive to preservation indicates that similar artifacts may have existed in other regions. In general, prehistoric land use in the Southeast involved dispersed small group activities, such as nut collecting (Meltzer 1988). These activities left few archaeological remains and small archaeological sites.

Anderson (1990) also argues that early sites in the Southeast contain few archaeological remains due to taphonomic processes. Extensive precipitation, flooding, and acidic soils have resulted in a lack of "hard" subsistence data or organic materials from the Southeast. Without direct evidence of Paleo-Indian period subsistence, archaeologists were perhaps unduly influenced by findings from excavations in the western part of North America.

To develop a detailed description of Paleo-Indian colonization of the eastern woodlands, Anderson (1990) used a regional approach, examining broad ecological variables and their relationship to the distribution of Paleo-Indian projectile points. His colonization model proposes that Paleo-Indian groups moved through the ice-free corridor into the North American continent, following major river valleys southward. Groups expanded into the Missouri and then into the lower Ohio, Cumberland, and central Tennessee River valleys of the mid-south. Once Paleo-Indian peoples reached these ecologically rich river valleys, they settled into so-called staging areas, while adjusting to these newly encountered environments.

As populations increased, Paleo-Indian groups moved out from initial staging areas, aggressively colonizing the surrounding regions and, in some instances, setting up secondary staging areas from which more extensive colonization could follow. According to this model, coastal areas of the southeast remained relatively uninhabited during the Paleo-Indian period, with regions such as Florida remaining nearly vacant until the latter part of the Paleo-Indian period. Coastal regions may have posed special problems to early logistically based foragers. In these areas, foragers had to learn how to adapt to the homogeneous nature of hardwood forests blanketing much of the deep South during the early Holocene. In contrast, coastal areas during the later part of the Paleo-Indian period are marked by an increase in occupation due to the development of new adaptive strategies. The Tennessee River valley remained the most intensely utilized region during the Paleo-Indian period, while coastal regions in the Northeast were the last to be occupied. The latter part of the Paleo-Indian period thus represents expansion into these previously unused areas and continued population growth overall. Despite Poor preservation and the low site visibility in the Southeast, there is a well-developed model for Paleo-Indian period colonization of the region (Anderson 1990, Dent 1995).

2.1.3 GREAT LAKES

In the Great Lakes region, there are four successive early Paleo-Indian phases (Shott 1990). Each of the first three phases is identified by a specific fluted biface style: Gainey, (Clovis type) (10,900 BP), Barnes/ Parkhill type (10,700 BP), and Crowfield (10,500 BP) (Ellis and Ferris 1990). During the latter part of the Paleo-Indian period, the Holcombe phase (10,300 BP) appears. The Holcombe phase is identified by the presence of small fluted and unfluted projectile points. The Paleo-Indian period terminates with the appearance of slightly side notched projectile point forms around 10,000 BP. These Hi-Lo projectile points are similar to Dalton points in the Southeast.

The debate among researchers in the Great Lakes region has centered on the overemphasis placed on Paleo-Indian sites located along formally active glacial lake strandlines (Jackson 1990). Glacial strandlines, dating to the Paleo-Indian Period, have been the focus of intensive archaeological surveys and have proven a successful means for locating early sites (Deller 1976, 1979, Storck 1982). However, the focus on strandline environments has given archaeologists a limited view of Paleo-Indian lifeways. Despite the discovery of significant upland Paleo-Indian sites, systematic archaeological surveys continue to largely neglect interior regions.

The intense focus on Paleo-Indian settlement along glacial strandlines has biased explanations of early hunter/gatherer lifeways, while leaving a host of research areas unexplored. For example, researchers (Deller 1976, 1979, Storck 1982, Peers 1986, Ellis and Deller 2000) in the Great Lakes have emphasized strandlines as a central organizing feature for early Paleo-Indian settlement suggesting coastal environments were an ideal location from which to intercept caribou. This line of thinking has driven much of the Paleo-Indian research in the Great Lakes region, with significant inland sites, such as the Barnes site, being misinterpreted as having been located along active strandlines (Jackson and McKillop 1991).

The Holcombe site (Fitting et al. 1966) helped support the notion that the adaptive strategies of early peoples across Lower Michigan were also focused on glacial strandlines (Cleland 1965, Jackson and McKillop 1991). Here faunal remains, including fragmentary caribou remains, suggest that active glacial strandlines formed an important part of the Paleo-Indian adaptive strategy acting as caribou migration corridors. Researchers have shown that similar to the Barnes site (Voss 1977), the Holcombe site did not lie along an active glacial strandline (Jackson and McKillop 1991). In addition, the fragmentary nature of the caribou remains does not demonstrate the extent to which large game animals were utilized by early hunter/gatherers in the Great Lakes (Dent 1995).

Artifact collections of few early Great Lakes sites have been studied, further complicating the understanding of Paleo-Indian adaptive strategies. Of those collections examined, nearly all were large sites, such as the Barnes, Butler, Fisher, Gainey, and Parkhill sites. As a result, large Paleo-Indian Period sites in the Great Lakes are generally viewed as isolated events on the landscape, rather than as part of a broad regional settlement system. In other words, due to the preoccupation with large tool assemblages and glacial strandlines, very few researchers have attempted to examine the regional settlement patterning of either coastal or inland settlement systems in the Great Lakes during the Paleo-Indian Period. Smaller sites are of particular importance when attempting to understand the regional significance of larger Paleo-Indian sites in an integrated settlement system. A recent lithic study by Jackson (1998) at small interior archaeological sites in Ontario has begun to provide insights into the entire Paleo-Indian settlement system.

Surveys conducted by Jackson and McKillop (1991), provide a wide range of information on interior settlement and the seasonal round of Paleo-Indian peoples occupying the Great Lakes region (Jackson 1990, 1998). Rather than focusing on areas likely to contain early sites, Jackson and McKillop spent several years surveying different types of landforms in interior regions of Southern Ontario. This enabled them to determine the potential for Paleo-Indian period settlement not only in upland areas, but also along a variety of physiographic features. They found a series of thirty small interior Paleo-Indian sites evenly distributed throughout the landscape (approximately two miles apart), and evenly distributed across physiographic features as well. They estimate ten small sites and between 100-200 tool loss or kill sites lie within every 100 square kilometers of interior areas.

It appears that the interior Paleo-Indian sites Jackson has identified in Central Ontario were occupied during the warm season by small task groups (Jackson 1998). In many instances, these small interior archaeological sites may have resulted from single-person events. Caribou remains from the region around Rice Lake seem to suggest that these small groups would have been hunting migratory caribou herds within their summer range. Tool forms and the presence of Collingwood chert suggest cultural ties to larger activity areas, such as the Udora site, lying outside the area Jackson surveyed. In fact, these groups may represent the northern most extensions of the Gainey phase with sites such as Udora acting as intermediate locations or staging sites at which bands returned to for tool rearmament.

Due to the poor forage and extreme climatic conditions of the recently deglaciated environment occupying northern Lower Michigan during the Paleo-Indian period, (Cleland et al. 1998, Krist and Schaetzl 2001) caribou and other herbivores may have avoided this region in favor of the open parkland and tundra environments that occupied Central Ontario. These regions would have had contained better developed soils that could support the plants necessary for large herds of caribou to sustain themselves. As a result, very few Paleo-Indian sites nor late Pleistocene faunal remains have been located north of the "Mason Quimby" line in central Lower Michigan. In fact, early Paleo-Indian groups may have moved into southern Ontario during the growing season in pursuit of migratory caribou rather than moving northward into northern Lower Michigan. This connectivity is evidenced by the presence of Gainey projectile points made from Upper Mercer chert in southwestern Ontario (Simons 1997). The presence of a Parkhill type fluted projectile point at the Samels Field site in northwestern Lower Michigan (Dekin 1966) suggests that environmental conditions were more conducive to human settlement and subsistence activities, at least on the leeward side of Glacial Lake Algonquin (Krist and Schaetzl 2001), by the middle of the Paleo-Indian period.

Larger Paleo-Indian sites appear to have been in locations that allowed for the interception of large numbers of migrating caribou during fall and or spring (Storck 1982, Peers 1986, Simons 1997, Ellis and Deller 2000). From a regional perspective, Jackson (1990) suggests that small, highly mobile Paleo-Indian groups moved about larger band territories in seasonal pursuit of caribou. In other words, early hunter/gatherers in the Great Lakes region were specialized caribou hunters similar to those of the Northeast as postulated by Curran and Grimes (1989). This model is supported by lithic procurement patterns in the Great Lakes similar to those of the Northeast. The interpretation of these patterns is that early hunter/gatherer bands obtained lithic raw materials while in the pursuit of caribou and other resources; specific task groups were not utilized to procure lithic resources in more remote areas.

Despite the presence of fragmentary caribou remains at several sites, and the widespread assumption that Great Lakes Paleo-Indian groups were predominately specialized caribou hunters, this assumption is still a tentative one (Jackson and McKillop 1991, Storck and Speiss 1994). Detailed paleoenvironmental reconstructions are needed to determine the extent to which caribou and other resources were utilized by Paleo-Indian peoples in the Great Lakes (Jackson and McKillop 1991). Recent reexaminations of the paleoenvironmental data indicate a closed spruce forest occupied much of the lower Great Lakes by the time early hunter/gatherers arrived in the region (Shott and Welch1984, Garland and Cogswell 1985, Karrow and Warner 1990, Storck and Spiess 1994, Kapp 1999). As a result, the presence of migratory caribou and their movements throughout the lower Great Lakes may not have been as extensive or as predictable as previously suggested. In addition, the heterogeneous nature of the boreal forest ecosystem (Winterhalder 1981b) may have required early peoples to depend on a wider range of resources than previously thought.

Evidence from southeastern Wisconsin suggests that early Paleo-Indian groups in the Great Lakes may also have been scavengers as well as hunters (Overstreet 1998). Overstreet has located a number of sites yielding mammoth remains that appear to have unambiguous butchering marks. Subsequent excavations at the Schaefer and Hebior sites uncovered mammoth remains in direct association with chipped stone tools. The chop/hack cut-marks on mammoth remains from southeastern Wisconsin are very similar to those found on specimens from the Clovis site in New Mexico. The cut-marks at the Clovis site are interpreted as being the result of scavenging activities. Unfortunately, Overstreet has been unable to firmly date these sites, which he has assigned to the Chesrow Complex. The fact that archaeological sites in neither Ontario nor Michigan contain Paleo-Indian artifacts in direct association with mammoth or mastodon remains does not necessarily indicate early peoples did not hunt these species. Disarticulartion patterns, burned bones, and potential cut marks found on mastodon bones at the Pleasant Lake site near Ann Arbor Michigan strongly suggest the Paleo-Indian utilization of mastodon in the region (Fisher 1981, 1984, 1987).

Other work in the western Great Lakes supports the notion that at least late Paleo-Indian peoples were generalized foragers utilizing a wide range of animal species rather than focusing on large game (Kuehn 1998). Excavations at the Deadman Slough and Sucices sites, in northern Wisconsin, yielded fish, turtle, bird (possibly migratory waterfowl), mussel, beaver, and porcupine remains. Despite the presence of smaller animal species at these sites, larger game such as white-tailed deer appear to have been a major component of Paleo-Indian diets. The presence of wetland and riparian species is also a clear precursor to the adaptive strategies of later Archaic groups.

2.1.4 SIMILARITIES AMONG EASTERN PALEO-INDIAN SITES

Within eastern North America, there are striking similarities among Paleo-Indian period sites and tools, despite vastly different environments and physiographic features (Dent 1995). The most obvious similarities are among projectile point types. Due to the humid climate and acidic soils, preservation throughout many regions of eastern North America is poor, leaving much about Paleo-Indian period lifeways undetermined.

Paleo-Indian period sites are generally small with low artifact densities, indicating that early hunter/gatherers were highly mobile. Further support of their highly mobile life is the apparent lack of food storage and the presence of "fire-floors" lacking the stone linings found in formal hearths at later prehistoric sites (Deller and Ellis 1992, Shott 1993). As a result, many Paleo-Indian period sites are devoid of subsurface features, which normally may contain floral and faunal remains.

Artifacts at early sites, however, are usually found in discrete clusters. These clusters may well represent individual family units, reoccupation of sites, or specific activity areas within the larger site (Dent 1995, Devisscher and Wahla 1970, Fitting 1966, Voss 1977). Despite the many similarities discussed above, there are important differences between settlement and subsistence strategies and the amount or significance of large game hunting during the Paleo-Indian period across eastern North America. Because most Paleo-Indian sites were excavated prior to the wide acceptance and utilization of archaeological techniques such as flotation that could accommodate the recovery of small botanical and faunal remains that are typically not recovered during standard screening techniques archaeologists are just beginning to pinpoint differences in settlement and subsistence within and between regions of eastern North America.

2.1.5 MOVING AWAY FROM WESTERN INTERPRETATIONS

The recovery of megafaunal remains, in direct association with artifacts left by early hunter/gatherers in the West, has had a profound effect on how archaeologists in the East view their archaeological data (Shott 1990, Dent 1995). As a result, many archaeologists throughout Eastern North America view Paleo-Indians as "big-game" hunters, despite the lack of archaeological data in support of this assumption (Dent 1995).

Recently, archaeologists have begun to realize that in many areas of Eastern North America, early hunter/gatherers probably relied on a diverse subsistence base. A wide range of faunal types recovered from Paleo-Indian sites across Eastern North America supports this interpretation. Remains of large faunal species found at eastern Paleo-Indian sites range from caribou and bison to the giant tortoise. Small mammals such as the arctic fox and hare were identified at the Udora site in Central Ontario (Storck and Spiess 1994). Plant remains, including various types of berries and nuts, have also been recovered from Paleo-Indian period sites in the East (Anderson 1990, Dent 1995, McNett 1985, Spiess et al. 1998). There is little lithic evidence that would suggest the utilization of plant materials. However, many of the artifacts used in plant processing may have been organic and did not survive within the archaeological record.

Ecosystems in the East would have enabled early peoples to utilize a rather diverse resource base, with much less dependence on a single large animal species in comparison with early hunter/gatherer societies in the West (Bamforth 1988, Dent 1995). Paleoenvironmental studies have demonstrated that the grassland regions of the Great Plains lacked the variety of edible plant and small mammal species that are found within eastern North America (Bamforth 1988). Therefore, large game hunting on the Plains represents a strategy constructed around a very limited subsistence base in comparison to the East. As a result, models of Paleo-Indian hunter/gatherer adaptive strategies in the Great Plains should be used with extreme caution when interpreting archaeological remains recovered from Eastern North America.

2.1.6 SUMMARY

An examination of the literature addressing Paleo-Indian settlement and subsistence strategies throughout eastern North America has identified two schools of thought. Traditionally, Paleo-Indian peoples were thought to reside in a barren ground environment, engaged in highly specialized subsistence strategies focused on large animals, such as caribou. To the contrary, recent works suggest Paleo-Indian groups resided in a wide variety of environments, ranging from tundra to forest, and that they utilized both small and large mammals. Paleo-Indian cultures employed a multitude of adaptations, used plant and animal species, which were also adapting to changing Late Pleistocene/Early Holocene environments. Central to the growing shift in Paleo-Indian research, is the re-evaluation of existing data sets, utilizing detailed reconstructions of Late Pleistocene/Early Holocene faunal and floral distributions.

2.2 BEHAVIORAL MODELS IN PALEO-INDIAN PERIOD RESEARCH: A CRITIQUE

When generating models of Paleo-Indian behavior, researchers have predominately focused on the chronology, typology, and technology of the lithic materials left by early hunter/gatherers (Shott 1990). Since most Paleo-Indian period sites, particularly those in eastern North America, have yielded few faunal or floral remains the emphasis on lithic artifacts is not surprising. Unfortunately, these models have only documented the antiquity of Paleo-Indian period technical skills, while telling us relatively little about the social organization of early hunter/gatherers.

Models of Paleo-Indian social organization have been generated less often (Shott 1990). When faunal and floral remains are present, the conspicuous nature of large game resources in the archaeological record, particularly at western sites, has resulted in behavioral models centered on dietary aspects of Paleo-Indian adaptive strategies. Recently, researchers have moved away from a focus on Paleo-Indian diets, to the generation of holistic subsistence models that consider the social context in which resources are procured (Custer and Stewart 1990, Jackson 1990, Jackson 1998, Spiess et al. 1998, Shott 1986). These newer models enable archaeologists to discover more about the Paleo-Indian decision making processes and generate inferences on social practices that are part of a subsistence strategy such as decision making rules, and risk-minimization.

While these approaches have undoubtedly helped to interpret archaeological remains from the Paleo-Indian period, they are limited in their behavior modeling ability (Kelly 1988, Shott 1993, Shott 1990). The most significant problems with these approaches have resulted from the misuse of data sets that are inherently flawed. The following discussion examines the shortcomings Paleo-Indian behavioral models have encountered. In particular, some of the major issues that arise when Paleo-Indian behavioral models are generated using ethnographic, paleoenvironmental, and artifact assemblage data are examined.

2.2.1 BEHAVIORAL MODELS BASED ON ETHNOGRAPHIC DATA

Although ethnoarchaeology has provided invaluable insights for interpreting archaeological remains, utilizing ethnographic data without understanding its limitations for the study of Paleo-Indians is problematic. These data are unsuitable for narrow and even broad interpretations of the archaeological record because modern analogs to Paleo-Indian societies are lacking and the ethnographic data is often systematically biased. (Kelly 1988, Shott 1990, Shott 1993, Wobst 1978). Compounding this is the fact that the ethnographic record may not be capturing the lifeways of the hunter/gatherers as they were prior to contact with other modern societies. Despite this hunter/gatherer societies were seen as Paleolithic relicts preserved by remoteness. Modern foragers also appear pristine because of their subordinate status within a larger social system. Recently however, revisionist critiques have demonstrated these peoples were not pristine isolates (Shott 1990, 1993, Wilmsen and Denbow 1990) but rather, have been significantly altered or marginalized by centuries of contact with other societies. Therefore, ethnographic facts can only provide general information for the reconstruction of Paleo-Indian societies.

The paucity of direct archaeological evidence on eastern Paleo-Indian subsistence practices has resulted in a greater reliance on ethnographic data to interpret the archaeological record (Cable 1996, Deller and Ellis 1988, Johnson 1992, Krist and Brown 1994, Peers 1986, Simons 1994, Storck 1982). Even when subsistence models are generated directly from food remains, they are fraught with biases, e.g. differential decomposition rates have resulted in the over representation of large game animals, such as caribou, at Paleo-Indian sites (Shott 1990, 1993). Unfortunately, ethnographic data contains biases as well, introduced by both the interviewer; through the means by which observations are recorded and interpreted and in the way the informant presents that information to the observer (Wobst 1978). For example, modern forager groups can vary along the forager/collector continuum throughout the seasonal round with low residential mobility occurring during the winter and high mobility occurring during the summer (Binford 1980). The ethnographer, inadequately describing them for archaeological research (Binford 1980, Shott 1990), may inadvertently typologically place these foragers in the wrong category.

Despite the issues discussed above, ethnographic data still provide insights into the social systems of Paleo-Indians. Due to the limitations of ethnographic information, archaeologists must remember to test hypotheses constructed from ethnographic data in an appropriate deductive framework. For example, researchers in the Great Lakes region have utilized ethnographic data to generate models of Paleo-Indian subsistence/settlement that indicate early forager economies were centered on caribou hunting (Deller and Ellis 1988, Krist and Brown 1994, Peers 1986, Simons 1994, Storck 1982). Despite the limitations of ethnographic information and the scant faunal remains, archaeologists quickly adopted the model of caribou herd reliance without testing the model first (Jackson and McKillop 1991). Recent works by Krist and Brown (1994), Jackson (1997), and Spiess (2001) have with some success begun to test hypotheses about caribou hunting. Ethnographic data are useful for hypothesis generation related to early hunter/gatherers as Krist and Brown have demonstrated. The real danger in utilizing such data arises when the information is considered a clone of past human behavior and variability, and is subsequently used as a direct analog for Paleo-Indian lifeways (Wobst 1978).

2.2.2 BEHAVIORAL MODELS BASED ON ECOLOGICAL DATA

Recently, a wealth of paleoenvironmental data has become available to archaeologists including pollen, fossil vertebrate, and geomorphic data (Delcourt and Delcourt 1987, Guthrie 1984, Holman et al 1986, Kapp 1999, Webb et al 1983). Subsequently, paleoenvironmental reconstructions are more accurate, enabling archaeologists to better understand Paleo-Indian habitats and behaviors. As in ethnographic studies, paleoenvironmental reconstructions contain systematic biases and lack modern analogs, which inhibit the development of behavioral models utilizing ecological data (Shott 1990, Kapp 1999).

Since the early archaeological work conducted on Paleo-Indian sites in the Western United States, Paleo-Indian studies have been affected by the biases in the paleoenvironmental record generated from archaeological remains (Shott 1990). Early Paleo-Indian groups were considered dependent upon large game because remains of large game resources, such as bison and mammoth, were over represented in the archaeological record at Western sites (Sellards 1952). In the East, this view was supported by the discovery of caribou bones and although sparse, these remains dominated the Paleo-Indian faunal record (Cleland 1965, Spiess et al. 1985, Storck 1988). The recent discovery of botanical remains at the Shawnee-Minisink site in Pennsylvania and the identification of small mammal remains at the Udora site in Ontario, demonstrate that Paleo-Indian foragers were not exclusively dependant on large game animals (McNett 1985, Storck and Spiess 1994). These discoveries are often ignored because the paleoenvironmental record is skewed toward the representation of large game resources. When considering preservation rates, archaeological recovery techniques, and the physical size of large game animals, it becomes readily apparent that paleoenvironmental reconstructions can be fraught with errors (Shott 1990).

Due to the successional/transitional ecologic communities that inhabited regions following deglaciation, the environments Paleo-Indian peoples occupied were complex, making paleoenvironmental reconstructions difficult at best (Kapp 1999). The mosaic of ecosystems occupying eastern North America, in combination with the vast extent of glacial ice and changing lake and sea levels during the late Pleistocene, was unlike that of any modern environment (Kelly 1988). This resulted in "disharmonious" mixes of modern and now-extinct species rather than simple southward or downslope displacement and compaction of modern plant/animal communities (Guthrie 1984, Kelly 1988). For example, the central Great Lakes region was occupied by semi-open spruce dominated herbaceous woodland from 11,500 to 11,000 rather than a pure closed spruce forest that exists in modern high-latitude habitats (Shott and Welch 1984). In addition, many treeless areas across the upper Great Lakes may have consisted of prairie with arid southwest characteristics, rather than treeless tundra (Anderson 1954, Kapp 1999). Late Pleistocene plant/animal communities were generally more diverse than modern ones, without the pronounced drop in the number of available species from south to north that occurs in modern environments (Kelly 1988, Shott 1990). Compounding the complexity of the environment even further was the rapid rate of change ecosystems were undergoing between 11,000 and 10,000 BP (Kelly 1988). The complexity of late Pleistocene ecosystems and the lack of direct modern analogs to Paleo-Indian period environments has hindered the development of behavioral models based on paleoenvironmental data.

Similar to artifacts left by past societies, ecological remains are subject to the same post-depositional processes or N-transforms (Schiffer 1976). These processes skew the view of the ecological record, leading to misinterpretations of the paleoenvironmental data. Misinterpretations of the ecological record are compounded by the complex nature of the environment during the late Pleistocene. Despite these limitations, paleoenvironmental data provides insights into the past, while acting as a point of departure for models of Paleo-Indian behavior. As paleoenvironmental reconstructions become increasingly more accurate, archaeologists will better understand the resources that Paleo-Indian groups had access to. Researchers are also utilizing glacigenic and lacustrine processes operative during the late Pleistocene to generate paleoenvironmental reconstructions. For example, Krist and Schaetzl (2001) suggest that summertime paleowinds were both very strong and dominantly from the east and southeast in the upper Great Lakes during the Paleo-Indian period. Their model suggests conditions were so climatically severe that Paleo-Indian period settlement and subsistence strategies were affected near the windward shore of glacial Lake Algonquin.

2.2.3 BEHAVIORAL MODELS BASED ON ASSEMBLAGE STUDIES

Inferences on behavior have come primarily from the study of Paleo-Indian artifact assemblages (Shott 1990). Unfortunately, technological studies have only provided a limited view of Paleo-Indian subsistence strategies, due to their focus on dietary composition. As discussed earlier, this focus is due, in part, to the limited amount of archaeological remains from the Paleo-Indian period. Since technological change plays a significant role in the efficiency with which resources are obtained, the study of Paleo-Indian assemblages should be a critical part of economic behavior modeling (Belovsky 1988). As Shott (1993) illustrates, the study of Paleo-Indian technology should be viewed "...as an attempt to expand the scope of anthropological inference from sparse archaeological remains than to provide a full account of Paleo-Indian cultures in all of their social and economic dimensions."

Despite the usefulness of technology, studies for building economic behavioral models focusing solely on Paleo-Indian assemblages have several key limitations. First, social complexity is typically associated with an abundant and diverse archaeological record (Shott 1993). With such a limited material record, Paleo-Indian culture is generally viewed as being simplistic. This view lessens the role of decision-making processes, while overemphasizing the role of the environment in determining Paleo-Indian adaptive strategies. Second, site formation processes have left archaeologists primarily with a lithic material record from the Paleo-Indian period (Shott 1993). Undoubtedly, Paleo-Indians possessed an extensive material culture that was not lithically based. Materials such as clothing, bone and wood tools did survive the processes of time

(Shott and Wright 1999). Third, the means by which artifacts are located and collected can limit our understanding of the range of variation found within Paleo-Indian assemblages. Until recently, archaeologists in the Upper Great Lakes had focused on large archaeological sites, biasing our knowledge about Paleo-Indian artifact assemblages (Jackson and McKillop 1991, Jackson 1998). Jackson and McKillop clearly demonstrate that smaller interior sites are much more numerous than once thought, enabling researchers to assemble a holistic view of Paleo-Indian assemblages (Jackson 1998). Fourth, several authors (Ellis and Deller 1988, Goodyear 1989, Lothrop 1988, Shott 1986) have illustrated that tool classification schemes often do not properly characterize Paleo-Indian artifact assemblages. For example, schemes may lack the classes needed to account for variability between assemblages and or classes may not be distinctive enough to allow direct comparison between sites (Shott 1990). Lastly, social complexity is difficult to determine from artifact assemblages alone (Shott 1993). As a result, ethnographic data are necessary to assign meaning to the archaeological record (Binford 1978). The use of ethnographic data to develop and test models demonstrates the need for models that utilize multiple lines of evidence.

2.3 CONCLUSIONS

Researchers face a wide range of difficulties when attempting to develop models of Paleo-Indian behavior. Most of these stem from the fact that the material record of the Paleo-Indian period is limited primarily to lithic artifacts and the remains of large game animals. As a result, a great deal of emphasis has been placed on the analysis of lithics, and in particular fluted points. This has led to the construction of behavioral models that address only a limited portion of the Paleo-Indian lifeway, one focused on hunting strategies. Using the behavioral model outlined in chapter five as a vehicle, simulations of settlement and subsistence behaviors related to a wide range of plant and animal species is presented within chapter six in hopes of shedding new light on early hunter/gatherer adaptive strategies.

Much like the Paleo-Indian archaeological record the ecological record from the late Pleistocene is also limited in content. However, recent discoveries are providing new insights into the type of ecosystems that occupied the landscape throughout the Paleo-Indian period. These data, presented in chapter three, in conjunction with topographic and physiographic data, will be manipulated within a Geographic Information System (GIS) to produce a simulation depicting the spatial arrangement of key species within the late Pleistocene ecosystem. This simulation, presented as a series of habitat models, is outlined within chapter four.

Unlike many traditional Paleo-Indian behavioral studies that have focused on chronology, typology, and technology (Shott 1990) the approach presented in this research focuses on modeling Paleo-Indian decision-making as it relates to the ecology of the period. Because of the lack of modern analogs to Paleo-Indian society ethnographic data will play a limited role within this research. Ethnographic facts will simply provide a point of departure from which the broad goals and objectives of Paleo-Indian hunter/gatherers are hypothesized for the models constructed within chapter six.

Chapter III

THE STUDY AREA AND THE LATE PLEISTOCENE ENVIRONMENT

The study area for this research encompasses all, or portions of, Midland, Saginaw, Clinton, Genesee, Oakland, and Monroe counties in southeastern Lower Michigan (Figure 3.1). Areas in and around these six counties were not included in the analysis due to the quality or lack of key GIS data layers such as soils and topography data. In addition, many of the counties left out of the analysis contain few recorded early Paleo-Indian sites. Wayne and Macomb counties were not included in this analysis due to extensive urbanization that has significantly altered the physiographic features in the region.

The region was chosen for three reasons. First, a large proportion of southeastern Lower Michigan, compared with other regions of the state, has been surveyed by archaeologists (Cleland et al. 1998). Second, the region contains several documented and extensively excavated early Paleo-Indian sites, including the Barnes, Butler, Gainey, Leavitt, and Lux sites that all lie within counties examined in this research (Shott 1993, Simons 1984, 1997, Voss 1977). Third, the counties chosen contain sufficient digital cartographic data to implement the model outlined in chapter five and six.

3.1 CLIMATE

The paleoclimate during the late Pleistocene was cooler and drier than modern climatic conditions (Karrow et al 1975, Krist and Schaetzl 2001, Shott and Welch 1984,

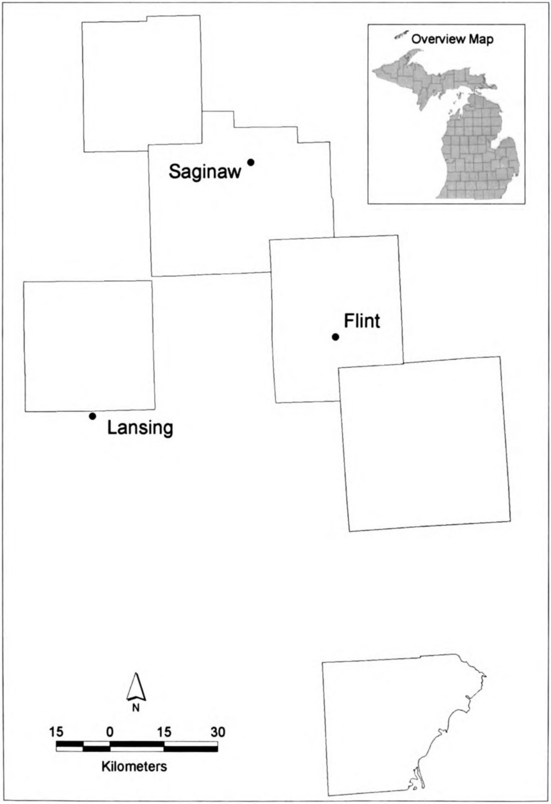

Figure 3.1. The Study Area, Located In Southeastern Lower Michigan

Webb et al. 1993). This is due, in large part, to the presence of the Laurentide ice sheet across northern Michigan, which had a large, cold, dry, glacial anticyclone over it (Kutzbach et al 1993, Manabe and Broccoli 1985). Cool, dry air descended anticyclonically along the margins of the glacier driving the predominately easterly winds that moved through the upper Great Lakes (Krist and Schaetzl 2001). The sedimentology of paleo-spits along the glacial Lake Algonquin strandline in northern Lower Michigan also suggest that the prevailing winds during the early Paleo-Indian period were out of the east and southeast in northern Lower Michigan. In addition, the size and texture of well-rounded gravels within these spits indicate the east to southeasterly winds were very strong and, therefore, greatly affected the paleo-climate of Michigan (Krist and Schaetzl 2001). During the growing season, winds along some coastal regions of eastern Michigan would have frequently reached hurricane force. Recent evidence also seems to suggest that the anticyclone developing over Michigan would have remained within a few hundred miles of the ice margin while very strong west and northwesterly winds would have persisted south of the Saginaw Valley (Muhs and Bettis 2000, Schaetzl personal communication).

The pollen record from in, and around the study area indicates that "boreal-type" plants occupied the region during the early Paleo-Indian period (Cleland et al. 1998, Garland and Cogswell 1985, Kapp 1999, Karrow and Warner 1990, Karrow et al. 1975, Shott and Welch 1984). Microfossils, from a spruce pollen zone at the Kincardine Bog in southwestern Ontario, suggest that mean annual temperatures ranged from –1.8 to 3.3 degrees Celsius (Karrow et al. 1975, Shott and Welch 1984). Therefore, the floral models constructed in chapter four are built on the assumption that the climate during the early Paleo-Indian period in southeastern Michigan supported a closed spruce forest.

3.2 GLACIAL HISTORY: A REGIONAL PERSPECTIVE

At its maximum, the Laurentide ice sheet in the Great Lakes region, comprised of the Green Bay, Michigan, Saginaw, and Erie lobes, extended south of Michigan into central Ohio, northwestern Indiana, and northeastern Illinois (Figure 3.2) (Farrand and Eschman 1974, Fullerton 1980, Larson and Schaetzl 2001). Beginning around 15,500 BP, the Laurentide ice sheet began slowly melting back from southcentral Lower Michigan. During the next 5,500 years, continued recession was interrupted by minor oscillations or ice margin re-advances that formed a series of end moraines across central Lower Michigan.

While retreating, a series of proglacial lakes formed at the margin of the Laurentide ice sheet at locations where the land sloped toward the ice front. These were constrained by the ice margin and topography of varying elevations. Their outlets and water budgets controlled the surface elevation of these lakes. The earliest proglacial lakes to form in Lower Michigan were Glacial Lake Chicago and Lake Maumee within the Lake Michigan and Erie basins, respectively (Figure 3.3). Throughout its 2,000-year history, the level of Lake Maumee fluctuated in response to a receding and re-advancing ice margin (Calkin and Feenstra 1985, Eschman and Karrow 1985). The lake level stabilized long enough to form three successively lower beach ridges. Like many of the ridges associated with postglacial lakes, these ridges lay many miles inland from the

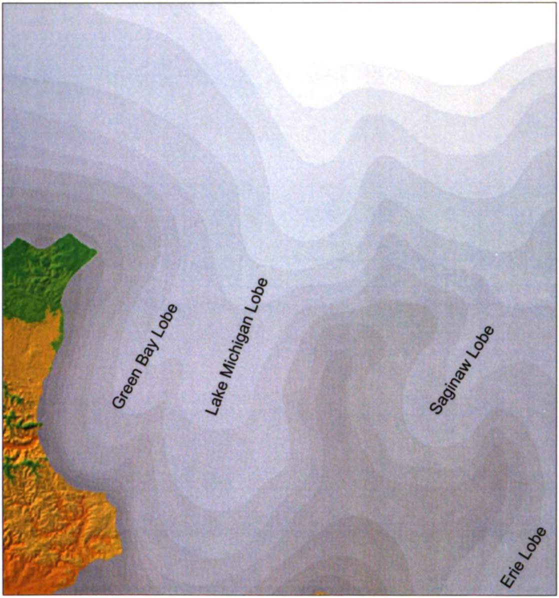

Figure 3.2. Glacial Ice Just Prior To Its Retreat From Lower Michigan ca. 17,800 B.P.

Figure 3.3 Early Stages Of Glacial Lake Chicago And Maumee ca. 13,900 B.P.

modern shores of the Great Lakes. The first two phases of Lake Maumee drained southwestward into the Wabash valley (Figure 3.4). The final phase drained northward into Early Lake Saginaw then westward into the Saginaw valley. By 13,700 BP, glacial Lake Saginaw drained westward across central Lower Michigan through the Maple/Grand River Valley into Glacial Lake Chicago (Figure 3.5). Glacial Lake Chicago persisted for several thousand years primarily draining southward into the Mississippi valley (Bretz 1964, Hough 1963, 1966). The level of glacial Lake Chicago appears to have been relatively stable with periodic down cutting of the outlet at Chicago resulting in lower lake phases (Larson and Schaetzl 2001). As the ice continued to melt back exposing the "Thumb" of Michigan, Glacial Lake Arkona formed within the Lake Saginaw and Huron basins (Eschman and Karrow 1985) (Figure 3.6).

Around 13,000 BP after the Lake Michigan and Saginaw lobes had melted back into northern Lower Michigan, the Laurentide ice sheet surged back into the Lake Michigan, Huron, and Erie basins (Larson et al. 1994, Larson and Schaetzl 2001) (Figure 3.7). This surge, called the Port Huron re-advance, resulted in the formation of Glacial Lake Saginaw and Lake Whittlesey in the Lake Huron and Erie lake basins, respectively. The Port Huron end moraine marks this significant re-advance throughout much of Lower Michigan (Blewett 1991, Winters and Rieck 1991). Continued melting after the Port Huron advance, once again exposed the "Thumb" of Michigan, leading to the formation of Glacial Lake Warren around 12,800 B.P (Figure 3.8).

The Laurentide ice continued to retreat, exposing the northern tip of Lower Michigan and the Indian River lowlands, allowing water to drain eastward from the Lake

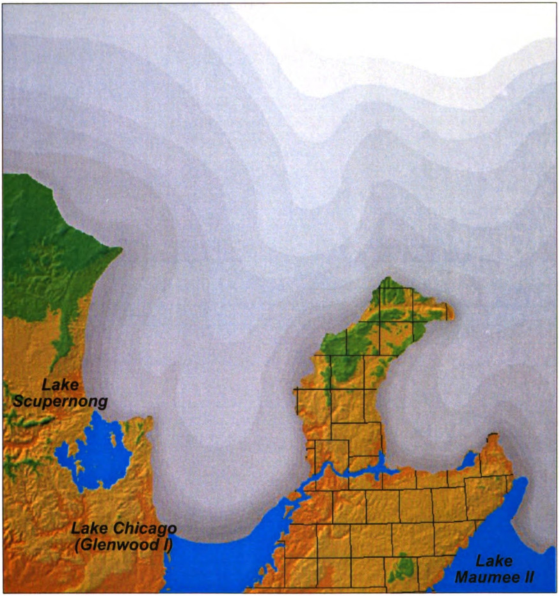

Figure 3.4. Glacial Lake Maumee II And
The Glenwood I Phase Of Glacial Lake Chicago

Figure 3.5 Glacial Lake Maumee III, Early Saginaw, And Glenwood I

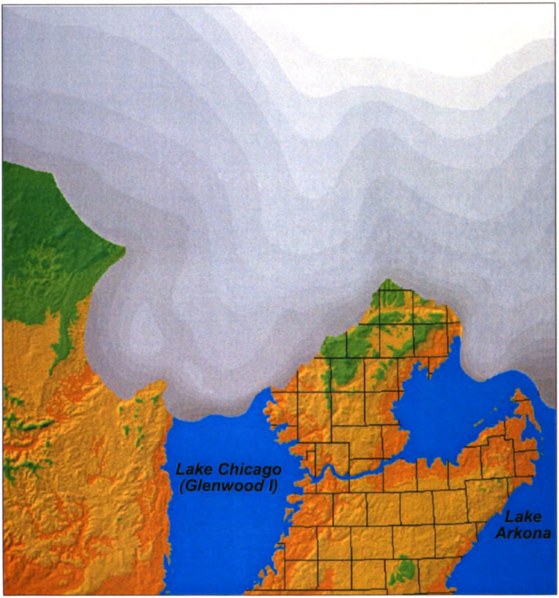

Figure 3.6. Glacial Lake Arkona And Glenwood I ca. 13,600 B.P.

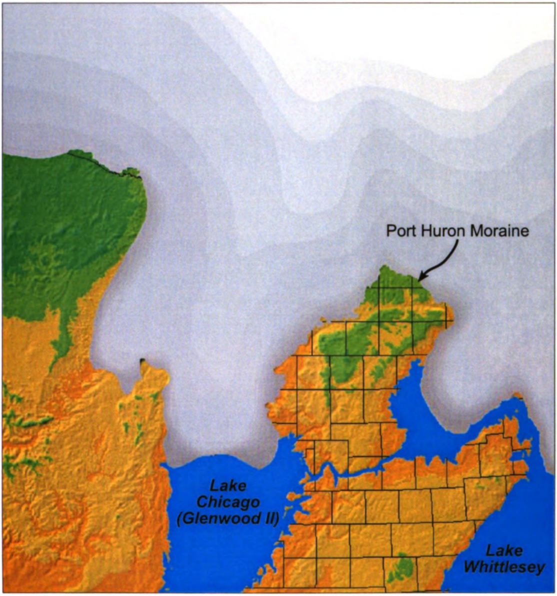

Figure 3.7. The Port Huron Ice Reaches Its Maximum ca. 13,000 B.P.

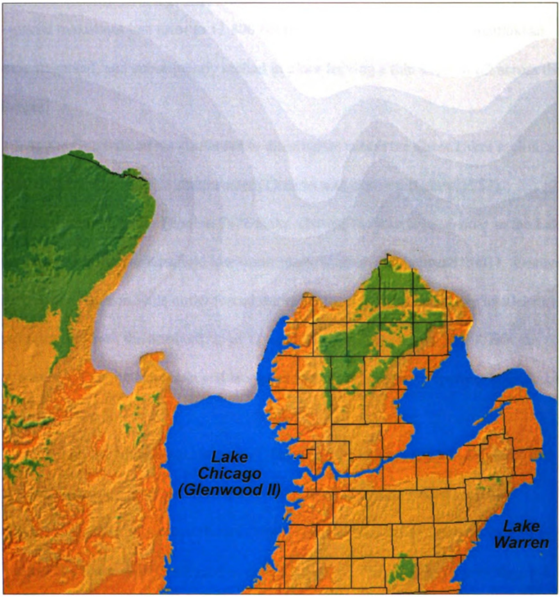

Figure 3.8. A Retreating Ice Front Forms Glacial Lake Warren In The Huron Basin While The Glenwood II Phase Occupies The Michigan Basin

Michigan basin into the Huron basin (Larson et al. 1994, Larson and Schaetzl 2001) (Figure 3.9). By about 12,000 BP, the Straits of Mackinac were also free of glacial ice. This retreat was short-lived as ice then re-advanced into Lower Michigan, reaching its late- glacial maximum just prior to 11,800 BP (Figure 3.10). Ice from the Greatlakean advance stagnated, and subsequently melted in place leaving a thin sheet of till across the landscape.

As the Greatlakean ice continued to disintegrate across the Great Lakes region, a new outlet at Fenelon Falls in southwestern Ontario was exposed (Larsen 1987). Drainage through the lower Fenelon Falls outlet allowed the lake level to drop in the Lake Huron basin, forming the Kirkfield low water phase (Larsen and Schaetzl 2001). Isostatic uplifting of the Fenelon Falls outlet forced the water level to rise. Once the Greatlakean ice had retreated from the northern tip of Lower Michigan just prior to 11,000 BP, the rising waters within the Michigan and Huron basins again coalesced, forming Main Lake Algonquin (Figure 3.11).

Although the Main Lake Algonquin shoreline is easily identifiable as an uplifted beach ridge throughout northern Lower Michigan, such shoreline features are not discernable in southern Michigan (Larsen 1987). The reason for this lack of features is still subject to debate, with two hypotheses being argued. The first hypothesis suggests that the southward transgression of Lake Algonquin never reached the Port Huron outlet and thus shoreline features would now be under water (Larsen 1987, Larson and Schaetzl 2001). This interpretation has significant ramifications for the archaeology of the region since it suggests that early Paleo-Indian sites in southwestern Ontario, thought to be along the Lake Algonquin shore, would have been several miles inland from the nearest active

Figure 3.9. The Tip Of Lower Michigan Is Exposed Allowing Water To Drain Eastward Into The Lake Huron Basin ca. 12,300 B.P.

Figure 3.10. The Greatlakean Readvance Reaches Its Maximum ca. 11,800 B.P.

Figure 3.11. Lake Algonquin Forms Within The Lake Michigan And Huron Basins ca. 11,000 B.P.

strandline. Under the second hypothesis, shoreline features in the southern half of the Michigan and Huron basins are no longer visible because the strandlines were not uplifted like their counterparts to the north (Eschman and Karrow 1985). Rather, these strandlines remained at the same elevation, which was later occupied by the Nipissing Great Lakes (Eschman and Karrow 1985), eroding away any remnants of the earlier shorelines. An alternate theory indicates that a Post-Algonquin lake, Ardtrea, was above the Main Algonquin low level in the southern Lake Huron basin and may have been strandline upon which sites such as Parkhill lay (Ellis and Deller 2000).

The continued northerly retreat of the glacial ice exposed a series of lower outlets near North Bay, Ontario resulting in successively lower lake levels (Farrand and Drexler 1985, Larson and Schaetzl 2001). Water levels continued to drop to the level of Lake Chippewa and Lake Stanley, despite a minor re-advance that pushed into the Lake Superior basin around 10,500 BP (Lowell et al. 1999) (Figure 3.12). This re-advance was short-lived, with the last remnants of glacial ice melting back from upper Michigan by 9,000 BP.

As the ice melted back from the Lake Superior basin prior to 9,000 BP, two small glacial lakes were formed on either side of the basin (Farrand and Drexler 1985, Larson and Schaetzl 2001). Glacial Lake Duluth occupied the western part of the basin, while Lake Minong formed in the eastern part (Figure 3.13). Lake Duluth drained southward across upper Michigan through the Au Train-Whitefish channel into Lake Chippewa while Lake Minong drained southward into Lake Stanley.

During the next several thousand years, isostatic rebound continued across the Upper Great Lakes raising the outlet of the postglacial lakes occupying the Michigan and

Huron basins. By 5,500 BP, Nipissing Great Lakes water levels had risen as much as fifteen meters above modern levels (Figure 3.14). Drainage was now through the southern outlets at Port Huron and Chicago. The outlet at Port Huron was slowly down cut to bedrock around 2,200 BP, at which time the water levels in the Michigan and Huron basins lowered to their modern levels (Larson and Schaetzl 2001). Contemporaneously, the isostatic uplifting at the bedrock sill near Sault Ste. Marie separated the Superior and Huron basins.

3.3 FLORA

The interrelationship between plants, climate, and soils form the habitat, or ecosystem, in which animals and humans reside (Kapp 1999). As a result, the distribution of floral species is an important part of modeling the late Pleistocene habitats of animal species and the activities of early hunter/gatherers related to resource acquisition. Prior to modeling the distribution of plants, the pollen records from the region in and around southern Lower Michigan were examined to identify the key set of floral species that likely occupied the region during the early Paleo-Indian period. Rather than being exhaustive, this research focuses on species likely to have directly or indirectly affected the early Paleo-Indian resource base; including edible plant species and those that may have affected the distribution of the fauna identified in the next section.

Early Paleo-Indian period pollen records from in and around southern Lower Michigan indicate the region was occupied by a spruce dominated forest mix that included pine, and to a lesser extent, deciduous tree and shrub species (Ahearn and Bailey 1980, Cleland et al.1998, Garland and Cogswell 1985, Holloway and Bryant 1985, Karrow and Warner 1990, Shott and Welch 1984, Webb et al. 1993). Favorable climatic conditions, much like those found in the boreal forest of the Laurentian shield today, enabled a spruce ecosystem to thrive in a region historically lacking spruce. Spruce persisted in the region until ca. 10,000 BP when pine and then hardwoods began to dominate. The following discussion describes the forest setting in southern Michigan during the early Paleo-Indian period.

Due to site preference, the most common species of spruce throughout Lower Michigan during the late Pleistocene was probably white spruce (*Picea glauca*). White spruce prefers moderately well drained uplands, flood plains, former glacial lakebeds and alluvial fans while being intolerant of excessively and poorly drained areas (Bonnan 1992, Burns and Honkala 1990, Elliott-Fisk 2000, Kapp 1999, Larsen 1980). Black spruce (*Picea mariana*), the only other species of spruce occupying Lower Michigan during the late Pleistocene, would have frequently been found on wet, acidic soils while forming pure stands on peat and muck soil. In limited numbers, black spruce stands also occupied drier upland sites containing sandy clays and loams. Labrador Tea (*Ledum groenlandicum*), a common food for moose, along with, but to a lesser extent, Mountain Cranberry (*Vaccinium vitis-ideae*) likely dominated the forest floor in spruce stands. The berries of the Mountain Cranberry are readily eaten by moose, and snowshoe hare and were available to foragers in late summer and fall persisting even into the winter (Rook 1999).

Spruce stands on drier sites tend to be thinner and are frequented by fire, enabling other species such as paper birch (*Betula papyrifera*), trembling aspen (*Populus tremuloides*), balsam fir (*Abies balsamea*), and jack pine (*Pinus banksiana*) to inhabit

Figure 3.12. Lakes Chippewa And Stanley Form Within The Lake Michigan And Huron Basins ca. 9,900 B.P.

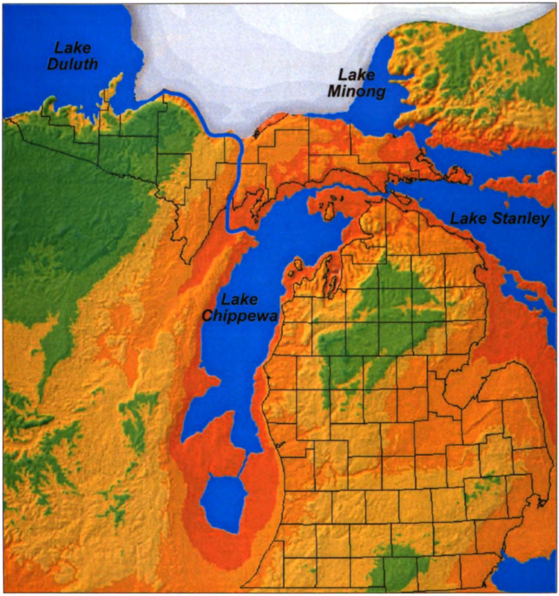

Figure 3.13. Lake Duluth And Minong Form Within The Lake Superior Basin ca. 9,700 B.P.

Figure 3.14. Water Levels Rise In The Great Lakes Region To The Nipissing I Level ca. 4,500 B.P.

these areas (Larsen 1980). In very limited numbers, drier sites with well-developed soils would have supported several other deciduous tree species not considered in this research including maple (*Acer spp.*), elm (*Ulmus spp.*), ash (*Fraxinus spp.*), and hickory (*Carya spp.*) (Cleland et al. 1998, Garland and Cogswell 1985). Due to their limited distribution, these deciduous species would have had a minimal effect on the overall ecology of southeastern Lower Michigan during the early Paleo-Indian period. On drier, open spruce sites, reindeer lichen (*Cladina* spp.) was likely the dominant ground cover. Within modern boreal forests, these areas are often referred to as "lichen woodlands" (Larsen 1980). Such open spruce forests were more likely to occur in the northern half of Lower Michigan during the late Pleistocene, along the tundra/forest transition zone. On wetter spruce sites, particularly cool areas with higher humidity, hanging lichen (*Usnea* spp.) undoubtedly covered the lower branches of many trees. Throughout the winter, caribou often rely on both arboreal and ground lichen for food.

Coarse textured sandy soils found on eskers, beach ridges, outwash plains, and in kamic areas supported jack pine, and some paper birch and trembling aspen (Larsen 1980, Shott and Welch 1984). By the end of the late Pleistocene, oak (*Quercus* spp.*)* began to appear on these sites as well. Chokecherry (*Prunus virginiana*) and serviceberry (*Amelanchier* spp.*),* likely sources of food for early Paleo-Indians (McNett 1985) were likely a common understory within jack pine forests. Reindeer lichen and various blueberry (Vaccinium spp.) species such as *Vaccinium angustifolium* and *Vaccinium myrtilloides* undoubtedly occupied the forest floor on very dry sites. *Cladina* prefer oligotrophic, sandy, gravelly, stony or rocky soils and are often displaced by mosses and other vascular plants in wetter areas. Within the closed boreal forest that occupied Lower

Michigan, *cladina* was probably the most common within the relatively open jack pine forests. In terms of total biomass and surface area covered, *Cladina* is the most abundant lichen in the modern boreal forest and will be further studied in this research. The *Cladina* lichen is also a staple winter food for caribou, thus its common name, Reindeer Lichen. Blueberries are a good food source for many types of wildlife and may have been utilized by early hunter/gatherers as well.

Open areas along the edges of wetlands, streams, and lakes support less shade intolerant species such as willow (*Salix* spp.), trembling aspen, alder (*Alnus* spp.), and thimbleberry (*Rubus parviflorus*) (Garland and Cogswell 1985, Larsen 1980). Moose commonly browse on these species, while thimbleberry was a viable food source for early hunter/gatherers (Allen et al. 1987, Darby 1979, Darby and Pruitt 1984, Schaefer 1996). Areas along many streams and wetlands probably also supported sedges (*Carex* spp.), horsetail (*Equisetum* spp.), and a variety of grasses (*Gramineae* spp.) that moose and caribou would commonly eat as well (Skoog 1968).

Many small lakes, wetlands, and bogs probably contained aquatic vegetation frequently eaten by moose, giant beaver and, to a lesser extent, muskrat (Holman 1996). Mastodons may also have been in pursuit of aquatic vegetation when they periodically fell into and became trapped within bogs and wetlands. Many inundated wetlands likely supported emergent vegetation as well. Due to the eutrophication that has occurred in wetlands across southern Lower Michigan since the Paleo-Indian period, many modern wetlands presently too dry to support aquatic vegetation were able to support aquatic plant species and in some instances fish (Shoshani et al. 1989, Shoshani and Smith 1996).

3.4 FAUNA

The mixed spruce ecosystem occupying Lower Michigan supported a fairly diverse set of faunal species, many of which are represented in the postglacial fossil record (Cleland et al. 1998). Of the twenty fossil mammal taxa found south of the Mason-Quimby line, only the Mastodon (*Mammut americanum*), caribou (*Rangifer tarandus*), moose (*Alces alces*), muskrat (*Ondatra zibethicus*), beaver (*Castor canadensis*), giant beaver (*Castoroides ohioensis*), and hare (*Lepus americanus*), will be considered in this research. Postglacial fossil finds and the late Pleistocene environment suggests these species occupied southeastern Michigan in numbers large enough to be accessible to Paleo-Indian hunter/gatherers (Holman 1975, 1995). Mammals such as the mammoth (*Mammuthus jeffersoni*), Scott's moose (*Cervalces scotti*), elk (*Cervus elaphus*), white-tailed deer (*Odocoileus virginianus*), and flat-headed peccary (*Platygonus compressus*) did not likely frequent the boreal forests of southeastern Michigan enough to play a significant role in Paleo-Indian subsistence strategies.

Mammoth and peccary preferred the open grassland environments that were following the melting glacier, rather than the relatively closed boreal forests of southern Michigan of the Paleo-Indian period (Holman 1975, 1995). The frequency of mammoth remains in the Saginaw Bay area suggests that during part of the Pleistocene, recently drained lake plains supported extensive grasslands. By the time Paleo-Indians arrived in southeastern Michigan, both the peccary and mammoth probably did not reside in the region.

Two species of moose occupied Lower Michigan during the late Pleistocene. Little is known about the habits of the Scott's moose (*Cervalces scotti*). However, having longer, thinner legs and higher shoulders than the modern moose, indicates the Scott's moose probably frequented wet areas, such as sphagnum bogs (Holman 1975, 1995). The recent discover of the remains of a Scott's moose at the Shelton Mastodon site supports the notion that the species frequented bog environments across southeastern Lower Michigan. The low frequency of fossil sites containing the remains of Scott's moose suggests that the species was relatively uncommon in postglacial Michigan. The modern moose probably out-competed the Scott's moose and was better adapted to the closed forests that began to occupy Michigan during the late Paleo-Indian period.

Elk and white-tailed deer, which thrive in open deciduous woodlands, were relatively uncommon in Michigan during the late Pleistocene. Both species are rarely found within modern boreal forests (Larsen 1980, Nelson 1973, Winterhalder 1981b). Although deer were frequently utilized by Paleo-Indians within the deciduous forests of eastern North America at sites such as Meadowcroft (Meltzer 1993), they were probably rarely hunted by early Paleo-Indian hunter/gatherers occupying the boreal forests of the region.

Despite its frequency across much of the Great Lakes region today, black bear (*Ursus americanus*) remains are virtually absent from Michigan Pleistocene deposits (Holman 1995) suggesting bear did not frequent the boreal forests of southern Michigan. In addition there are very few remains of other bear species, such as the grizzly (*Ursus arctos*) and short-faced bear from the Great Lakes region. With the large size of these species, preservation rates should be relatively high. Wisconsinan finds of the black bear indicate the species moved into Lower Michigan after the Paleo-Indian period.

Although there is a paucity of avian fossil evidence in the Great Lakes from the late Pleistocene, waterfowl and grouse may have been fairly common across southeastern Lower Michigan during the late Paleo-Indian period (Holman 1995, Larsen 1980). Several species of fish were also available to early hunter/gatherers particularly in shallower organic rich lakes and slower flowing streams (Bailey and Smith 1981, Shoshani and Smith 1996).

3.4.1 MASTODON

Prior to their disappearance sometime after 10,000 BP, the American mastodon (*Mammut americanum*) was relatively common within the forests of southeastern Michigan (Holman 1975, 1995). Over 200 mastodon finds have been located across southern Michigan, the majority from the southeastern part of the state. The fact that most fossil sites have been located within the sediments of shallow basins or kettle depressions indicates that mastodons frequented small lakes, streams, bogs or wetlands (Holman 1975, 1995, McAndrews and Jackson 1988). The teeth of the mastodon suggest they browsed within forests feeding on conifer cones, leaves, branches, twigs and other wetland plant species found near aquatic settings. Much like other herbivores of the period, mastodons probably ate aspen (*Populus* spp.), birch (*Betula* spp.), alder (*Alnus* spp.), and willow (*Salix* spp.). Like elephants, mastodon tusks were used to pry tree branches off, enabling them to reach vegetation. Mastodons also frequented the widespread salt licks across southeastern Lower Michigan. The high sodium requirements that plagued the mastodon drove them many miles to locations offering access to salt. In other words, mastodons, like modern elephants, were geographically "tethered" to salt-rich water holes or soils.

Unlike the modern elephant, the mastodon was probably not a very intelligent animal (Holman 1975, 95). Mastodons often ventured into small basins or open kettlehole bogs, covered with a thin layer of vegetation, in search of food. Once in the bog, many Mastodons found it impossible to escape, becoming mired down in the layer of peat and muck on the bottom. Since bogs across Lower Michigan were newly formed during the late Pleistocene, shore vegetation may have been poorly developed making access to a stranded mastodon easy for early hunters. As eutrophication occurs, the edge of a bog moves toward the interior leaving a partially forested wet border that is difficult or impossible for a human to traverse. Mastodon utilization by hunter/gatherers is supported by find spots from both Michigan and Wisconsin that indicate the large herbivore was both scavenged and hunted within the Great Lakes region (Fisher 1986, 1988, Mason 1981, Overstreet 1998).

3.4.2 CARIBOU

Many authors agree that across the Great Lakes region the primary animal species available to Paleo-Indians was the caribou (*Rangifer tarandus*) (Deller and Ellis 1992, Jackson 1997, Simons 1997, Storck and Spiess 1994). Two lines of evidence support this assumption. First, caribou remains, in direct association with archaeological features, have been identified at early Paleo-Indian sites within in the Great Lakes region (Cleland 1965, Jackson 1998, Storck and Spiess 1994). Secondly, early Paleo-Indian sites are often located in regions that were occupied by spruce and tundra ecosystems, are favorable habitat for seasonally mobile caribou populations (Stock and Spiess 1994). Researchers also suggest that many Paleo-Indian sites are located in topographic settings that enabled hunters to intercept herds of caribou (Krist and Brown 1994, Simons 1994).

Two subspecies of caribou, barren ground (*Rangifer tarandus groenlandicus*) and woodland (*Rangifer tarandus caribou*), probably the descendants of (*Rangifer muscatensis*) and *(Rangifer frichii)* respectively, occupied Michigan during the early Paleo-Indian period (Brown and Cleland 1968, Holman 1995). Given similar behavior during the late Pleistocene, there would have been several differences between these two species of caribou. Woodland caribou are somewhat larger than barren ground caribou and notoriously more difficult to locate due to herd mobility and small group size (Russell 1998). Despite frequent movements and in some instances relatively short migrations, woodland caribou do not seasonally migrate long distances. Barren ground caribou, on the other hand, are generally found in larger herds and migrate long distances between winter and summer ranges. Woodland caribou avoid openings in the forest; while barren ground caribou avoid large tracts of old-growth spruce forest even during the winter (Calef 1995). Woodland caribou prefer shrubs such as willow, birch, and blueberry in addition to grasses, sedges, lichen, and other plants that occupy the forest floor.

During the fall, large migratory herds of barren ground caribou likely moved south into Michigan from the open parkland and tundra regions of Ontario near the south and eastern edge of Georgian Bay (Storck and Spiess 1994). These herds dispersed into smaller groups intermixing with other caribou that occupied the region throughout the year. The mixed spruce (*Picea* spp.) forest ecosystem of southeastern Lower Michigan provided wintering habitat for both migratory and non-migratory woodland caribou. Despite the fact that the primary wintering habitat for caribou can vary from year to year, southeastern Michigan could have acted as a winter "center of habitation" in which caribou are in residence, with few exceptions, even during periods of low population density (Skoog 1968, Spiess 1979). Because the mixed boreal forest probably contained a higher amount of deciduous and grassland communities than modern analogs (Cleland and Brown 1968) the forest ecosystem of Southern Michigan may have been able to support even greater numbers of caribou.

The mixed boreal forest of southern Michigan was not homogenous (Brown and Cleland 1968); containing preferred caribou foods such as birch, willow, horsetails, sedges, and grasses found along the margins of lakes, streams, and wetlands, particularly in open areas free of competition (Calef 1995, Shott 1986, Spiess 1979). Despite being eaten by caribou, Labrador tea, blueberry, and thimbleberry make up a very low portion of the winter diet (Skoog 1968). Of particular importance is the presence of reindeer lichen that can make up as much as 70-80% of the winter diet of caribou.

During the winter, predominately west to northwesterly winds buffeted the landscape keeping snow depths to a minimum in open areas along lakes and wetlands, and exposing low-growing plants and shrubs. Westerly facing slopes and ridge tops with little or no tree cover probably also had shallower snow depths. Snow depth and texture greatly affect the caribou winter range and movements. Therefore, open areas exposed to easterly winds are highly favorable for caribou feeding (Calef 1995). However, the nearly hurricane force winds buffeting coastal regions north and east of the study area drove the snow into wind-packed crusts that would have been difficult for caribou to dig through.

These extreme wind areas were unfavorable for both human and animal occupation (Krist and Schaetzl 2001).

In summary, well-drained uplands and areas adjacent to the edges of lakes and wetlands provided the most favorable winter habitat for barren ground caribou. Regions adjacent to lakes and wetlands gave caribou access to low growing plants, shrubs, and trees including willow and birch twigs. Frozen lakes and wetlands also provided barren ground caribou a place to rest and ruminate while watching for predators (Calef 1995). Well-drained uplands, often lacking spruce cover contained lichens and other low plants that caribou utilize as winter foods. In particular, the open jack pine forest that occupied the driest uplands would have contained a heavy lichen mat on the forest floor that is easily accessible through the soft snow (Larsen 1980). The strong smell of reindeer lichen enables caribou to locate them in snow depths of up to a meter (Skoog 1968). The abundant lakes and rolling sand hills found within Jackson, Livingston, Lenawee, Oakland, Washtenaw, and southern Genesee counties would have been rich in lichen and the other preferred winter foods of caribou. This area may well have acted as a winter "center of habitation" for migratory barren ground caribou. Both barren ground and woodland caribou would have frequented the jack pine forests during the winter (Darby 1979, Darby and Pruitt 1984, Schaefer 1996, Skoog 1968). During the winter, woodland caribou are often found foraging within bogs located near stands of jack pine. The windward side of ridges contained lesser amounts of snow, while providing caribou with a vantage point from which to watch for predators.

During the spring, barren ground caribou migrated northward into regions of southwestern Ontario at least as far north as Georgian Bay and Rice Lake (Storck and

Spiess 1994). These regions of Ontario contained a mix of tundra and or parkland environments with rich open herbaceous meadows and patches of spruce woodland providing a highly favorable summer range for caribou (Calef 1995, Stock and Spiess 1994). The barren ground caribou that remained within southeastern Lower Michigan continued to forage along lakes, wetlands, and floodplains, slowly moving northward as rising summer temperatures reduced the quality of forage (Curren and Grimes 1989). Few caribou ventured into central Lower Michigan north of the Saginaw watershed due to the presence of widespread poorly developed sandy soils that supported few plant species (Cleland et al. 1998). Due to very strong easterly winds, coastal wetlands along the western shore of Lake Algonquin were rare. Conversely, the leeward side of Lake Algonquin contained many wetlands with areas rich in sedges and grasses, preferred foods of caribou (Spiess 1979). Woodland caribou become widely dispersed during the spring and summer foraging on low growing shrubs, such Labrador tea, willow, and Birch, within mature spruce forests (Calef 1995, Darby 1979, Larsen 1980, Russell 1998, Spiess 1979).

3.4.3 MOOSE

Although not found in direct association with artifacts, moose may well have been hunted by Paleo-Indian peoples occupying the Great Lakes region. The extinct Scott's moose, which appears to have primarily frequented wetlands, may well have been uncommon by the start of the Paleo-Indian period (Holman 1995). Therefore, the following discussion focuses on the habitat characteristics of the modern moose. This discussion assumes that the behavior of moose during the Paleo-Indian period would have been similar to moose occupying the boreal forests of the Great Lakes region today.

During the spring and summer, an adult moose consumes large quantities, twenty to thirty kilograms/day, of buds, stems, bark and leaves in addition to aquatic vegetation (Larsen 1980). As a result, young or immature mixed forests near water are the preferred habitat for moose (Joyal and Scherrer 1978). Willow and birch twigs are the main food of moose during the spring (Allen et al. 1987, Cushwa and Coady 1976). Moose are commonly found within willow thickets occurring along rivers and lakes (Nelson 1973). Other foods include dry leaves, horsetail (*Equisetum*), the leaves of mountain cranberry, aspen, Vaccinium, alder (*Alnus*) twigs, and sedges (Cushwa and Coady 1976). Moose also utilize mineral licks, which provide a high level of sodium, during the spring (Allen etal 1987). The sodium requirements of moose are also met by consuming aquatic vegetation during the summer. The end of June generally marks the beginning of aquatic feeding for moose, which increases in frequency until the second half of July and declines during August (Cushwa and Coady 1976). Moose average about one hour within the water, feeding on bullhead-lily (*Nuphar variegatum*), watershield (*Brasenia schreberi*), and submerged pondweed (*Potamogeton* spp.). Throughout much of the summer, moose remain within 0.5 to 1 kilometer of non-forested wetlands and water bodies that provide aquatic vegetation (Joyal and Scherrer 1978). During the summer and fall, terrestrial feeding centered on white birch (*Betula papyrifera*), willow (*Salix* spp.), cherry (*Prunus*), and aspen (*Populus tremuloides*), horsetail, and, to a lesser extent, grass and shrub birch leaves. In some areas, modern moose are known to gravitate to willow-covered bars found along the inner margins of river bends during the fall (Nelson 1973).

Twigs of birch, willow, aspen, alder, and the green leaves of the mountain cranberry (*Vaccinium vitis-idaea*) are preferred during the winter (Cushwa and Coady 1976). The frequency at which these primary foods are eaten is based on availability rather than preference. Moose also browse on dry leaves, the green leaves of the Labrador tea (*Ledum groenlandicum*), grass, fruit, horsetail (*Equisetaceae*), lichens, and spruce twigs throughout the winter. Moose aggregate within the most favorable areas during winter, often as numerous as twenty-five per square mile, particularly where snow depth is lessened by topographic features and in river valleys (Larsen 1980).

Early Paleo-Indian hunter/gatherers may have hunted moose in a variety of ways. During the fall, moose are easier to spot within willow thickets from the surrounding terrain or while traveling along a river (Nelson 1973). Tracks are often the most important means by which to locate moose and are easy to spot along the edges of streams. Nelson's (1973) ethnographic work from Alaska indicates that moose are generally hunted while they are feeding at dawn or dusk.

3.4.4 MUSKRAT

The muskrat, which likely would have frequented small lakes, ponds, streams, and oxbow lakes during the late Pleistocene, has been found in association with mastodon remains in southeastern Michigan (Holman 1995, Shoshani et al. 1989). Muskrats are currently distributed throughout much of North America and appear to have been fairly common within the boreal ecosystem, which occupied southeastern Lower Michigan during the early Paleo-Indian period. Although muskrats can be hunted throughout the year, winter, when muskrats are their fattest (Winterhalder 1981b), may have been the most preferred season to hunt them during the late Pleistocene. During late winter and early spring, muskrats can also be easily hunted from the ice (Nelson 1973).

The highest modern muskrat populations occur in areas interspersed with dense emergent vegetation and open water (Allen etal. 1984, Snyder 1993). Muskrats prefer water bodies dominated by about fifty to eighty percent persistent emergent vegetation cover such as cattail. Streams bordered by emergent or herbaceous vegetation with gradients less than four percent will also support muskrats. Emergent vegetation provides both food and material for lodge construction. Muskrats build lodges at or near the shoreline in shallow water ranging from 0.5-1.2 meters in depth. Foraging generally takes place within fifteen meters of the lodge from a feeding platform or within a feeding hut. In addition to cattail, modern muskrats also feed on a variety of aquatic emergent vegetation including bulrush, sedge, water lily, and smartweed. Lakes and ponds with islands and coves, that supply additional shoreline, generally provide more food and cover for muskrats.

Although potentially common across Lower Michigan during the early Paleo-Indian period, muskrat populations were likely subject to wide fluctuations that revolve around six to fourteen year cycles (Allen et al. 1984, Snyder 1993). Fluctuations in late Pleistocene climatic conditions, particularly during the winter when lakes or ponds may freeze out, could have directly resulted in significant muskrat population fluctuations.

3.4.5 HARE

The presence of hare (*Lepus*) at the Udora site in the Upper Great Lakes indicates that the species played a role in Paleo-Indian subsistence (Storck and Spiess 1994).

Fossilized remains of hare dating to the late Pleistocene have not been located in Michigan (Holman 1995). However, the small size of the hare could help to explain its absence thus far in the Michigan late Pleistocene fossil record. Snowshoe hare (*Lepus americanus*) is common throughout modern boreal forests (Larsen 1980) and may have been available as a food species to Paleo-Indian peoples.

Modern snowshoe hare prefer willow and alder thickets, which often occur along the borders of lakes, wetlands, and on sand/gravel bars formed by rivers and streams (Nelson 1973). Hare survival is also dependent on the presence of cover, such as a dense brush understory, that provides protection from predators (Carreker 1985, Sullivan 1995). Of particular importance to modern hare survival is the availability of winter browse. Areas with adequate winter browse generally contain enough forage for the summer months as well. During the winter, when thermal cover is critical, access to dense coniferous forest cover is also important.

Given similar behavior to its modern counterpart, hares during the Paleo-Indian period probably foraged on a variety of small trees and shrubs (Carreker 1985, Sullivan 1995). Bog birch (*Betula glandulosa*), willow (*Salix* spp.) and alder (*Alnus* spp.) twigs are the preferred winter food while the modern hare also consume paper birch (*Betula papyrifera*), aspen (*Populus* spp.), and black spruce (*Picea mariana*). During the spring, young blueberry leaves and horsetail shoots are generally consumed. Willow, paper birch, and aspen are eaten throughout the summer.

Although snowshoe hare may well have been very abundant during the late Pleistocene, based on current estimates, regional population peaks are generally cyclic with local variations from year to year (Sullivan 1995). Populations usually peak about every ten years with relative abundance lasting two to five years (Nelson 1973, Sullivan 1995). Hares are most easily hunted during fall when leaves are shed and rabbits start turning white, beginning in September (Nelson 1973).

3.4.6 BEAVER/GIANT BEAVER

Fossil remains of the modern beaver (*Castor canadensis*) from the late Pleistocene have been located in southeastern Michigan at the Shelton Mastodon site (Shoshani et al. 1989). Wood fragments, with evidence of gnawing, indicate that the behavior of the modern beaver was similar to its counter parts during the early Paleo-Indian period. The fossil remains, from the late Pleistocene, of the much larger extinct giant beaver (*Castor ohioensis*) are fairly common throughout southern Lower Michigan (Holman 1995). By the end of the Pleistocene, however, the modern beaver, better adapted to the boreal forest wetland ecosystem, began to replace the giant beaver in much of its habitat range. Both the giant and modern beaver were likely common enough to be utilized by Paleo-Indian hunter/gatherers. The remains of the modern beaver, discovered at the early Paleo-Indian Bull Brook site in Massachusetts, support this hypothesis (Spiess et al. 1985).

The giant beaver is significantly different from the modern beaver. Unlike the modern beaver, the giant beaver did not fell trees or build dams, but depended primarily on aquatic vegetation for food. Lacking the chisel-like incisors, large flat tail, and complex social life of the modern beaver, the giant beaver resembled a large, clumsy, water hog that frequented marshes and small lakes. The hind feet may have been webbed, enabling the giant beaver to easily maneuver in the water much like the capybara of South America (Holman 1995).

Like the giant beaver, the modern beaver would have required a permanent and relatively stable source of water (Allen 1983, Holman 1995). Although the modern beaver currently eats aquatic vegetation, such as duck potato, duckweed, and pondweed the twigs and bark of woody plants are critical for beaver survival, particularly throughout the fall and winter when aquatic vegetation is much less prevalent. Trembling aspen (*Populus tremuloides*), willow (*Salix* spp.), and alder (*Alnus* spp.) are the woody plants preferred by the modern beaver. Depending on availability, other deciduous species such as oak (*Quercus* spp.) are eaten as well. The modern beaver generally does not consume coniferous trees and vegetation further than 200 meters from a pond or stream (Allen 1983).

Modern beavers utilize the debarked branches of trees and shrubs to construct lodges and dams. Lodges, provide a source of cover for the beaver, and are often located along a convoluted shoreline where protection from waves can be sought. Branches and twigs are piled outside the lodge providing an underwater stockpile of food (Nelson 1973). To better control the depth and stability of water, particularly along streams, the modern beaver currently constructs an elaborate dam. When building a dam, the beaver generally chooses small streams with a gradient of less than six percent. Modern beaver usually does not inhabit large rivers and giant beaver likely avoided rivers during the late Pleistocene as well.

3.5 ARCHAEOLOGICAL SITES

Of the approximately 80 sites registered with the Michigan Bureau of History and attributed to Paleo-Indian activities lying within the counties selected for analysis throughout Southeastern Michigan, only 23 are likely associated with the early Paleo-Indian period (Table 3.1). Twelve of these early Paleo-Indian sites were identified as belonging to the Gainey cultural phase (ca. 10,900 BP), five to the Parkhill cultural phase (ca. 10,700), and one possibly to the Enterline cultural phase (ca. 11,000 BP) (Figure 3.15). All archaeological sites attributed to the early Paleo-Indian period were plotted using their 40-acre legal descriptions. Where possible additional information was used to plot site locations more precisely. Because sites examined in this research are often only referenced to the agricultural field or property on which they were located, many sites are mapped no more accurately than 40 acres.

Jackson (1997) identified three general categories that early Paleo-Indian sites usually fall into: "... 1) major tool production or rearmament sites with multiple activity areas, 2) smaller camps with unifacial and/or bifacial activity areas and 3) isolated hunting loss or kill/butchering sites." Each of the early Paleo-Indian sites identified in this research was placed into one of Jackson's categories for further analysis. The majority of the early Paleo-Indian sites recorded across southeastern Michigan, 13 Gainey phase, 3 Parkhill phase, 5 unidentified, and the Lux site, are either single projectile point find spots or contain very small assemblages, fall into Jackson's Type 3 category (Figure 3.15). Only the Gainey site belongs to the Type 1 classification while Butler and another unnamed Gainey phase site, Leavitt, Barnes, and both Parkhill phase sites, are all Type 2 site types. Undoubtedly, there are many undiscovered early Paleo-Indian sites across

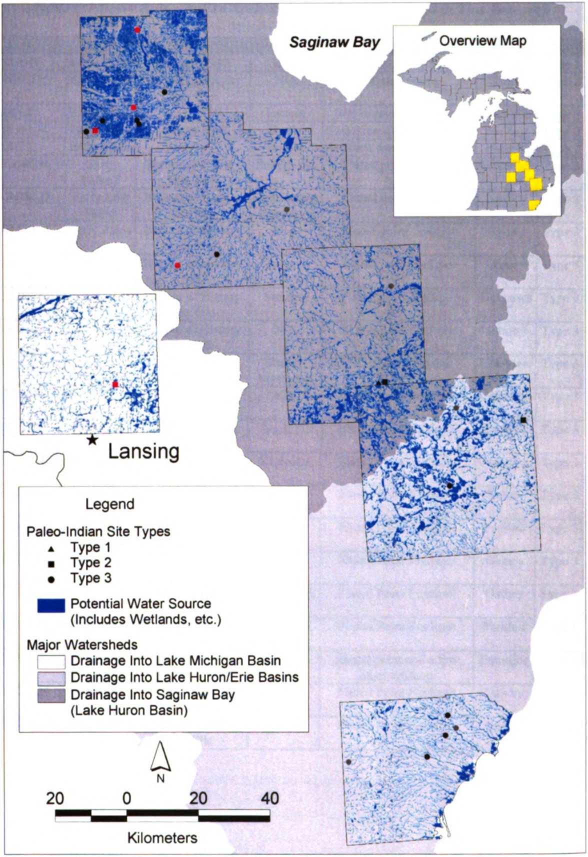

Figure 3.15. Early Paleo-Indian Archaeological Sites Within The Study Area

Table 3.1 Early Paleo-Indian Archaeological Sites Examined in This Research

Site	Age	Reference	Name	Comments	Phase	Type
20GS49	Early Paleo	Simons 1997	Gainey	Site excavated by Simons	Gainey	Type 1
20OK135	Early Paleo	Bureau of History Site File	N/A	3 fluted points	Gainey	Type 2
20CL81	Early Paleo	Shott 1993	Leavitt	Site excavated by Shott	Parkhill	Type 2
20GS104	Early Paleo	Simons 1997	Butler	Site excavated by Simons	Gainey	Type 2
20MD1	Early Paleo	Voss 1977	Barnes	Artifacts analyzed by Voss	Parkhill	Type 2
20MR296	Early Paleo?	Bureau of History Site File	Petteys d-1	Fluted point findspot	Unknown	Type 3
20MR122	Early/Late Paleo	Bureau of History Site File	Gethsemane Cemetery	Fluted point findspot	Gainey	Type 3
20MR131	Early Paleo	Bureau of History Site File	N/A	Fluted point findspot	Gainey	Type 3
20MR7	Early Paleo	Bureau of History Site File	Corcoran	Fluted point findspot	Gainey	Type 3
20MR582	Early Paleo?	Bureau of History Site File	Meiring	Fluted point findspot	Unknown	Type 3
20OK36	Early/Late Paleo	Bureau of History Site File	N/A	Fluted point findspot	Gainey	Type 3
20OK394	Early Paleo?	Fisher 1987	Shelton Mastodon	Mastodon Remains	Unknown	Type 3
20GS69	Early Paleo	Bureau of History Site File	N/A	Fluted Point Findspot	Unknown	Type 3
20SA1000	Early Paleo	Bureau of History Site File	Burk 71	Fluted Point Findspot	Parkhill	Type 3
20SA211	Early/Late Paleo	Bureau of History Site File	Kralosky	Fluted Point Findspot	Unknown	Type 3
20MD423	Early Paleo	Bureau of History Site File	N/A	Fluted Point Findspot	Gainey	Type 3
20MD328	Early Paleo	Bureau of History Site File	Kruger	Fluted Point Findspot	Parkhill	Type 3
20MD445	Early Paleo	Bureau of History Site File	N/A	Fluted Point Findspot	Gainey	Type 3
20MD472	Early Paleo	Bureau of History Site File	Varner Site	Fluted Point Findspot	Gainey	Type 3
20MD255	Early Paleo	Bureau of History Site File	N/A	Fluted Point Findspot	Parkhill	Type 3
20SA196	Early Paleo	Shott 1999	Lux	Fluted point and a few other artifacts	Enterline	Type 3
20MD124	Early Paleo	Bureau of History Site File	Porter 1	Fluted Point Findspot	Gainey	Type 3
20MD81	Early Paleo	Bureau of History Site File	N/A	Fluted Point Findspot	Gainey	Type 3

Lower Michigan (Shott 1993). It is hoped this research will guide the search for other early Paleo-Indian sites across the Great Lakes region.

The Lux site, located in southern Midland County, may be among the earliest of all excavated Paleo-Indian sites in Michigan. This Type 3 site yielded only five definitive tools that appear to belong to the Enterline phase (Shott and Wright 1999). Enterline bifaces have multiple flutes and are much smaller than either Gainey or Parkhill phase projectile points. It is unclear whether the projectile points found at the Lux site are indeed Enterline and thus contemporaneous with Plains Clovis occupations dating before 11,000 BP or are variants of Gainey projectile points. Enterline type sites are extremely rare in Michigan and with the exception of the Lux site are represented by isolated projectile point finds.

The Gainey and Butler sites are located in southern Genesee County along the northern edge of a northeasterly trending interlobate region that contains rolling hills, dominated by sands and gravels, interspersed with wetlands and lakes in southern Genesee County. Gainey is positioned on a prominent hilltop overlooking an extensive marshland south of the site. The site is large for an early Paleo-Indian site, encompassing nearly 11,000 square meters, much of which was excavated under the direction of Donald Simons (Simons 1980, 1997, Simons et al. 1984, 1987). In addition to a staggering 3,400 whole and fragmentary stone tools, approximately 22,000 pieces of debitage were recovered from the site. Artifacts at the Gainey site were distributed in eight clusters and included "...106 whole or fragmentary bifaces with flutes (points), 74 complete end scrapers, 62 complete side scrapers/knives, and 25 gravers..." (Simons 1997). The majority of the stone tools at Gainey are made on Upper Mercer chert, the source of which lies 350 km to the south of the site in Ohio. Ten Mile Creek chert, the source of which is also located to the south, is common at the Gainey site, while Bayport chert is scarce. At least twenty possible hearths were also identified at the Gainey site. Simons (1997) suggests Gainey served as a base camp from which migratory caribou hunting and interception took place. The Gainey site was probably occupied sometime after 11,000 BP, but prior to 10,400 BP.

The Butler site located on a lower hilltop 1.6 km to the east of the Gainey site is smaller, covering approximately 4000 square meters (Simons et al. 1992, Simons 1997). Despite its smaller size, Butler is a significant early Paleo-Indian site yielding nearly 9000 pieces of debitage, "...36 whole or fragmentary bifaces with flutes, 68 whole end scrapers, 32 whole side scraper/knives, 22 gravers with complete spurs, and 52 channel flake fragments." (Simons 1997). The Butler assemblage, distributed in five major clusters, is primarily made from Bayport chert. Projectile point fluting characteristics suggest the site lies between Gainey and Parkhill type sites. Therefore, Butler appears to have been occupied somewhat later than the Gainey site and just prior to the Leavitt site. Hearths were not located at the Butler site, interpreted by Simons (1997) as a migratory caribou kill and processing site.

The Leavitt site is located along a narrow east-west trending ridge in central Clinton County (Shott 1993). Twenty-two bifaces, 24 end scrapers, 15 side scrapers, and several miscellaneous tools make up the Leavitt assemblage. The assemblage recovered from the Leavitt site indicates a late Gainey or early Parkhill phase placement. Biface and uniface discard processes at the site indicate that tools were being heavily used at the site. Thirteen bifaces were broken in use while four exhibit recycling. Most of the unifaces

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recovered from the site were lost or discarded due to depletion. The large amount of flake debris, 4,416 pieces of debitage, indicates that tool reworking and manufacture occurred at the site. Although tool use appears to be the primary activity, Shott does not specifically outline what activities did occur. He suggests however, that Leavitt may have been a "general residential site". Spruce, oak and basswood (Tilia spp.) recovered from a feature at the Leavitt site indicates these species may have been used as a fuel source. In addition, the presence of spruce indicates a possible placement of the site within a region that would have allowed peoples to take advantage of spruce as a thermal cover during the dormant season.

In southwestern Midland County, the Barnes site is situated along the Lake Warren strandline (Voss 1977). Although the shoreline was inactive during the occupation of the Barnes site, the Warren beach would have provided a well-drained vantage point on which to locate a site. Compared with the Butler and Gainey assemblages, the Barnes assemblage is relatively small. Nine projectile points, five bifaces, 102 channel flakes, and five endscraper fragments were recovered from the site. The presence of a large number of channel flakes and fluted points, in various stages of manufacture, supports the notion that early hunter/gatherers occupying the Barnes site were focused on projectile point manufacture. The retooling that occurred at Barnes was probably related to hunting activities that took place in the region.

With the potential exception of the Lux site, Gainey appears to represent the earliest northward movement of peoples into Michigan during the Late Pleistocene (Anderson 1990, 1996, Anderson and Gillam 2000). Lithic raw materials indicate that these peoples either maintained ties with southern groups or spent part of their seasonal round south of Michigan. During the end of the Gainey phase, as groups became more familiar with their environment, early hunter/gatherers began utilizing lithic materials from the Saginaw Valley. This becomes apparent with the dominance of tools made from Bayport chert at both the Butler and Leavitt sites (Shott 1993, Simons 1997). Prior to the end of the Parkhill phase, projectile points, like those located at the Barnes site, are made almost exclusively of Bayport chert (Voss 1977, Shott and Wright 1999). It also appears that the north/south movement of peoples during the Gainey seasonal round continued throughout the Parkhill phase. However, the seasonal round during the Parkhill phase across the Great Lakes appears to have shifted northward with peoples moving between Central Ontario and Southern Michigan (Jackson 1997, 1998, Shott and Wright 1999).

3.6 SUMMARY

Throughout the Paleo-Indian period, hunter/gatherers had access to a number of different plant and animal species. Not all species are examined here. Undoubtedly, other species such as deer and the mammoth may have been found across southeastern Michigan during the Paleo-Indian period. However, it is assumed that these species were much less frequent due to the ecosystem makeup and may not have had much of an overall affect on the adaptive strategy utilized by early hunter/gatherers occupying southeastern Michigan. The data presented within this chapter was used as a basis from which to construct the general habitat models found in chapter four. In addition, the resultant data from these habitat models and the early Paleo-Indian settlement locations presented in this chapter will be used to test the hypotheses outlined in Chapter 6.

Chapter IV

MAPPING LATE PLEISTOCENE FLORAL AND FAUNAL DISTRIBUTIONS

The floral and faunal suitability maps presented in this chapter are used as input for the hunter/gatherer decision model outlined in chapter five. Suitable areas for each critical floral and faunal species identified in chapter three were mapped utilizing a series of multi-criteria models. All multi-criteria models generated for this research were constructed in the raster Geographic Information System (GIS) ARC/INFO GRID utilizing the weighted overlay process. Within a raster GIS data structure, the landscape is represented by a continuous matrix of x, y locations at which an attribute value, such as elevation or soil type, is stored. Thus, a single cell, or pixel, in a thirty-meter raster grid represents thirty square meters of the "real world". All raster grids generated for this research utilize a thirty-meter pixel size. For further discussions on GIS and raster data structures as they relate to archaeology see Kvamme (1989, 1999).

The weighted overlay, or weighted linear combination, provides a process for combining multiple criteria in the form of raster GIS layers, which influence or determine the distribution of floral and faunal species. Factors are combined with the weighted linear combination by multiplying the factor weight by each criteria value followed by a summation of the results (Eastman 1999):

$$S = \Sigma w_i x_i \quad \text{where } S = \text{suitability}$$

w_i = weight of factor i

x_i = criterion score of factor i

The weighted overlay process can begin once the pixel values for each layer, or criteria, are standardized based on a common evaluation scale such as zero to ten. In this scenario, pixels with a value of zero do not meet the criteria while values of ten fully meet the criteria. After standardization, weights are generated for every criterion. Weights are based on the influence, or affect, a criteria has on the final model outcome, or suitability. The weight for every criterion is expressed as a percent of influence and all weights must sum to 100 percent. After assigning weights, each criterion is multiplied by the assigned weight and the results from every layer are added together. For example, a criterion pixel with a standardized value of seven and a weight of eighty percent will receive a score of 5.6. Another criterion falling on the same raster cell, receiving a score of 1.8 derived from a twenty percent weight and a standardized value of nine would be added to the 5.6 producing a final suitability value of 7.4. Pixels with the highest summed values are the most suitable, while areas with the lowest value are unsuitable.

Multi-criteria modeling based on the weighted overlay technique is becoming a widely utilized tool for habitat simulation (ESRI Reference). Agencies, such as the Michigan Department of Natural Resources, have successfully utilized multi-criteria models to model and manage wildlife habitats (Doepker, personal communication). These models not only provide an efficient means by which to simulate habitat potential, the multi-criteria weighted overlay approach also provides a framework that facilitates changes and updates in criteria. Criteria can easily be added to an existing model and the weights adjusted accordingly.

4.1 FLORAL SUITABILITY MODELS

The habitats for thirteen floral species likely to have inhabited southeastern Lower Michigan during the Early Paleo-Indian period were simulated for this research. Understanding the distribution of these species is critical to assessing where potential resources were located during the Early Paleo-Indian period. Soil texture, drainage, and competition from other plant species were identified as the primary criteria to use in the simulation of the distribution of key plant species (Barnes and Wagner 1981, Burns and Honkala 1990, Elliott-Fisk 2000, Kapp 1999, Larsen 1980). Criteria for black spruce (*Picea mariana*), white spruce (*Picea glauca*), jack pine (*Pinus banksiana*), and trembling aspen (*Populus tremuloides*)/paper birch (*Betula papyrifera*), were reviewed for correctness by Dr. John A. Witter of the University of Michigan, Ann Arbor. In each weighted overlay model, the criteria were all given equal weight. Soil pH and organic matter content, which are in large part formed by resident plant species, were not considered as criteria in this analysis. Modern measurements of pH and organic matter do not represent values that existed during the late Pleistocene (Kapp 1999, Schaetzl, personal communication). In fact, soils laid down after deglaciation in southeastern Lower Michigan would have been very calcareous due to the underlying limestone. Only coarse textured soils allowed enough leaching after deglaciation to lower the pH enough to support acid loving plants such as blueberries (*Vaccinium* spp.) during the Early Paleo-Indian period. Despite the dynamic nature of many soil characteristics, soil types and their interplay with the local topography are a good indicator, or predictor, of ecological factors (Kapp 1999).

The output suitability values for each suitability model range from 0 to 10, with ten being the most suitable and zero the least suitable. An area with a high suitability, values ranging between 7 and 10, indicates the plant species being modeled likely occurred in that area. Such a high score also indicates that the species probably dominated either the understory or overstory in that area. Medium suitability values, ranging between 4 and 6.9, suggest a mixed ecosystem. For example, an area receiving a suitability score of five for white spruce and five for jack pine contained a mixed spruce/pine forest. Values lower than 3.9 indicate a species did not occupy an area in great enough numbers to have significantly affected the local ecosystem. Therefore, all areas with values 3.9 or lower were set to zero suitability.

To account for the fact that a limited number of species can inhabit any single location at one time, species were placed into one overstory and two understory and one ground cover groups (Figure 4.1). The overstory group consists of seven tree species listed in order of their ability to out-compete other species in areas of overlapping suitability: black spruce, white spruce, jack pine, trembling aspen, paper birch, alder (*Alnus* spp.), and willow (*Salix* spp.). Since each overstory species competes with others for light and nutrient habitat, models were used as criteria for shade in tolerant species. Likewise, the habitat models of dominant understory species were used as criteria in the simulation of habitat for intolerant species. Species in the understory are also affected by the overstory, which were included as criteria in many cases. Within the understory tree/large shrub group, the habitats of three species are modeled: balsam fir (*Abies balsamea*), chokecherry (*Prunus virginiana*), and serviceberry (*Amelanchier* spp.). The shrub understory species group consists of: thimbleberry (Rubus parviflorus), mountain cranberry (*Vaccinium vitis-idaea*), Labrador tea (*Ledum groenlandicum*), late low blueberry (*Vaccinium angustifolium*) and velvetleaf blueberry (*Vaccinium myrtilloides*). The final group, ground cover, only contains a single species: reindeer lichen (*Cladonia* spp.).

The methods and criteria used to generate floral habitat models are presented in this section. Prior to assembling each model, digital soil and topography data were obtained and then manipulated within a GIS system. In counties where digital cartographic soil data were not available from the United States Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS) Soil Survey Geographic (SSURGO) database, data were obtained from the Michigan Department of Natural Resources (MDNR). The MDNR has digitized many of the published county soil surveys that have not been vectorized by NRCS. Soil attributes for all counties were acquired from the USDA-NRCS Map Unit Interpretation Database (MUIR) database. Topographic data were derived from the United States Geological Survey's (USGS) National Elevation Dataset (NED).

Soil data were assigned scaled texture and drainage values prior to rasterizing. The texture and drainage values for each soil type were obtained from the COMP table from within the MUIR database. Texture values were taken only from the primary sequence and the top layer of every map unit. Within the six counties examined in this research, the majority of the soils do not exhibit significant differences in texture values between the first two layers.

To determine the spatial variability of soil wetness, drainage class assignments were assigned a base drainage index value (Schaetzl 1986). Drainage index values range from ninety-nine for open water to zero for rock. To account for the affects of terrain on soil moisture, slope values calculated from a NED Digital Elevation Model (DEM) were placed into slope class modifiers (see Schaetzl 1986) that could be subtracted from the drainage index value. Subtracting the slope class modifiers from the drainage index values accounts for water run off, particularly in regions with hilly or rolling topography.

In the case of complexes, polygons or map units made up of more than one soil type, the values of the dominant soil type were utilized. In other words, soil types encompassing the greatest area within a polygon were considered the dominant type. Once a single texture and moisture value was assigned to each soil polygon, the values were scaled according to their suitability for each floral species. Due to the large number of unique soil moisture values found within the entire study area, scaled values were assigned using the FUZZY module within the IDRISI GIS software. The FUZZY module provides a simple means for re-scaling or stretching a continuous range of numeric values (Eastman 1999). Prior to running the module, end points were selected at which moisture values become suitable and unsuitable for a particular plant species. The thirty-seven unique texture values found within the study area, on the other hand, were assigned scaled suitability scores for every floral species manually. The re-scaled texture and moisture grids were weighted and combined within ARC/INFO GRID. NODATA values were given to urban areas and other modern disturbances that were left out of the analysis.

Matrices identifying criteria, most of which are based on soil texture and drainage, and their respective weights for each plant species is presented in Appendix A (Table A.1

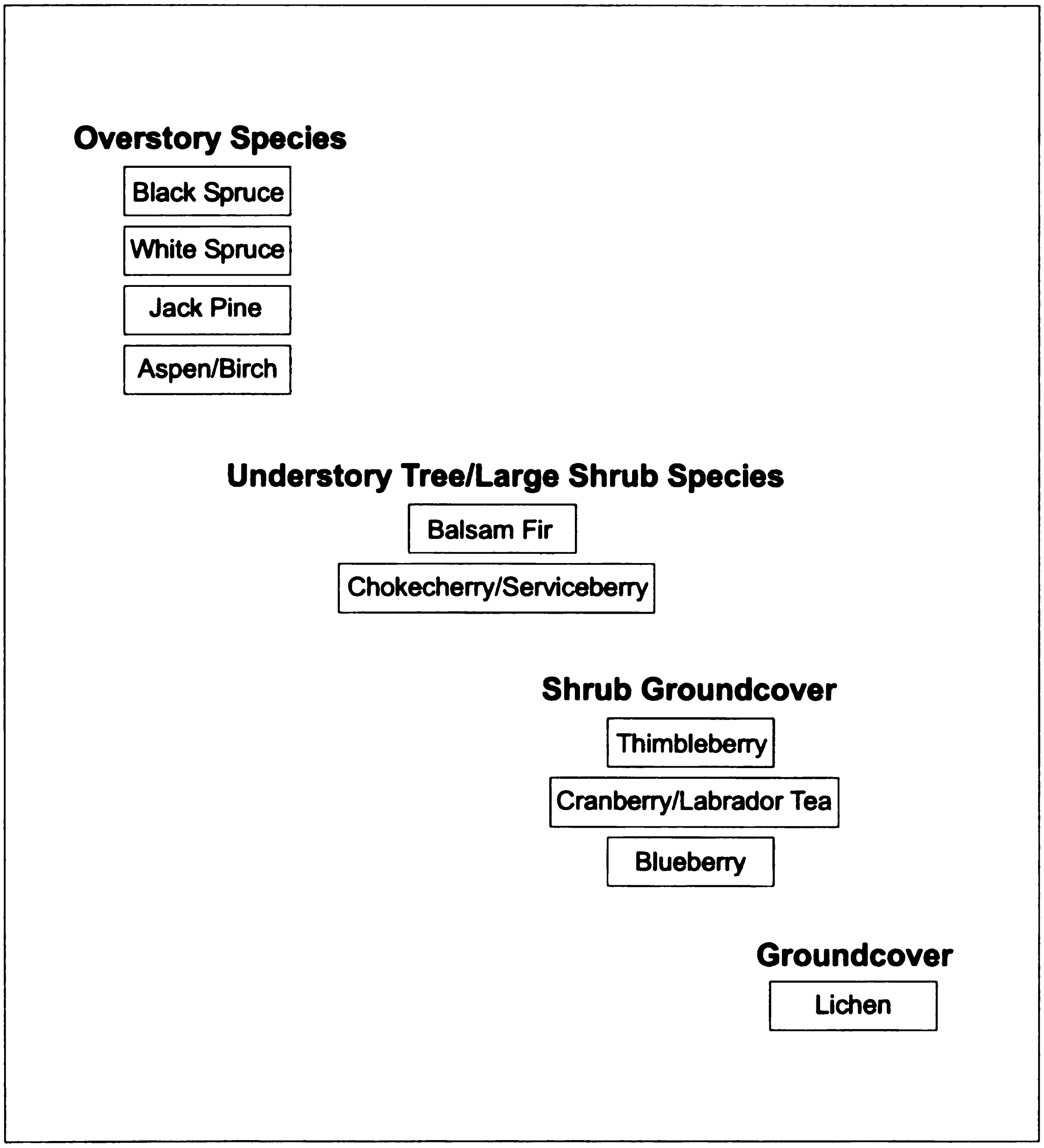

Figure 4.1. Relative Position of Plant Species Within The Boreal Forest

– A.11). A sample set of the commands utilized to generate each suitability model, documented within a set of ARC/INFO 8.1 programs written in the Arc Macro Language (AML), is presented in Appendix D. Although the models presented in this section do not account for all the potential factors that affected the distribution of plant species, they do, however, attempt to incorporate many of the significant factors. The primary goal of these suitability models is to simulate the general distribution of floral species during the late Pleistocene in southeastern Michigan.

4.1.1 BLACK SPRUCE

Black spruce (*Picea mariana*) prefer the muck and peat often found at or near bogs and is able to survive on very poorly drained acidic sites on which many trees cannot grow (Appendix A: Table A.1) (Barnes and Wagner 1981, Burns and Honkala 1990, Elliott-Fisk 2000, Larsen 1980). Black spruce also thrives in areas that are neutral or slightly alkaline in pH. Due to their ability to tolerate shade, black spruce was likely the dominant species within much of its habitat and the location of other tree species was not considered as a factor in its suitability. In fact, the ability to out-compete other tree species within the boreal forest ecosystem, including white spruce, makes black spruce a factor in the distribution of many of the other tree species simulated in this research, where suitable habitats overlap.

Well-drained soils with a drainage index value of forty or lower were considered unsuitable for black spruce habitat and were assigned a value of zero (Appendix A: Table A.1). Very poorly drained or wetter soils, with a drainage index value of ninety or greater, were considered the most suitable, excluding open water, of course. These values were given a score of ten. All moisture values falling between forty and ninety were assigned ascending scores ranging from zero to ten by the FUZZY module. Both soil moisture and texture were given an equal weight of fifty percent within the weighted overlay conducted in ARC/INFO (Appendix A: Table A.1).

4.1.2 WHITE SPRUCE

Within the spruce dominated forest ecosystem that occupied southeastern Lower Michigan during the early Paleo-Indian period, white spruce (*Picea glauca*) was probably the dominant tree species across much of the landscape (Elliott-Fisk 2000, Garland and Cogswell 1985, Larsen 1980, Shott and Welch 1984). White spruce prefers fine textured silts and loams with basic pH. As a result, the calcareous nature of much of the soil during the late Pleistocene favored white spruce. Due to both climatic and soil conditions, white spruce was likely the most dominant tree species within the late Pleistocene boreal forest ecosystem.

The most suitable soil drainage class, well drained, was given a score of ten while drier soils were considered unsuitable and assigned a value of zero (Appendix A: Table A.2). Poorly to very poorly drained areas with drainage index values higher than eighty were also regarded as unsuitable. The FUZZY module within IDRISI was used to stretch the remaining drainage values.

Despite its dominance, white spruce was likely limited in its distribution by black spruce. Therefore, the habitat suitability map, generated for the more shade tolerant black spruce, was deemed a significant factor in white spruce distributions where the two suitable habitats overlapped. Within areas moderately favorable to both white and black spruce, black spruce is assumed to have been the dominant species. To account for this the IDRISI FUZZY module was used to invert the black spruce suitability scores. A high score is assigned to areas with low suitability values; conversely, a low score is assigned to areas that are suitable for black spruce. Once inverted, the suitability map values are divided by 10 to produce a percentage. The percentage is multiplied by the white spruce suitability map, thus reducing the suitability in areas where the two suitability maps overlap. For example, an area with a suitability of six for black spruce and ten for white spruce would receive a reduced suitability value of four for white spruce. This location likely contained a mixed black and white spruce stand. The approach ensures that the summed value of suitability maps for dominant and co-dominant species within the same group, e.g. overstory, understory tree/large shrub, shrub ground cover, and ground cover, will never exceed ten (Figure 4.1). As a result, the model accounts for the fact that only a limited number of plant species can occupy any single location at once. Areas completely unsuitable for black spruce will retain their original suitability value.

4.1.3 JACK PINE

In the late Pleistocene ecosystem found across southeastern Lower Michigan, jack pine (***Pinus banksiana***) was probably the most common tree species on dry sites (Elliott-Fisk 2000, Larsen 1980, Shott and Welch 1984). Jack pine grows best on well-drained sands and loamy sands that are slightly acidic in pH (Barnes and Wagner 1981, Burns and Honkala 1990, Elliott-Fisk 2000, Larsen 1980). In addition to site characteristics, the distribution of jack pine was undoubtedly affected by the presence of spruce, which is more tolerant of shade and basic soil conditions.

Well-drained or drier soils were considered the most suitable with soils somewhat poorly drained, or wetter, being unsuitable (Appendix A: Table A.3). Drainage values between well and somewhat poorly drained were rescaled with the FUZZY module. In areas equally favorable to both jack pine and spruce, spruce is assumed to have been the dominant species. As a result, regions that are favorable for black or white spruce were assigned a low suitability score. Conversely, areas unfavorable for spruce habitat were assigned a high suitability score.

4.1.4 TREMBLING ASPEN/PAPER BIRCH

Trembling aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*) thrive in deeper, well-drained to moderately well drained loams, sandy loams, and silt loams (Appendix A: Table A.4) (Barnes and Wagner 1981, Burns and Honkala 1990, Elliott-Fisk 2000, Larsen 1980). As a result, aspen and paper birch are often with jack pine and white spruce. Due to the their intolerance of shade, spruce and jack pine generally dominate, often limiting the distribution of paper birch and aspen in favorable areas. Within a spruce dominated boreal forest ecosystem, trembling aspen and paper birch are found in open areas along streams, lakes, and wetlands.

Well-drained soils, providing the most suitable habitat for aspen and birch, were assigned a score of ten with excessively drained and very poorly drained soils being deemed unsuitable (Appendix A: Table A.4). Suitable areas for spruce and jack pine were considered unsuitable in this model with the exception of areas within sixty meters of perennial streams, lakes, and unforested wetlands where white spruce and jack pine suitability was not considered. In these regions, aspen and birch stands generally obtained enough sunlight to be successful except in areas where black spruce persists (Barnes and Wagner 1981). The National Wetlands Inventory (NWI) maps, maintained by the United States Fish and Wildlife Service (USFW), were used to identify unforested open wetlands during the early Paleo-Indian period. Due to the prolonged period of eutrophication that occurred in most wetlands since the late Pleistocene (Shoshani et al. 1989), the model assumes wetlands classified with the following NWI water regime modifiers were inundated and unforested: permanently flooded, intermittently exposed/permanent, and intermittently exposed. Lakes and perennial streams were taken from the MIRIS GIS database that is derived from USGS 7.5 Minute quadrangle maps. Artificially flooded wetlands and lakes were eliminated from the model. A sixty-meter buffer was placed around water features within which the affects of jack pine and white spruce suitability were eliminated.

4.1.5 ALDER/WILLOW

Alder (*Alnus* spp.) and willow (*Salix* spp.) thickets are primarily found in moist areas along streams and lakes, or in wetlands (Appendix A: Table A.5) (Larsen 1980, Barnes and Wagner 1981, Elliott-Fisk 2000). Willow and alder thrive on mucks, silts, and loams and are able to tolerate a wide range of acid or basic conditions. Due to their intolerance for shade, alder and willow are usually limited to open areas adjacent to streams, lakes, and wetlands.

Both willow and alder have a high moisture requirement, preferring poorly drained soils, which were given a score of ten (Appendix A: Table A.5). Moderately well drained or drier soils, considered unsuitable, were given a value of zero. Due to the shade intolerance of alder and willow, favorable areas for spruce, jack pine, aspen, and birch were considered unsuitable for alder and willow habitat. Like aspen and birch, alder and willow are often found in open areas along streams, lakes, and wetlands where sunlight is accessed (Barnes and Wagner 1981). Therefore, the spruce and jack pine suitability maps, generated for the aspen and birch model, with areas within sixty meters of perennial streams, lakes, and unforested wetlands was used in this model. The habitat suitability for aspen and birch along perennial streams, lakes, and unforested wetlands was included in this model since aspen and birch shaded out alder and willow stands.

4.1.6 BALSAM FIR

Balsam fir (*Abies balsamea*) grows best on poorly drained mineral soils (Appendix A: Table A.6) (Barnes and Wagner 1981, Burns and Honkala 1990, Elliott-Fisk 2000, Larsen 1980). A fairly shade tolerant species, it is found in pine and deciduous forests as an understory. However, balsam fir is very susceptible to fire and is often replaced by a number of post fire pioneer species such as aspen, birch, jack pine, or black spruce. Once replaced, balsam fir is slow to recover, usually being absent for several post fire decades. Therefore, stands of black spruce, white spruce, aspen, birch, and jack pine probably affected the late Pleistocene distribution of balsam fir (Rook 1999).

Well drained, or drier soils, considered unsuitable, were given a score of zero, while poorly drained or wetter soils were the most suitable. All other values were stretched within the IDRISI FUZZY module. Favorable areas for black spruce, aspen, birch, and jack pine were also regarded as moderately unsuitable. Despite the fact that these species are generally able to out compete balsam fir within the boreal forest ecosystem (Rook 1999), balsam fir is often found as an understory within these stands. As a result, the suitability models for black spruce, white spruce, aspen, birch, and jack pine were considered a factor within the balsam fir suitability model (Appendix A: Table A.6). This accounts for the fact that an area very favorable for black spruce may have contained some balsam fir as an understory. Balsam fir distributions probably fluctuated throughout the early Paleo-Indian period; however, the primary goal of this model is to identify the primary regions where balsam fir was most likely to occur.

4.1.7 CHOKECHERRY/SERVICEBERRY

Chokecherry and serviceberry flourish on a wide range of sands, and loamy sands (Appendix A: Table A.7) (Barnes and Wagner 1981, Rook 1999). Both chokecherry and serviceberry are fairly shade tolerant and often found as understory species in pine and aspen forests. These species grow well on a wide range of loams and sands. Despite their tolerance of shade, serviceberry and chokecherry were probably unable to compete in dense spruce stands or in areas with balsam fir understory or overstory. As a result, areas suitable for both spruce and balsam fir were considered unfavorable.

4.1.8 THIMBLEBERRY

In addition to tolerating dry sands thimbleberry (*Rubus parviflorus*) thrives on moderately well drained loams, including gravelly loam and clay-loam soils (Appendix A: Table A.8) (Barns and Wagner 1981, Rook 1999). Although thimbleberry can tolerate both acidic and basic soils, the species is shade intolerant, restricting its distribution to openings along lakes, streams, and wetlands. When found as a shrub understory thimbleberry can only persist in trace amounts providing little in the way of berry production. The best growth occurs on burned-over or disturbed sites devoid of trees (Barnes and Wagner 1981).

Aside from texture, soil drainage and the distribution of other overstory and understory species were considered as criterion for this model. Excessively and very poorly drained soils were regarded as unsuitable, while moderately well drained soils were given the highest suitability score of ten. Due to their relatively small size and shade intolerance, regions favorable for spruce, jack pine, aspen, birch, alder, willow, balsam fir, chokecherry, and serviceberry were regarded as unfavorable for thimbleberry habitat. Spruce and jack pine suitability was not considered a factor in regions within sixty meters of lakes, wetlands, and perennial streams because it is assumed the edges of these features would have allowed access to more sunlight despite the presence of these overstory species. Thimbleberry is a large enough shrub, however, to have inhibited the growth of cranberry, Labrador tea, and blueberries.

4.1.9 CRANBERRY/ LABRADOR TEA

Both mountain cranberry (*Vaccinium vitis-idaea*) and Labrador tea (*Ledum groenlandicum*) share the same habitat, preferring acidic peat and muck soil, although they are often found on poorly developed mineral soils with a pH as high as 8.4 (Barnes and Wagner 1981, Rook 1999). These species also grow well on mineral soils (Rook 1999). Cranberry and Labrador tea often form a shrub ground cover in both black and white spruce forests.

Well-drained soils were considered unsuitable, while poorly drained or wetter soils were given a score of ten (Appendix A: Table A.9). On dry, open sites thimbleberry likely competed with both mountain cranberry and Labrador tea. Therefore, areas suitable for thimbleberry were regarded as unsuitable for cranberry and Labrador tea.

4.1.10 BLUEBERRY

Most *Vaccinium* species, known as "blueberries", prefer acidic dry sandy soils and are found in association with jack pine as a shrub ground cover (Barnes and Wagner 1981, Rook 1999). Both the late low (*Vaccinium angustifolium*) and velvetleaf blueberries (*Vaccinium myrtilloides*), common within the boreal forest ecosystem, are considered in this model. The calcareous nature of the soils throughout southern Lower Michigan during the late Pleistocene limited the distribution of blueberries to sites with coarse textured soils. In these areas, leaching lowered the pH (Schaetzl, personal communication). Texture ranks were adjusted accordingly by lowering the rank of loamy and fine textured soils.

Blueberries prefer excessively to moderately well drained soil with moderately well drained or wetter soils being unsuitable (Appendix A: Table A.10). Since blueberries are shade tolerant, the location of overstory tree species was not considered a factor in this model. Larger shrubs, such as the cranberry, Labrador tea, and thimbleberry, were probably able to overtake blueberries in most situations. Therefore, in the areas where suitable habitats overlapped, it is assumed that blueberries would have been replaced by thimbleberry, cranberry, and Labrador tea.

4.1.11 REINDEER LICHEN

The slow growing reindeer lichen (*Cladonia* spp.) is a dominant or co-dominant ground cover in jack pine, and spruce forests (Rook 1999). Reindeer lichen grows particularly well in upland jack pine forests that are generally more open than spruce forests. The ability of reindeer lichen to take up moisture from the air allows them to thrive on coarse very dry sandy soils. As a result, well-drained or drier soils were regarded as the most suitable for reindeer lichen habitat (Appendix A: Table A.11).

4.1.12 AQUATIC AND WETLAND VEGETATION

The aquatic and wetland vegetation potential for such species as bullhead-lily (*Nuphar variegatum*), watershield (*Brasenia schreberi*), submerged pondweed (*Potamogeton* spp.) and cat-tail (*Typha* spp.) was based on the presence of water throughout the year during the late Pleistocene. Aquatic vegetation generally prefer shallow to deep, slow moving water while cat-tail is found along the edges of lakes, marshes, and streams in shallow water (Chadde 1998). As a result, areas suitable for aquatic and wetland vegetation were determined from the water regime modifiers and wetland classes associated with the National Wetlands Inventory (NWI). Water regime modifiers were ranked based on their likelihood to contain standing water year-round. In order to account for the affects of eutrophication during the last 11,000 years (Shoshani et al. 1989), wetlands with permanently flooded, intermittently exposed/permanent, intermittently exposed, and semipermanently flooded NWI water regime modifiers were considered highly likely to have contained open water and therefore aquatic vegetation. Wetlands designated as seasonally flooded, saturated/semipermanent/seasonal, and seasonally flooded/saturated were given a medium to low potential for having standing water throughout the late Pleistocene. Support for these rankings come from excavations at the Shelton Mastodon site in southeastern Michigan suggest that the region in around the site contained standing water during the early Paleo-Indian period (Shoshani et al. 1989). The remains of beaver, mastodon, moose, and muskrat support the notion that the site supported aquatic and wetland vegetation even though much of the region currently saturated much soil rather than open water.

The NWI taxonomic unit, class, was used to identify regions with potential for emergent vegetation throughout the early Paleo-Indian period. Wetlands within the emergent class, dominated by emergent vegetation, likely contained both open water and emergent vegetation during the late Pleistocene (Lusch personal communication). These regions were given the highest suitability ranking for emergent vegetation potential. Scrub-shrub dominated wetlands with a second emergent class were also given a fairly high ranking. Due to eutrophication these areas were probably dominated by emergent vegetation while containing some open water. No other criteria were used to simulate aquatic and emergent vegetation potential. Separate models were not calculated for aquatic or emergent vegetation, but rather the aquatic model was incorporated into the habitat model generated for beaver/giant beaver, mastodon, and moose (Appendix A: Table A.12, A.14, A.16). The emergent model was built into the muskrat habitat model (Appendix A: Table A.15).

4.2 FAUNAL SUITABILITY MODELS

The habitats of six species that likely inhabited southeastern Lower Michigan throughout the early Paleo-Indian period were simulated for this research. These habitat models are used as input in the hunter/gatherer behavioral models presented in chapter six. The primary goal of these models is to determine the most likely regions for animal activity. Therefore, these models are critical for understanding the distribution of potential resources and simulating Paleo-Indian resource use.

Similar to the floral habitat models, the suitability values for each faunal habitat model range from zero to ten. Regions highly suitable for a particular species received values ranging from seven to ten indicating that the animal species in question frequented the area. Scores falling between four and 6.9 indicate that a species was less likely to frequent an area. The distribution of faunal species can vary greatly from year to year due to environmental conditions. Therefore, a highly suitable area does not guarantee that a species occupied a location at any single point in time, but does suggest that over time, a species was more likely to occur in that area.

The faunal models outlined in this section are based on a wide range of varying criteria including the distribution and type of food, cover or protection from the elements, water, and wetlands. When modeling the distribution of food and cover types, the results of the floral suitability models presented in the previous section were also utilized. The first model, moose habitat, provides an overview of the faunal suitability modeling process. The remaining discussions focus on differences in the criteria rather than on the specifics of model construction that were outlined in the first section. Appendix D contains a sample set of the commands utilized to generate each faunal model, written as an AML program.

4.2.1 MOOSE

In general, moose exhibit two distinctly different patterns of habitat use, thus two habitat models are needed to simulate moose behavior during the early Paleo-Indian period (Allen et al. 1987). Throughout the growing-season, the preferred browse species consist of trembling aspen, paper birch, willow, and chokecherry. Mountain cranberry and to a lesser extent thimbleberry and blueberry are also eaten during the growing season. In addition, moose browse on aquatic vegetation during part of the growing season, often remaining within two kilometers of wetlands or other water bodies (Allen et al. 1987, Joyal and Scherrer 1978). For the duration of the dormant season, moose prefer trembling aspen, paper birch, willow, chokecherry, and mountain cranberry. Moose also browse on balsam fir, which provides critical shelter during midwinter. White spruce, however, was likely the preferred species for thermal cover within the late Pleistocene ecosystem. Even with inadequate browse, moose will confine themselves to dense coniferous cover especially during periods of significant snow depth.

Once the critical florae consumed by moose were identified, each was assigned a scaled suitability value ranging from zero to ten (Appendix A: Table A.12 – A.13). This scaled value represents the suitability of a particular plant species for consumption by moose. Since most areas are suitable for multiple plant species, the scaled values must be modified according to the suitability of an area for moose browse. To accomplish this modification, each rank is divided by ten, producing a percent, which is then multiplied by the suitability values for each floral species, effectively reducing their suitability. For example, if the scaled value for a flora species is ten and the suitability of that species in a given area is eight, then the adjusted value would be eight. Modifying the suitability in this fashion ensures that values will never exceed the maximum suitability score of ten, while adjusting the scaled values according to the likelihood of a plant species occupying a specific location. The process was repeated for each plant species. Once altered, the suitability maps were summed creating a final set of suitability maps based on the floral species groups defined in the previous section: understory trees/large shrubs, and shrub groundcover (Figure 4.1).

For the growing season suitability model, the distance to areas with aquatic vegetation potential were also considered using the model presented in section 4.1.12 (Appendix A: Table A.12). Regions adjacent to perennial water bodies, where moose most likely resided while in search of open water and aquatic browse, were given the suitability of that wetland type for containing aquatic vegetation and open water. Areas farther than two kilometers from a water body were regarded as unsuitable (Joyal and Scherrer 1978). The wetland ranks were reduced as the distance from each wetland increased reaching a value of zero at two kilometers. For example, an area 100 meters from a permanently flooded wetland received a value of five rather than the original suitability value of the wetland, which in this case was ten. In order to rescale the distance values ranging from zero to one kilometer, the IDRISI FUZZY module was utilized.

Lastly, the diversity of floral species occupying a single region was considered a key factor in the summer moose model (Allen et al. 1987). Pixels with at lease two species, favorable for moose browse, were considered suitable (Appendix A: Table A.12). A value of ten was assigned to all areas with five or more species present. During the dormant season, regions with three or more browse species in the same location were assigned the highest suitability ranking because moose require less diversity at this time.

In addition to browse and species diversity, the dormant season habitat model included as criteria adjacency to winter cover (Appendix A: Table A.12). Only regions with a high potential for balsam fir and or white spruce, suitability values ranging from seven to ten for one or both species, were considered likely to contain dense enough cover to provide thermal cover for a large species such as a moose. Areas adjacent to cover were considered the most suitable and assigned a value of ten, while regions further than 500 meters from cover were considered unsuitable (Allen et al. 1987). The remaining values were rescaled in IDRISI and the resultant cover maps overlayed.

For the dormant season, a suitability map of each of the rescaled maps was combined utilizing a linear weighted overlay. Both browse and species diversity was given an equal weight of forty-five percent (Appendix A: Table A.13). Because the boreal forest ecosystem occupying Southeastern Michigan during the late Pleistocene was dominated by forest species that provided ample cover for moose, forest cover was given a low weight of ten percent. For the growing season, browse and species diversity were assigned a weight of forty-five percent while access to aquatic vegetation was given a lower weight of ten percent. Aquatic vegetation was assigned a very low weight because overall, moose spend relatively little time foraging on aquatic vegetation (Allen et al. 1987, Joyal and Scherrer 1978).

4.2.2 MASTODON

Without modern counterparts, very little is known about the habitat characteristics of the Mastodon. The locations of fossil remains suggest that much like moose, mastodon frequented the edges of lakes, streams, and wetlands (Holman 1975, 1995) although this observation may reflect taphonomic as well as behavioral processes. Mastodons may have eaten the aquatic vegetation that grew along the shore of water bodies often venturing out into deeper water where the animals were stranded. The dental structure of the mastodon indicates that much like other large herbivores, such as moose, they may have eaten the trembling aspen (*Populus tremuloides* spp.), birch (*Betula* spp.) alder (*Alnus* spp.), and willow (*Salix* spp.) that were often found in these open areas. Due to the lack of evidence, only a single habitat model can be generated for both the growing and dormant seasons.

Since it is impossible to determine the precise suitability of each potential browse species, all species were assigned the highest suitability rank of ten (Appendix A: Table A.14). Therefore the original suitability values were not adjusted prior to summing the suitability maps. Adjacency to a water body with aquatic vegetation was also considered a factor. Like the summer moose model regions within two kilometers of areas with open water/aquatic vegetation potential were considered suitable. NWI wetland ranks were reduced as the distance from each wetland type increased reaching a value of zero at two kilometers. Both suitable areas for browse and open water/aquatic vegetation were given an equal weight of fifty percent when they were combined using a weighted overlay.

4.2.3 MUSKRAT

Muskrat prefer wetlands containing emergent vegetation that are inundated throughout the year (Allen and Hoffman 1984). Emergent vegetation is used for lodge construction and is consumed by the muskrat. Due to uncertainties about the exact composition of wetland vegetation during the Paleo-Indian period, a general habitat model was constructed based on the potential for each wetland system to contain both emergent vegetation and open water.

Wetlands with emergent vegetation potential, discussed in section 4.1.12, were determined from the NWI maps (Appendix A: Table A.15). Wetlands with an emergent or scrub-shrub wetland class were given a high ranking for emergent vegetation potential. The presence of or adjacency to regions with open water was the final criterion within the muskrat model. Permanently flooded wetlands were regarded as the most suitable for muskrat habitat, while wetlands that are drier than seasonally flooded to saturated were considered the least suitable. The rankings for these wetland types are based on excavations conducted at the Shelton Mastodon site that indicate a significant amount of eutrophication has taken place across the study area since the early Paleo-Indian period (Shoshani et al. 1989). Lakes and perennial streams are also considered as sources for open water. Although usually a factor in muskrat habitat, stream gradient was not considered because the study area is relatively flat.

4.2.4 BEAVER/GIANT BEAVER

Little is known about the habitat characteristics of the giant beaver (*Castoroides ohioensis*) although it appears to have behaved much like the capybara or water hog of the South American wetlands (Holman 1995). Because only a single criterion, the potential for a wetland or water body to have contained aquatic vegetation during the late Pleistocene, can be identified for the giant beaver, an individual habitat model was not created. Regions suitable for the modern beaver, which also contain open water and a high likelihood of aquatic vegetation, are also considered suitable for giant beaver habitat (Appendix A: Table A.16).

With its larger brain the modern beaver is capable of more complex behavior than that of the giant beaver (Holman 1995). The habitat requirements for the modern beaver (*Castoroides canadensis*) appear to have been more complex than the giant beaver as well. The modern beaver prefers water bodies with aquatic vegetation adjacent to trembling aspen (*Populus tremuloides*), alder (*Alnus* spp.), and willow (*Salix* spp.) stands (Allen 1983). These tree species are both eaten and used as building materials. Spruce (*Picea* spp.) and pine (*Pinus* spp.) are also used as building materials, but are not typically eaten. Recent evidence from the Shelton Mastodon site supports the notion that the behavior of the modern beaver was much like it is today (Shoshani et al. 1989).

Aspen stands were considered the most suitable terrestrial food for the modern beaver (Appendix A: Table A.16). Regions suitable for alder and willow were considered less suitable for beaver habitat and were assigned a scaled value of eight. Using the methods outlined for the summer moose habitat model, the suitability values for alder and willow were adjusted according to their scaled value. Once altered, the alder/willow and aspen suitability maps were summed. Adjacency to water bodies with aquatic vegetation potential was also considered a factor in beaver habitat with areas farther than 200 meters from water regarded as unsuitable (Allen 1983). As the distance from each wetland type increased, the rank of that type was lowered reaching zero at 200 meters. Terrestrial browse and the adjacency to open water/aquatic vegetation were given equal weight within the beaver habitat model, because both factors are required for suitable beaver habitat.

4.2.5 CARIBOU

During the early Paleo-Indian period, both barren ground (*Rangifer tarandus groenlandicus*) and woodland (*Rangifer tarandus caribou*) caribou were found in southeastern Michigan (Cleland 1965, Holman 1975, 1995), particularly during the winter and the fall and spring migration. As a result, two models were constructed, the first depicting migration corridors of barren ground caribou and the second wintering habitat. Because the wintering range of the woodland caribou was within that of the barren ground caribou a single model was generated for both species. A caribou habitat model for the growing season was not generated for this research due to the highly dispersed nature of woodland caribou and the fact that barren ground caribou likely migrated northward.

Barren ground caribou migration corridors are predictable and usually remain constant over many hundreds of years (Calef 1995, Gronnow et al. 1983, Krist and Brown 1994, LeResche and Lindermand 1975, Miller et al. 1972, Skogland and Molmen 1979, Spiess 1979). When moving across the landscape, migrating caribou usually follow a path of least resistance. Caribou accomplish this by abiding by three geographic principles. First, caribou often follow ridge tops or side slopes that provide easy migration routes and better visibility from which to view predators. Second, if they must be traversed, lakes, streams, and wetlands are crossed at the narrowest point. Caribou course hydrologic features for long distances in search of a suitable crossing that may be physically easier to traverse. Third, caribou generally follow a path of least topographic resistance by avoiding steep slopes.

In order to simulate fall and spring migration corridors, the relative cost of moving throughout the landscape was modeled for each of the geographic principles caribou follow (Appendix A: Table A.17). Areas of little or no resistance to caribou movements were assigned a value of zero, while the most difficult areas to traverse were given a score of ten. Later in this section, the reason why suitable areas were assigned a value of zero instead of ten will be explained. Two resistance or friction maps were generated. The first map accounts for the principle that caribou cross water at the narrowest point. The second accounts the principles that caribou follow ridge tops or side slopes and follow a path of least resistance by avoiding steep slopes. These resistance maps were combined producing a single friction layer representing the relative cost to traverse each pixel or grid cell within the study area. Separate friction maps were constructed for both the spring and fall migrations.

The affects of hydrologic features on the movement of caribou were simulated using lake and stream maps obtained from the MIRIS GIS database, and wetland maps obtained from National Wetlands Inventory. Hydrologic features with open water were assigned a value of ten, while intermittent streams provide the least resistance and were assigned a value of three (Appendix A: Table A.17). Due to their low foot loading, caribou are very efficient at traversing soft wet surfaces (Fancy and White 1987, White and Yousef 1978). Therefore, wetlands lacking standing water during the early spring and fall were given low resistance values of three.

Estimating the topographic energy expenditures for caribou was a complex task. First, to account for up and down slopes during the spring and fall migrations, the slope and the direction each slope faces, or aspect, was calculated from 30-meter resolution NED DEM data. Slopes facing south or southeast during the spring migration were uphill, while slopes facing north or northeast were downhill. The opposite was true for the fall migration. Next, recent research (Fancy and White 1987, White and Yousef 1978) provided the framework from which to estimate the resistance that various slopes posed to caribou. On a level grade, the mechanical efficiency of a caribou walking is about 60%. As the gradient increases, approaching 5%, the efficiency drops to around 50% (Appendix A: Table A.17). While traversing a 9% gradient, the net energy cost of raising 1 g of body weight 1 km becomes twice as difficult lowering the mechanical efficiency for caribou to around 30%. This research suggests that slopes steeper than 12% were nearly impossible to traverse. White and Yousef (1978) also found that a caribou walking down a grade of –5% would recover energy, thus raising the mechanical efficiency to around 70%. However, as the downward gradient increases, the caribou recovers less and less energy utilizing energy to resist gravity. Extrapolating from White and Yousef's (1978) efficiency estimates, ascending gradients steeper than 12 % and descending gradients greater than 20% were given a value of ten. Descending slopes with a value of -5% provided the least resistance and were given a value of zero. The remaining gradients were assigned friction values within the IDRISI FUZZY module.

To account for side slopes and the direction of migration, the following equation was used to alter the slope values prior to stretching them in IDRISI:

$$\text{Aslope} = \text{slope} * \cos(\text{Taspect} - \text{Saspect})$$

Where Aslope is the adjusted slope value and slope is the original gradient value, Taspect is the direction toward the migration origin, and Saspect is the slope aspect. The latter half of the equation generates a number ranging from +1 to –1. A value of +1 represents ascending slopes, a value of –1 represents descending slopes, and a value of 0 represents side slopes. Values falling between 0 and + or –1 depict a moderate ascent or decent respectively. Multiplying these numbers by their corresponding slope adjusts the gradient according to the direction of travel by assigning negative values to descending slopes and lowering the effect of side slopes that can act as level terrain providing little resistance. This process was repeated for both the fall and spring migrations and the final friction maps were combined with a weighted overlay. Equal weight was given to each friction map. Ridgelines are depicted as side slopes and automatically receive a low energy expenditure, or friction value, because the model accounts for the direction each slope faces. Side slopes are considered flat areas because the direction of travel is along the slope face and not up or down it.

Least cost pathways, or migration corridors, were calculated from each of the final friction maps. To accomplish this, the ARC/INFO GRID PATHDISTANCE command was used to identify the cumulative cost of moving across the study area based on the friction maps. In other words, the PATHDISTANCE module is able to calculate how much it would cost each cell to return to a source cell or set of cells. The pixels along the southern boundary of the study area acted as the source cells for the spring migration, while pixels along the northern and eastern edges of the study area acted as the source cells for the fall migration. Output from the PATHDISTANCE module was subsequently entered into the COSTPATH module to specifically simulate the migration corridors. The COSTPATH module identifies adjacent cells of least resistance producing a least-cost path between the source cells and a destination cell. Several destination cells were chosen for each migration. Regions where least-cost pathways converged suggest that caribou funneled through an area due to its suitability for caribou movement.

The winter habitat model for barren ground and woodland caribou is based on the distribution of food and water resources. Regions suitable for reindeer lichen, grasses, horsetail, and sedges were considered highly suitable for caribou habitat and were assigned a score of ten (Appendix A: Table A.18). Since sedges, horsetail, and grasses are found in a wide range of habitats within openings along streams, unforested wetlands, and lakes (Chadde 1998) all areas within a sixty-meter buffer around these features were considered suitable. A formal habitat model was not constructed for these species. Areas suitable for trembling aspen, paper birch, and willow were considered fairly suitable for caribou habitat and were given a rank of seven. Low shrubs, such as Labrador tea, mountain cranberry, thimbleberry, and blueberry were regarded as much less suitable and were assigned a low rank of three. Since caribou often rest on frozen lakes and ponds, these areas were considered highly suitable for winter caribou habitat. The NWI water regime modifiers were used to rank regions on their ability to contain open water. The open water potential map was overlayed on the browse map to generate the final habitat suitability map.

4.2.6 HARE

Snowshoe hare (*Lepus americanus*) habitat is determined by both the presence of adequate cover and food (Carreker 1985, Sullivan 1995). Although having a small home range of less than five square miles (8 km), the hare does prefer slightly different foods during the dormant and growing seasons. During the growing season, hare prefer willow (*Salix* spp.), alder (*Alnus* spp.), aspen (*Populus* spp.), and blueberry (*Vaccinium* spp.) vegetation (Appendix A: Table A.19). Alder and willow are still the preferred foods during the dormant season while aspen, birch, and black spruce (*Picea mariana*) are eaten in lesser quantities and received lower ranks within the habitat model.

Cover is a critical part of hare survival and received the same weight as the overstory and understory food types included within this habitat model (Appendix A: Table A.19). Since hare need immediate protection from predators, it is assumed that mixed stands containing both food and cover provided the best habitat. As a result, the distance to species providing cover was not considered a factor within this model. Black spruce was regarded as the most suitable cover species while balsam fir (*Abies balsamea*), willow, and alder were considered suitable cover types and given ranks of eight and seven respectively.

4.3 SUMMARY

With the aid of Geographic Information Systems twelve floral and six faunal models were developed to simulate the distribution of key species either likely to or known to have occupied southeastern Michigan during the late Pleistocene. Each of these species affected, directly or indirectly, the decisions early Paleo-Indians made regarding resource use and settlement. For example, spruce likely provided early hunter/gatherers with direct thermal cover during the winter, while indirectly affecting the resource base by limiting the distribution of forage species such as aspen. Although the list of species examined in this research is not exhaustive, it does focus on the more common species affecting resource utilization of humans occupying a boreal forest setting (Nelson 1973, Rook 1999).

The goal of the models outlined in this chapter is to provide a spatial description of the late Pleistocene resource base. The resultant data from these models is used as input into the behavioral model offered in Chapter 5 to test the hypothesis outlined in Chapter 6. The simulations from this chapter are examined in Chapter 7 to gather insight into how individual resource distributions may have affected the behavior of early hunter/gatherers. Due to the lack of floral and faunal remains at Paleo-Indian sites within the Great Lakes region, very little is known about local ecosystems in which early Paleo-Indian activities took place. The models within this chapter provide a unique picture of what the late Pleistocene environment may have looked like across Lower Michigan.

Chapter V

SIMULATING HUNTER/GATHERER BEHAVIOR: A DECISION BASED MODEL

The aims of this research are twofold. The first goal is to provide anthropologists with an efficient means of simulating hunter/gatherer behaviors resulting from decisions regarding resource use and settlement. Because decision-making processes are not readily discernable from the archaeological record, models of human ecosystems are often biased toward the examination of matter and energy (Reynolds 1986). Therefore, resource distributions are seen as the driving force behind hunter/gatherer behaviors resulting in environmentally deterministic models. According to Flannery, (1986) modifications in hunter/gatherer strategies and or behaviors are the result of internal stress brought on by decisions that do not satisfy the needs of a group of hunter/gatherers. The model presented here demonstrates how hunter/gatherer decision-making can be incorporated into subsistence and settlement models. In fact, decision-making is viewed as the driving force behind hunter/gatherer behaviors. The second aim is to utilize this approach to better understand which adaptive strategies were chosen by Great Lakes Paleo-Indian peoples to survive in a dynamic environmental setting. A decision-based model for simulating hunter/gatherer behavior is developed to meet these goals. The model is used to simulate the resource use strategies and settlement patterns of early Paleo-Indian peoples occupying Southeastern Lower Michigan. The simulations are based on three competing hypothesis about Great Lakes early Paleo-Indian adaptive strategies discussed in detail within Chapter 6.

The decision-based behavioral model presented here takes a deductive, or explanatory, predictive approach borrowed from decision theory. As a result, the following discussion begins with a brief overview of decision theory as it relates to the model utilized in this research.

5.1 DECISION THEORY

Decision theory outlines the logic used to make choices between alternatives (Eastman et al. 1995). Alternatives come in a variety of forms and vary depending on the social and economic problem(s) encountered. For instance, Jochim (1976) states that hunter/gatherers throughout the world encounter economic problems related to resource use. The hypotheses hunter/gatherers may have or had about the availability of resources, or different courses of action that may be taken to procure these resources, are examples of these alternatives.

According to decision theory, choices between alternatives are based on two forms of criteria: factors and constraints (Eastman 1999). Factors enhance or detract from the suitability of an alternative. For example, resource patches containing a diversity of edible foods are considered highly suitable by an individual seeking dietary variety, while other areas are less suitable. Constraints, on the other hand, limit the number of possible alternatives from which an individual may choose. In the case of a hunter/gatherer with the ability to make foraging trips no greater than twenty kilometers round trip, for physical or social reasons, for example, would preclude areas outside this range regardless of their diversity. The same forager may not utilize diverse resource patches if they are too small as well.

Since decisions are not always based on simple alternatives, a particular real world setting may require an individual to consider a host of fuzzy criteria prior to making a decision. For example, how far will a forager walk to reach a particular patch of resources to satisfy the desire for variety? In this example, the forager must consider a more complex set of factors and constraints, such as walking distances, patch size, patch diversity, terrain roughness, etc. Similar to what the prehistoric hunter/gatherer may have done, the researcher must consider the degree to which varying criteria tradeoff and/or affect the final decision-making process.

Hunter/gatherer decisions and behaviors are guided, in large part, by a set of goals or objectives (Jochim 1976, 1998). Therefore, objectives help determine what features in the real world become criteria and which criteria are utilized by a group of hunter/gatherers. Although objectives are based on social perspective and motives that may vary between groups or individuals, there may be a limited set of universal goals, as discussed in Chapter 1, guiding the choices hunter/gatherers make (Eastman et al. 1995, Jochim 1976, 1998). If a population begins to meet its needs once a set of objectives are in place, these objectives are either consciously or subconsciously reinforced resulting in patterned and redundant decision-making (Egan 1993, Jochim 1998).

The final selection and evaluation of criteria is aided by a strategy, or set of strategies, known as a decision rule. The decision rule, formulated in the context of a given set of objectives, also contains the means by which selected alternatives will be acted upon. For example, hunter/gatherers utilizing a forager strategy (Binford 1980) as a decision rule, in which decisions regarding settlement locations and resource patches (criteria) are guided by a desire to move the entire group to resources, would find locations that provide direct access to resources more favorable.

5.2 THE MODEL

Despite earlier attempts by Steward (1943), predictive modeling in archaeology really began with Jochim's progressive 1976 work *Hunter-gatherer Subsistence and Settlement: A Predictive Model* (see Bettinger's forward in Jochim 19??). Jochim demonstrated that predictive models of hunter/gatherer subsistence, settlement, and population size could be generated from the presumed goals of a population and the resource characteristics of a region that a society occupied. Soon after the completion of Jochim's (1976) work, Arnold (1977) utilized his approach to construct a model of early archaic subsistence within Southeastern Michigan demonstrating that such a model is indeed applicable to prehistoric studies in the Great Lakes. The shortcoming of Jochim's predictive model was that it relied heavily on quantitative measures as input (Bettinger 1998, Jochim 1998). Quantitative prediction is difficult considering the unknowns of past ecosystems and the strategies that prehistoric hunter/gatherers utilized. In spite of these limitations, archaeologists continued to develop predictive models that relied heavily on quantitative measures for model inputs (Reidhead 1979, 1980, Keene 1981, Mithen 1990). Undoubtedly, these models have contributed greatly to our understanding of the behaviors of past societies, however, such models are very difficult to utilize and "...can be enormously useful in demonstrating the effects of certain variables..." because of their quantitative demands (Jochim 1998:17). An alternative to building predictive models on precise mathematical measurements is to utilize general relationships among factors. However, simplistic models are more likely to be unrealistic. The work by Egan (1993) has moved closer to resolving this problem by using detailed information to produce rankings that depict the general relationships between resources or factors. To address these issues, the model presented in this research takes a unique approach by standardizing information about factors affecting the behavior of hunter/gatherers through the production of ratings within a comparison matrix. Ratings may be based on either general relationships among factors, i.e. resource A tastes better than resource B, or quantitative measures that specifically assess the ability of a criterion to satisfy an objective, i.e. resource A has ten more grams of sugar than resource B. The ability to utilize both precise and non-precise measures when assigning ratings to every criterion enables the model to take advantage of all available information about the past while allowing the model to grow as the archaeological knowledge base increases.

The development of Geographic Information Systems (GIS) over the last twenty years has greatly stimulated the use of predictive models in archaeology (Kvamme 1995). Traditionally, predictive models constructed within a GIS environment have been inductive, doing little more than confirming that spatial correlations exist between settlements and the proximity of physiographic features (Ebert 2000). Recently, archaeologists have begun developing deductive predictive models within a GIS environment that consider how humans make choices (Dalla Bona 2000). However, these models do not consider the objectives of past hunter/gatherers or how these goals may have affected decision-making. Because these models are unable to explain why hunter/gatherers chose the resources and settlement locations they did, the applicability of GIS based predictive modeling for archaeological problem solving is in question. Despite the shortcomings of these models, they are becoming more common in archaeology due to their ability to efficiently locate sites in un-surveyed regions (Kvamme 1995). In general, the ability of GIS to efficiently manipulate and analyze large amounts of spatial and tabular data makes it a particularly useful tool for the construction of multivariate predictive models (Kvamme 1999). This research will demonstrate how a deductive predictive modeling approach rooted in both anthropological and decision theory can be efficiently implemented within a GIS system and used for archaeological problem solving.

The primary assumption of the behavioral model presented here is that the conscious decisions made by hunter/gatherers are directed toward achieving a set of specific goals or objectives, such as those outlined in Chapter One. In addition, the model assumes that there is a limited set of objectives guiding hunter/gatherer decision-making about resource use and settlement (Egan 1993, Jochim 1976). It is also assumed hunter/gatherers make rational decisions based on their ability to satisfy this limited set of objectives. Therefore, goals/objectives are the guiding force behind the development of an adaptive strategy utilized by a group of hunter/gatherers.

Despite the fact that the model presented here assumes hunter/gatherers make rational decisions, the model did not borrow from rational choice theory per say. Decision models constructed with rational choice theory are generally based on a hierarchical decision framework (Kohler and Parker 1986). Within a hierarchical decision framework, factors are evaluated sequentially until an alternative with the "correct value" has been identified. The research design proposed here assumes choices can and are often based on additive factors in which low factor values can be "balanced off" by higher factor values.

The model offered here is designed to simulate the outcome of hunter/gatherer problem solving. Although the model is implemented within a raster GIS system, such a system is not required to run the model, evaluations may be calculated by hand. The model is divided into three modules in which both hypothesized and observed information about hunter/gatherer behavior and the environment, related to a particular problem such as resource use, may be input: 1) objectives, 2) decision rule, 3) criterion, (Figure 5.1). The first module requires the researcher to determine the objectives of the hunter/gatherer group being studied and the relative importance in solving the objectives of a particular problem. For the second module, the researcher establishes the adaptive strategy utilized by the hunter-gatherer group to meet their objectives. For example, a group of hunter/gatherers may determine that in order to meet their objectives of minimizing energy expenditure while obtaining enough food resources for survival, a forager strategy dependant on large game may be the best solution. The decision to pursue large game and the objectives surrounding this choice help to formulate a worldview by determining which features on the landscape become factors and constraints that are entered into the model using the criterion module. The information entered into the modules is combined utilizing weighted linear multi-criterion evaluations. In this third module, suitability values predicting the likelihood that human behavior(s) occurred at a particular location(s) for comparison to the archaeological record are produced.

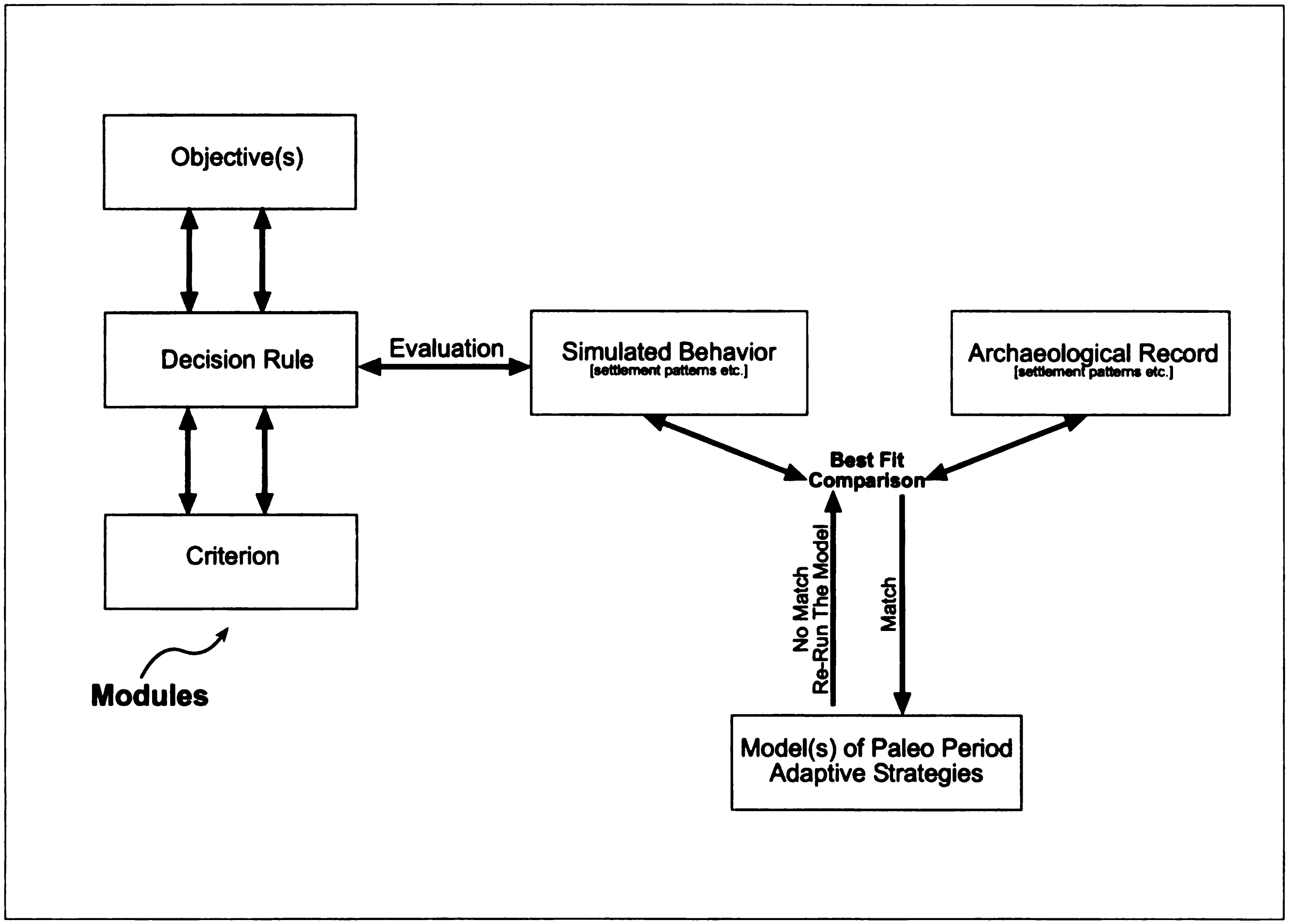

Figure 5.1. Location Of Modules Within The Decision Model Advocated In This Research

The methodology presented below borrows from the decision strategy analysis presented by Eastman (1995, 1999). Although GIS software is not required to run the model presented below, it is particularly useful when examining an entire region or evaluating a large number of objectives and criteria. The GIS software IDRISI is recommended because the software possesses an existing set of tools for conducting multi-criterion evaluations (Eastman 1999).

5.2.1 OBJECTIVES

Certain aspects of hunter/gatherer behavior are highly patterned redundant, suggesting that there is a limited set of universal goals guiding hunter/gatherer decision-making (Egan 1993, Jochim 1976, 1998). These cross-culturally observed behavioral patterns, outlined in detail by Jochim (1976), provide a starting point for researchers to build hypotheses about the objectives of past hunter/gatherers.

Once a set of objectives for the hunter/gatherers under study has been defined, the relative importance of each objective is entered into a pairwise comparison matrix. This matrix is used to generate a set of weights representing the relative importance of each objective in affecting hunter/gatherer behaviors. For example, finding areas with direct access to resources may be a more important goal in solving the problem of settlement placement than locating regions that are sheltered from winds and other elements. Prior to entering values into the pairwise matrix, comparisons must be made between each objective using a 9-point continuous rating scale. Ratings represent the relative importance of each objective compared to one another (Figure 5.2). In the above example, if direct access to resources were significantly more important in determining

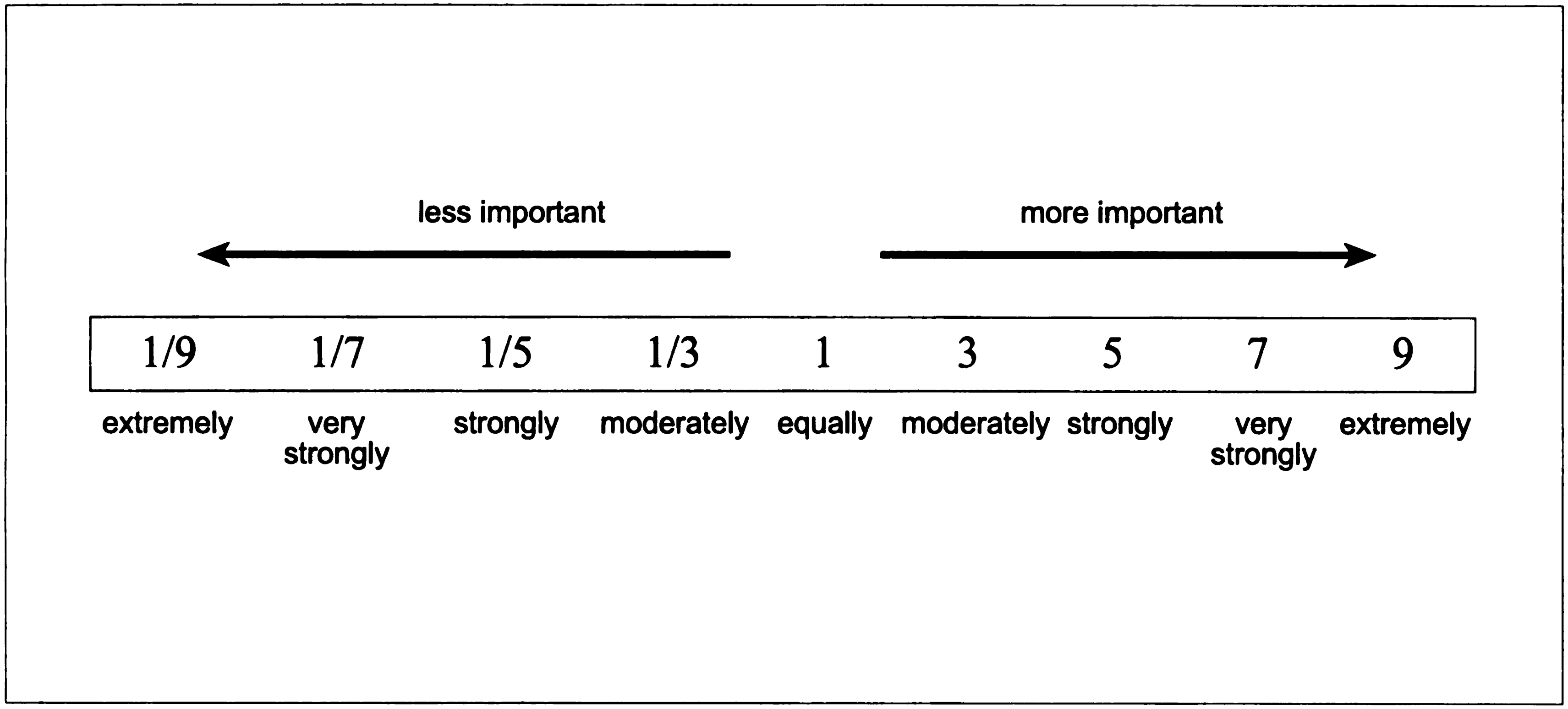

Figure 5.2. Nine Point Continous Rating Scale (After Eastman 1999)

settlement placement, this objective would receive a value of five. The inverse would be true for areas sheltered from winds and would receive a value of 1/5. Every possible pairing of objectives must be compared and entered into the pairwise matrix (Table 5.1).

Table 5.1. Partial Pairwise Comparison Matrix For The Objective Of Settlement Placement

	Resource Proximity	Shelter	View
Resource Proximity	1		
Shelter	1/5	1	
View	1/7	1/2	1

A pairwise comparison matrix is an efficient method for assessing the comparative importance of variables whether they are objectives or criteria (Eastman 1999). The pairwise comparison method is particularly useful for evaluations that include multiple objectives or criteria, such as in this research. The pairwise matrix also has the advantage of being symmetrical, only the lower triangular half must be filled in because the remaining cells in the matrix are reciprocals of the other half (Table 5.2).

Table 5.2. Entire Pairwise Comparison Matrix For The Objective Of Settlement Placement

	Resource Proximity	Shelter	View
Resource Proximity	1	5	7
Shelter	1/5	1	2
View	1/7	1/2	1

For example, if the rating of resource access relative to shelter is five; the rating of shelter relative to resource access would be 1/5. After entering the ratings into the comparison matrix, the principle eigenvector is calculated for the matrix. The principle eigenvector is used to produce a best-fit set of weights from the criteria ratings (Table

5.3). Within the GIS software IDRISI 32, the WEIGHT command is used to calculate these weights, which sum to one. The WEIGHT module also determines the degree of consistency that was utilized in generating the criteria ratings. An index of consistency or consistency ratio is produced every time a set of weights is calculated. A consistency ratio value of less than 0.10 indicates that the comparison matrix values were probably not generated at random. When values greater than 0.10 are obtained, the matrix ratings require reevaluation. The weights produced by this process are similar to the percent weights generated within Chapter 4; however, the comparison matrix provides a more rigorous means of generating them. An approximation of the weights generated from the principal eigenvector can be generated by filling out the entire matrix and summing each column to get the column marginal total. Each rating in the matrix is then divided by the marginal total of its column. Finally, the weights across the rows are averaged; the result should be similar to that generated from the principal eigenvector within the WEIGHT module.

Table 5.3 Examples Of Weights Resulting From Calculation Of Principal Eigenvector Of The Pairwise Comparison Matrix For Settlement Placement

Criteria	Weight
Resource Proximity	0.7396
Shelter	0.1666
View	0.0938

5.2.2 DECISION RULE

The decision rule requires the researcher to determine what strategy might have been used by a group of hunter/gatherers to meet their objectives. Generally, the decision rule is derived from a hypothesis, or set of expectations, of how hunter/gatherers may have behaved in the past. Information about the decision rule is not entered directly into the model per say, but the decision rule and the objectives that have the greatest affect on the determination of criteria for this model (Eastman et al. 1995, 1999). Once a group of hunter/gatherers decide on a strategy that will meet their objectives, that strategy determines how resources, settlement locations, etc. will be considered within the decision making process (Jochim 1999).

Two broad examples of a decision rule are Binford's (1980) forager and collector settlement strategies. Food resources play a different role in the decision making process for each of these strategies. Foragers choose residential locations based on their proximity to food resources including water, while collectors select residential settlement locations based on their proximity to key non-food resources that are required for immediate survival, such as water (Kelly 1995). Collectors use logistical forays as a primary means of bringing food resources to their settlements. When simulating the activities of foragers, immediate access to food resources become the dominant criteria affecting decisions regarding forager settlement patterns. Each resource acts as a criterion since foragers move people from resource to resource. For collectors, adjacency to key non-food resources in areas that allow remote access to a wide range of food resources are the main criteria affecting decisions about collector settlement patterns. Thus, direct access to food resources plays only a minimal role in collector settlement selection.

5.2.3 CRITERIA

Criteria, or factors, are features on the landscape that enhance or detract from the suitability of a location toward meeting an objective (Eastman 1999). As discussed earlier, determining which criteria played a role in hunter/gatherer decision-making is based on the objectives and adaptive strategy found within a group of hunter/gatherers. Depending on the number of criteria the researcher identifies for each objective, the model can be relatively simple or quite complex. Factors can also be changed and the model re-calculated to test different hypotheses. The criteria themselves are generated from known facts about the landscape, such as the availability of plant or animal resources. The objective to obtain shelter from the elements, for example, may consist of several factors such as, forest cover, slope, and aspect (Table 5.4). More specifically, hunter/gatherers attempting to avoid locations exposed to northerly winds likely considered relatively steeper slopes facing south more suitable for settlement than flat areas. As a result, this type of model places the driving force behind the criterion rankings in the pairwise matrix on the desires of the hunter/gatherers under study. The model is a vehicle by which hypotheses about the desires of hunter/gatherers can be tested and the outcome simulated.

Table 5.4. Examples Of Pairwise Comparison Matrix For Shelter Factors

	Forest Cover	**Slope**	**Aspect**
Forest Cover	1		
Slope	2	1	
Aspect	2	1	1

The accuracy of most criteria depends on our understanding of past ecosystems and the role they played in hunter/gatherer decision-making. Fortunately, the model presented here is able to accommodate general or specific criteria, unlike other decision based hunter/gatherer models, such as linear programming, that require a high level of detail and accuracy (Kelly 1995, Jochim 1998). For example, a general suitability model depicting the potential availability of a particular plant species as high, medium, or low will be adequate. However, the final output is only as precise as the least accurate input data.

Once criteria and the ratings are determined, the principle eigenvector for each pairwise matrix is calculated generating a set of weights for each objective's factors (Table 5.5). Factors are ranked based on their relative importance in the decision making process. In other words, each objective is assigned a group of criteria for which a comparison matrix is constructed (Figure 5.3, B).

Table 5.5. Examples Of Weights Resulting From Calculation Of Principal Eigenvector Of The Pairwise Comparison Matrix For Shelter Factors

Criteria	**Weight**
Forest Cover	0.2
Slope	0.4
Aspect	0.4

After calculating the principle eigenvector for each pairwise matrix, generating a set of weights for each objective's factors, a list of constraints, if any exist, must be identified for each objective. Constraints are not ranked, but represent areas to avoid

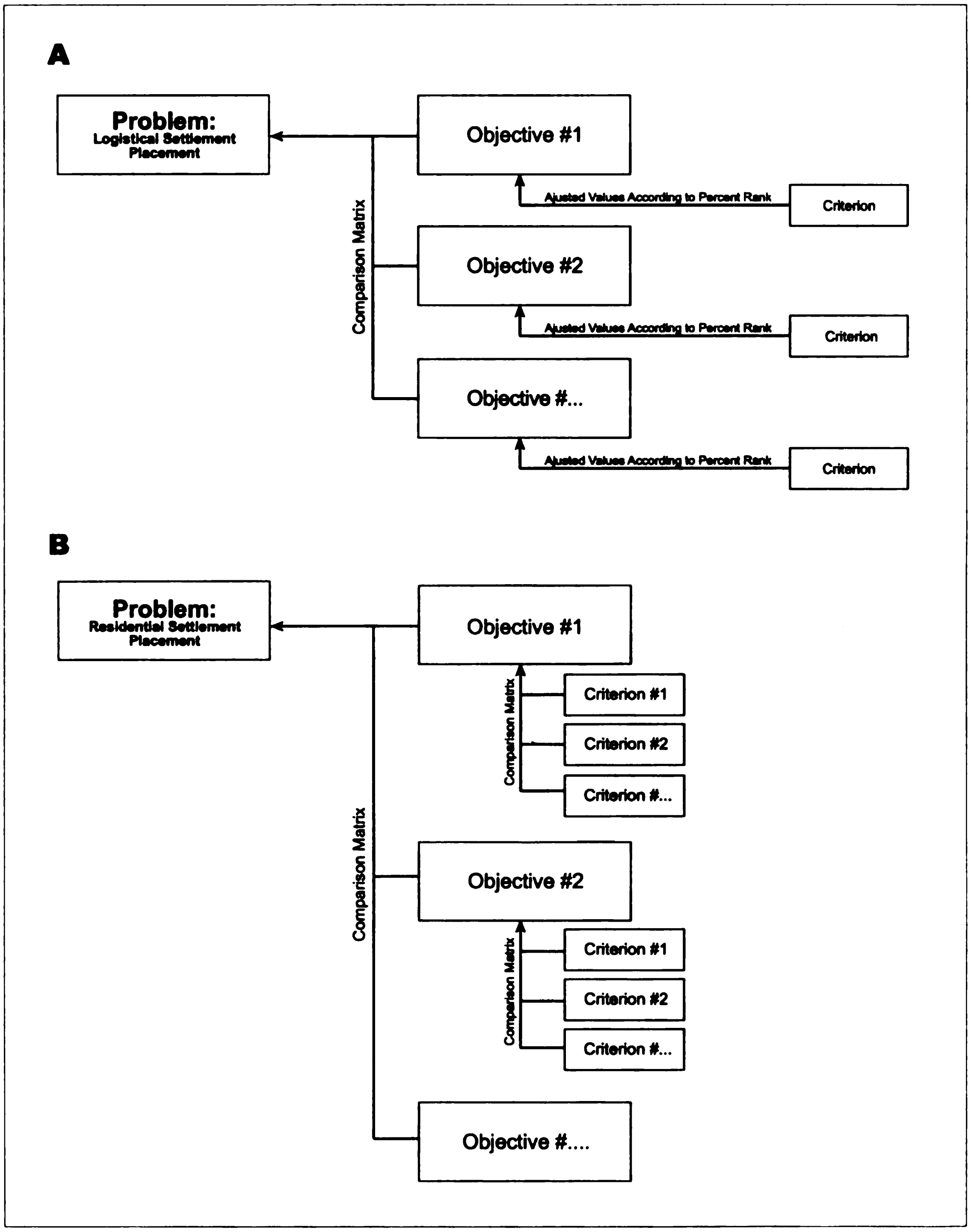

Figure 5.3. Relationship Between The Problem, Objectives, And Criteria For Objectives With A Single Criterion (A) And Multiple Criteria (B)

regardless of the factors that may be present. Regions may be inaccessible due to territorial boundaries or because of a physical desire to walk fewer than 12 miles per day. Once the criterion weights have been developed, each factor or constraint must be represented within the model. A single location under study is assigned a numeric value based on the potential to satisfy particular criteria. For example, for the factor of caribou availability, a location that contains caribou 100 % of the time is assigned a value of 255, while a location that caribou rarely inhabit receives a value of 0. The location under study is given a value for each factor that exists. Factors receive a numeric value ranging from 0 to 255 to ensure standardization. Other standardized scales can also be used in addition to 0 - 255, common scales include 0 – 1 and 0 – 10. In order to remain consistent with the habitat models presented in Chapter Four, the model presented here uses a range of 0 - 10 to standardize values. Standardizing factors enables the comparison of criteria that are based on different techniques or values such as slope and tree cover. Standardization is achieved by performing a linear scaling between the minimum and maximum factor values as follows:

$$x_i = (R_i - R_{min}) / (R_{max} - R_{min})^* \text{ standardized\_range}$$

where R = raw score

Factor values may be stretched with a variety of membership functions. For further discussion of these functions, see Eastman (1999).

Depending on the adaptive strategy, objectives may be satisfied by only a single criterion (Figure 5.3, A). For example, resource use at logistical camps is often intensely focused on a single resource patch or activity (Binford 1980, Jackson 1998). In order for a group of foragers to identify which resource to focus on at a logistical site, the suitability of each resource is evaluated individually in the context of the group's objectives.

When a single criterion exists for each objective, a comparison matrix is not necessary. This is because factors are not being compared to one another to determine how well a group of criteria satisfies each objective. Instead of assigning a weight to a criterion using a 9-point continuous rating scale, an individual criterion is ranked based on how well it satisfies each objective using a percent. Percents range from zero to 100 with 100% fully satisfying an objective. The percent rank adjusts the original factor value according to its ability to satisfy an objective. In order to adjust the value, each factor rank is multiplied by the criterion value, thus lowering the original value. For example, an unreliable and unpredictable resource would not satisfy an objective to minimize risk and therefore would receive a low rank. If the resource has a suitability value of eight at a particular location and the rank is 40% the adjusted value is 3.2. On the other hand, this same resource may satisfy the population aggregation objective of a group and receives a high rank for this goal.

The next section discusses how multiple criterion values are adjusted within an evaluation utilizing the weights derived from a comparison matrix. Once a criterion's value has been adjusted for each problem's objectives, the adjusted factor values are ready to be combined within a weighted linear combination that is also discussed in detail within the next section.

5.2.4 EVALUATION

Once the factor values and a set of weights have been generated for each objective's factors, the information is combined using a weighted linear combination multi-criterion evaluation. The procedure for developing objective/factor values and weights and their combination is summarized in the flow chart, Figure 5.4. Factors are combined utilizing the weighted linear combination by multiplying the factor weight by each criteria value followed by a summation of the results (Eastman 1999):

$$S = \Sigma w_i x_i$$

where S = suitability
w_i = weight of factor i
x_i = criterion score of factor i

In the locations containing constraints, the following equation would apply:

$$S = \Sigma w_i x_i * \Pi c_j$$

where c_j = criterion score of constraint j
Π = product

The output from the weighted linear combination is a value ranging from 0 to 255 with the highest values representing the most suitable locations for meeting a particular objective. The weighted linear combination also has the ability to identify what behaviors may have resulted based on a hypothesized objective and strategy. For example, at a particular location, a high suitability value for resource procurement could mean that plant gathering and caribou hunting were the most likely activities to occur given the current objective and strategy utilized by a group of hunter/gatherers. Correlations

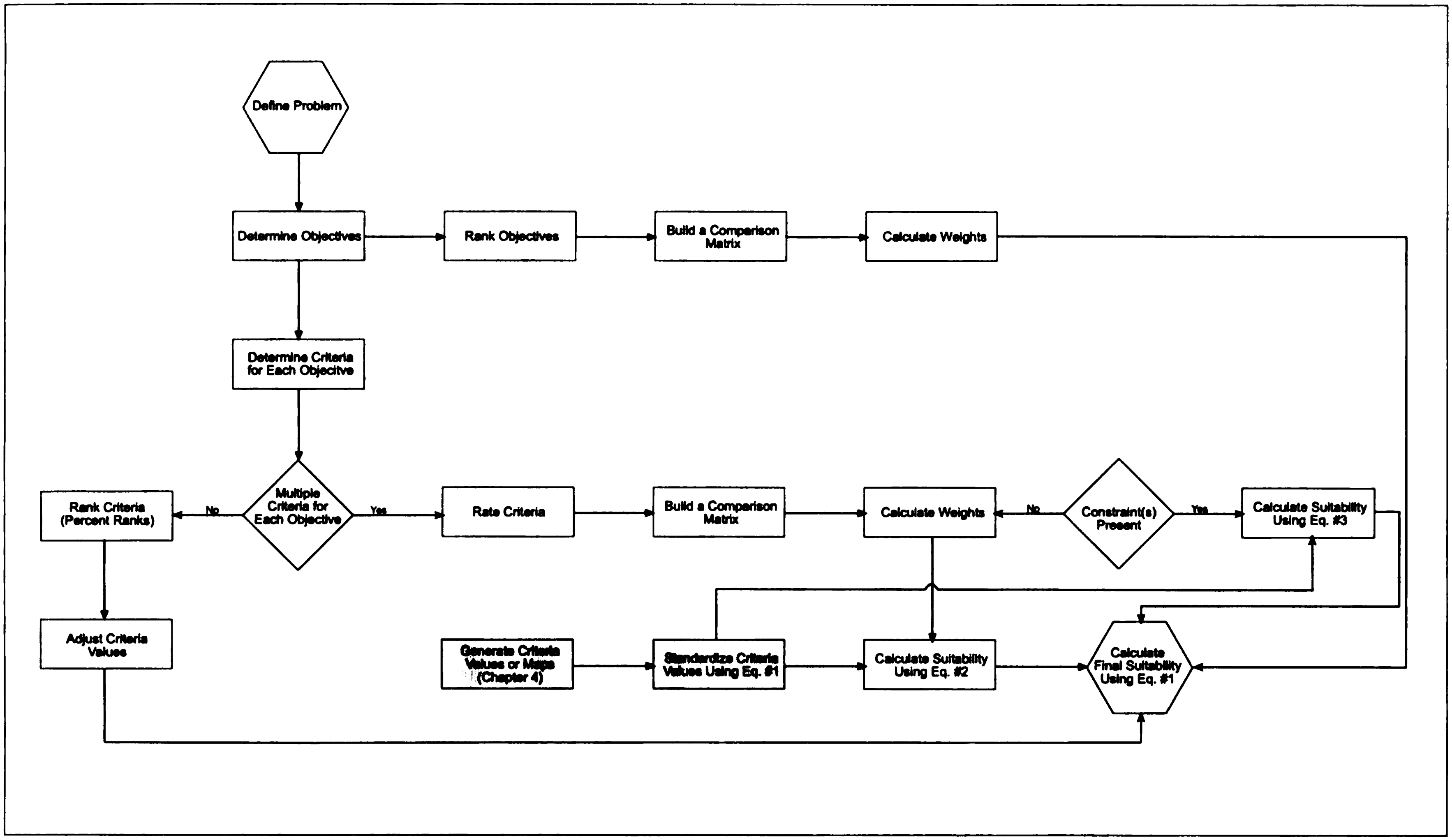

Figure 5.4. Flow Chart For The Behavioral Model Outlined In Chapter 5

between simulated activity areas and similar activity areas within the archaeological record suggest that the culture under study did indeed base their decisions on the hypothesized objective and strategy.

Hunter-gatherer decision-making behavior is complex and multi-dimensional and care must be taken not to oversimplify. For example, decisions hunter/gatherers make in regard to a particular problem consist of multiple objectives. Jochim (1976, 1998) suggests that the problem of resource use, i.e. deciding what resources to use, and where to obtain them, consists of the following objectives:

a) Attainment of a minimum amount of food and manufacturing materials
b) Population aggregation
c) Efficiency in the form of energy and time minimization
d) Risk minimization
e) Attainment of good tasting foods
f) Attainment of a variety of foods
g) Attainment of resources that carry prestige
h) Maintain differentiation of sex roles

The output from the weighted linear combination, calculated for each objective's criteria, is combined using another weighted linear combination with the weights generated from a pairwise comparison matrix created for the objectives. This produces a final suitability value depicting the likelihood that a location(s) was utilized as a solution to a problem based on the objectives and strategies of a group of hunter/gatherers. If a set of objectives contains a single factor, the adjusted values for this factor are also combined using the weighted linear combination (Figure 5.3, A).

The amount each objective, or criteria, affected the decision making process can be determined by examining criteria or suitability values for any given location. If a location receives a final suitability value of 225, for example, is this due to the variety of low-risk resources carrying high prestige that are likely to be found there? Such a question can be answered by examining each objective's suitability values. The criteria values at a location will provide estimates about the effects of individual factors on the final suitability. These values also indicate how much of a resource was available for exploitation or how many people a settlement location could have supported.

How do we account for risk-taking that several researchers (Cashdan 1990, Halstead and O'Shea 1989, Jochim 1998) have identified as a critical part of hunter/gatherer decision-making? Risk can be accounted for in this model in three ways. The simplest way to examine the possible effects of risk minimization is to use the highest suitability values in the final output, eliminating any regions that have the potential to be risk adverse. The second means of modeling risk minimization is to incorporate it as an objective of the hunter/gatherers that are being studied, as Jochim (1976) did. Having risk as an objective allows control over the weight, or effect, although it is a more complicated method. This method has the potential to address the question of how much risk minimization factored into hunter/gatherer decision-making. The third method, which is the most complicated, can be used in conjunction with the second. An ordered weighted averaging (OWA) approach may be used to combine the factor values. The OWA method is similar to the WLC, but the OWA accommodates a second set of weights. This second set of weights control the degree to which weighted factors are aggregated (Eastman 1999). In the OWA approach, factors with low values receive extra weight in the outcome regardless of their original weight. Thus, highly weighted factors are prevented from dominating suitability scores in locations where all other factor scores are much lower. Therefore, orienting the second set of weights toward the minimum factor values ensures the final suitability does not contain high values in locations based on any single factor. For example, weighting minimum factor values higher creates a low risk suitability model in which higher suitability values represent areas containing the likelihood that several resources will be available in that area. If one resource fails, the hunter/gatherer will have something to fall back on.

5.3 IMPLEMENTING THE MODEL

The model outlined within this chapter provides an efficient means for simulating the resultant behaviors from hunter/gatherer decisions that are made based on the goals and needs of a society. Although the model is able to accommodate a wide range of decisions and their resultant behaviors, cultural universals are used as a point of departure within this research because those universally occurring behaviors are likely to have existed in prehistoric societies (Jochim 1976), such as the early Paleo-Indian. Therefore, this research assumes decision-making is patterned and thus redundant with decisions that lead to the long-term fulfillment of a society's needs being reinforced (Egan 1993).

The behavioral model presented here will be used as a tool to provide insight into early Paleo-Indian period (ca 11,000 BP) hunter/gatherer decision-making that contributed to the archaeological patterning seen today in the Great Lakes region. Specifically, the model will be used in Chapter Six to simulate the early hunter/gatherer behaviors related to resource use and settlement. Since the model is based on the hypothesized objectives of the hunter/gatherers under study, a match between expected patterns and activity areas within the archaeological record suggests these goals did indeed play a role and help explain the decisions hunter/gatherers made. The IDRISI 32

GIS software environment (Eastman et al. 1995, 1999) will be the primary vehicle through which the model is implemented for the early Paleo-Indian period. IDRISI 32 has a unique set of decision support tools which are designed to accommodate the human decision making process.

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A PREDICTIVE MODEL OF PALEO-INDIAN SUBSISTENCE AND SETTLEMENT

VOLUME II

By

Frank J. Krist Jr.

A DISSERTATION

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Chapter VI

IMPLEMENTING THE MODEL WITHIN A GIS: SIMULATING PALEO-INDIAN BEHAVIORS

6.1 HYPOTHESIZED PALEO-INDIAN ADAPTIVE STRATEGIES

A debate over the nature of late Pleistocene hunter/gatherer subsistence strategies continues due primarily to the lack of zooarchaeological and botanical remains from Great Lakes Paleo-Indian sites. In particular, little is known about the role or importance of various plant and animal species within the Paleo-Indian subsistence system Jackson 1997, (Meltzer and Smith 1986). As a result, three competing theories have been developed regarding Paleo-Indian foraging behavior in the Great Lakes. The first two theories suggest that Paleo-Indians primarily relied on hunting rather than plant gathering (Kelly and Todd 1988). Under this so-called focal strategy (Cleland 1976), Paleo-Indians across the Great Lakes were mainly large game hunters, dependant on migratory caribou with a lesser or equal reliance on other large herbivores, such as mastodon, for subsistence (Deller and Ellis 1992, Fisher 1981, 1987, Jackson 1997, 1998, Kelly and Todd 1988, Overstreet 1998, Storck 1982, 1997). Because many authors argue that migratory caribou was the primary large game species hunted by Paleo-Indians (Cleland 1965, Deller and Ellis 1992, Jackson 1997, Simons 1997, Storck 1982) occupying the Great Lakes region, the first hypothesis will test the assumption that early hunter/gatherers were caribou hunters. In addition to caribou, the second hypothesis explores the role mastodon may have played in Paleo-Indian subsistence. Currently incontrovertible evidence of Paleo-Indian mastodon hunting is lacking from Michigan (Shott and Wright 1999). As a result, Hypothesis Two examines the potential for mastodon hunting to have occurred in southern Michigan. The third hypothesis suggests that Paleo-Indians relied on a more generalized foraging strategy, sometimes known as diffuse, (Cleland 1976) or broad spectrum, utilizing a wide range of floral and faunal species including fish, and waterfowl (Meltzer and Smith 1986, Kuehn 1998). Under this second hypothesis, Paleo-Indian groups dependent on hunting only occupied the northernmost reaches of the Great Lakes where a tundra ecosystem still existed. Throughout the closed boreal forests of the lower Great Lakes, early Paleo-Indians utilized a generalized foraging strategy.

Recent discoveries of floral and faunal remains (Cleland 1965, Jackson 1998, Storck and Spiess 1994) at early Paleo-Indian sites have aided researchers little in definitively testing hypotheses about Paleo-Indian subsistence strategies (Table 6.1). This is due, in large part to the difference in preservation rates between large mammals, small mammals, and plant remains (Meltzer and Smith 1986). Interpretations of subsistence patterns are biased toward large mammal utilization because the remnants of large animal bones are often the last to disappear from the archaeological record. The lack of small mammal and plant remains in the Great Lakes region cannot be used as direct evidence of a foraging strategy because they are often completely decomposed at Paleo-Indian sites. Therefore, based on the current archaeological data, it is premature to assume early Paleo-Indians depended little on small game, fish, or plants for subsistence (Storck 1997). Due to these preservation problems, archaeologists must pay particular attention to taphonomic processes and the techniques used to recover biological remains or build alternative models that do not depend solely on archaeological remains for their construction. This research demonstrates the latter approach by implementing the hunter/gatherer behavioral model presented in Chapter 5.

Table 6.1. Floral And Faunal Remains At Great Lakes Paleo-Indian Sites

Site	**Location**	**Species**	**Reference**
Bull Brook	Massachusetts	*Castor canadensis*(Beaver), *Rangifer* or *Odocoileus* (Deer)	Spiess et al. 1985
Dutchess Quarry Cave	New York	Fish, Large Bird	Spiess et al. 1985
Fisher	Central Ontario	Use-wear analysis suggests utilization of fish.	Tomenchuk 1997
Holcombe	Michigan	*Rangifer* (Caribou)	Cleland 1965, Spiess et al. 1984
Leavitt	Michigan	*Picea* (Spruce), *Tilia* (Basswood), *Quercus* (Oak)	Egan 1993
Shawnee-Minisink	Pennsylvania		McNett 1985, Spiess et al. 1985
Whipple	New Hampshire		Spiess et al. 1985

It is quite apparent that the data from most Paleo-Indian sites in the Great Lakes area is far too limited to definitively interpret the organizational structure of early hunter/gatherers (Shott 1993, Storck 1997). It is hoped that by testing some of the major hypothesis about Paleo-Indian subsistence strategies with the behavioral model presented in this research, that more definitive conclusions may be made about the adaptive strategy of early hunter/gatherers. Further, this simulation will result in a relative ranking of current hypotheses about Paleo-Indian adaptive strategies. In particular, the hunter/gatherer behavioral model outlined in this research is used to simulate the behaviors related to resource use and settlement for three alternate hypotheses about Great Lakes early Paleo-Indian foraging strategies:

A1:

> Paleo-Indian peoples were highly mobile "focal" foragers relying heavily on one species of large game, migrating caribou (*Rangifer tarandus*), with a minimal reliance on smaller game and plant resources (Deller and Ellis 1992, Fisher 1981, 1984, 1987, Jackson 1997, Kelly and Todd 1988, Overstreet 1998, Simons 1997, Storck 1982, Storck and Spiess 1994).

A2:

> Paleo-Indian peoples were highly mobile "focal" foragers relying heavily on two species of large game, mastodon (*Mammut americanum*) and migrating caribou, with a minimal reliance on smaller game and plant resources (Deller and Ellis 1992, Fisher 1981, 1984, 1987, Jackson 1997, Kelly and Todd 1988, Overstreet 1998, Simons 1997, Storck 1982, Storck and Spiess 1994).

A3:

> Paleo-Indian peoples were highly mobile "generalized" foragers utilizing a forest-based adaptation that included a variety of both large and small game, and plant resources (Kuehn 1998, Meltzer and Smith 1986).

The first two hypotheses are based on the assumption that early Paleo-Indians were primarily reliant on large animal hunting rather than gathering (Kelly and Todd 1988). Two alternate hypotheses were chosen for this assumption because of the current debate over the role of large herbivores within the Paleo-Indian subsistence system (Fisher 1981, 1984, 1987, Overstreet 1998, Shott and Wright 1999). Evidence of burning and cut marks on mastodon bones suggest that this species may have been utilized by humans (Fisher 1981, 1984, 1987). However utilization by Paleo-Indians in Michigan cannot be confirmed due to the lack of diagnostic artifacts in association with bones having cut marks. The third hypothesis is based on Meltzer and Smith's (1986) assumption that Paleo-Indians occupying the boreal forest were "generalized" foragers.

The behaviors for each hypothetical foraging strategy are modeled within the context of the spruce (Picea) dominated ecosystem (11,500 - 10,400 B.P.) that occupied Lower Michigan during the Gainey (ca. 10,900) and Barnes/Parkhill (ca. 10,700) phases of the early Paleo-Indian period (Ahearn and Bailey 1980, Cleland et al. 1998, Garland and Cogswell 1985, Holloway and Bryant 1985, Karrow and Warner 1990, Shott and Welch 1984, Webb et al. 1993). Although the motives that early hunter/gatherers had for choosing a strategy were likely not solely based on the environment, early hunter/gatherers were limited by what they could forage for, and therefore, the environment certainly affected the adaptive strategy utilized by Paleo-Indian peoples. The behavioral model implemented here is able to accommodate both the motives Paleo-Indian peoples may have had, and the environmental limitations they may have encountered. The next three sections discuss some of the potential motives and limitations that likely confronted early Paleo-Indian hunter/gatherers under each hypothesis.

6.1.1 HYPOTHESIS 1

The first hypothesis is built on the assumption that small groups of Paleo-Indian foragers primarily chose high yield faunal resources, regardless of the amount of energy expended while pursuing and processing such resources. The selection of a strategy centered on hunting appears to be a wise choice for small groups of hunter/gatherers colonizing unexplored regions of the Great Lakes for several reasons. First, the widespread distribution and year-round availability of faunal resources make location and procurement of such resources throughout the entire year particularly easy in unexplored regions with a low hunter-gatherer population density (Kelly and Todd 1988). Edible plant species, on the other hand, typically have a more limited seasonal and spatial distribution making them more difficult to locate and procure without a network of contacts providing knowledge of a region's resource variation. Even though, from a nutritional and efficiency standpoint, Paleo-Indian people were better off utilizing plant materials which is unlikely, in many instances they simply may not have been aware of these resources or understood how to process them for maximum nutritional value, which is more likely. Second, plant processing can be extremely difficult, depending on the species; often requiring a great deal of experience, while processing game is relatively consistent from species to species. This is of particular importance when encountering new species of plants and animals. Third, if caribou or other migratory gregarious herbivores were available, caribou hunting could often be a very successful low risk foraging strategy that ensures a small group of hunter/gatherers will not starve (Spiess 1979). Fourth, the spruce ecosystem of southeastern Michigan offered little in the way of edible plant biomass for humans. Lastly, some researchers (Guthrie 1984, Kelly and Todd 1988) suggest that the boreal forests of the late Pleistocene had a higher game density and larger individuals than that of the modern boreal forests.

With a strategy primarily focused on hunting, Paleo-Indians were at the mercy of faunal populations in a constant state of flux (Holman 1995, Kelly and Todd 1988). As animal populations were hunted down, or moved, due to variations in climate and vegetation, late Pleistocene hunter/gatherers moved frequently into new territories to cope with resource stress and changing opportunities and circumstances (Kelly and Todd 1988, Shott 1986). In addition, the postulated spruce-fir ecosystem of Southeastern Michigan had a somewhat limited resource base (Brown and Cleland 1968). According to Brown and Cleland (1968), upland till plains and regions adjacent to wetlands and lakes may have been the most productive, allowing early hunter/gatherers to exploit ecological transition zones. Unlike many modern hunter/gatherers, Paleo-Indians were unable to occupy a particular territory for a long period and relied on frequent residential and logistical moves within a large range to keep them in tune with faunal resources. In other words, under the first hypothesis, Paleo-Indians chose an adaptive strategy that required them to make short-term and redundant use of each region they occupied.

Currently, there is a wide range of evidence from the lower Great Lakes supporting the first hypothesis. Frequent range shifts and the lack of rigid territories are suggested by the absence of regional fluted point styles and the fact that the majority of early Paleo-Indian Parkhill and Gainey phase sites were not reoccupied (Kelly and Todd 1988). The fluted point styles that do occur often have unidentifiable or vague regional distributions. The fact that many early Paleo-Indian sites consist of only isolated fluted point finds indicates that early hunter/gatherers were highly mobile with a considerably low population density. The lack of formal structural remains and overlap between activity areas at early Paleo-Indian sites in addition to the "portability" of the Paleo-Indian toolkit also indicate a highly mobile lifestyle. However, early Paleo-Indian sites such as Gainey, Holcomb, and Debert with overlapping activity areas, suggest that early hunter/gatherers occasionally gathered in large groups and occupied some regions for longer periods or reoccupied the same locale on a repetitive basis (Jackson 1997). The similarity between early Paleo-Indian toolkits, in a wide variety of physiographic settings, supports the notion that Paleo-Indians utilized the landscape in a redundant fashion with a singular strategy (Kelly and Todd 1988). Although a very tentative assumption, the presence of caribou remains at several early Paleo-Indian sites suggests that early hunter/gatherers were at least partially, if not largely dependent on caribou hunting

(Simons 1994, Spiess et al. 1985, Storck and Spiess 1994). Lastly, the topographic setting of many early Paleo-Indian sites also indicates that a caribou hunting strategy was utilized.

Despite the emphasis on hunting, in particular larger game hunting, the first hypothesis does not suggest that Paleo-Indians were only large game or megafaunal specialists; rather, the suggestion is that Paleo-Indian foraging centered on caribou hunting, while to a much lesser extent utilizing other resources. In fact, plants such as chokecherries, serviceberries, thimbleberries, blueberries, and cranberries were possibly used by early Paleo-Indians throughout the Great Lakes region in addition to caribou (Kelly and Todd 1988, McNett 1985). Undoubtedly, smaller game such as muskrat, beaver, and hare were also hunted (Storck and Spiess 1994). However, this hypothesis assumes that the use of various resource patches and settlement locations was driven by the desire to hunt caribou and that other resources were often only incidentally targeted while in the pursuit of caribou.

Gainey Phase sites across the Great Lakes region are located in areas once occupied by ecosystems ranging from spruce forests to tundra, with the largest sites occurring on the former in southeast Lower Michigan (Cleland et al. 1998). For modeling purposes, it is proposed that during the spring, large herds of barren-ground caribou migrated northward from southeastern Michigan into southwestern Ontario. Most caribou probably migrated into southeastern Ontario and central Lower Michigan, rather than into northern Michigan due to the extreme easterly winds and lack of ecological stability across eastern and northern Michigan (Cleland et al. 1998, Krist and Schaetzl 2001). During their seasonal migration, modern caribou tend to follow ridges and areas of least-resistance (Calef 1995, Gronnow et al. 1983, Krist and Brown 1994, LeResche and Lindermand 1975, Miller et al. 1972, Skogland and Molmen 1979, Spiess 1979). As a result, active and abandoned beach ridges in the Great Lakes area are thought to have played a significant role in caribou migration (Deller 1979, Storck 1982, 1997, Peers 1985). During the late Pleistocene, caribou occupying Lower Michigan probably made use of forested regions during the dormant season and parkland/tundra ecosystems throughout the growing season. As a result, caribou may have migrated southward from Ontario, into the spruce forests of Lower Michigan during the fall.

The Udora site, in southwestern Ontario, which yielded caribou remains, is an example of a Gainey Phase site that was likely occupied by hunter/gatherers intercepting migrating caribou along an active shoreline during either the spring or fall migration (Storck and Spiess 1994). Many other smaller Gainey phase sites have been located across regions of southwestern Ontario that were covered with open parkland to tundra ecosystems. These sites represent small residential and logistical camps from which Paleo-Indian peoples hunted caribou during the warm season (Jackson 1998).

It is proposed that the much larger Gainey Phase sites that occur in southeastern Lower Michigan may have been utilized for intercepting caribou during the beginning of the spring migration and at the end of the fall migration (Simons 1997). In addition, if many of the migrating caribou herds converged on Lower Michigan during the fall, utilizing this region as a wintering ground or center of habitation, then the area would have been particularly suitable for winter hunting as well.

As the climate continued to warm, pines and other deciduous tree species began replacing the gradually receding spruce forests around 10,300 B.P. (Shott and Welch

1984). This probably shifted the winter range of migratory caribou northward as well. The shift in habitat may be reflected in the northward movement of site distributions during the later Parkhill Paleo-Indian phase. However, since Parkhill sites appear to predate (ca. 10,700 B.P.) this transition and the fact that many sites are located along strandlines, this northward movement may actually suggest a shift in hunting strategy toward one relying primarily on the interception of caribou along migration routes (Jackson 1997, Storck 1982, 1997). By the Parkhill phase, Paleo-Indian peoples had likely identified the best topographic settings for intercepting migratory caribou that may well have occurred along strandlines. In other words, early hunter/gatherers would have identified the most consistent areas at which to intercept caribou, similar to modern caribou crossings at which Native Americans have hunted caribou well into historic times (Balikci 1970, Binford 1978, Mowat 1952). The open spruce parkland around the Fisher site in central Ontario probably continued to be a favorable area for summer/early fall caribou hunting during the Parkhill phase (Storck 1997).

The relatively large Parkhill sites found in Lower Michigan, such as the Leavitt and Barnes sites, likely had a similar function as the earlier Gainey phase sites, such as the Gainey and the Butler sites, from which migratory or wintering herds of caribou were hunted. The fact that these Parkhill Phase sites are smaller in Lower Michigan suggests that the best hunting locations, at which larger groups of people would have been supported, were located in southeastern Ontario along the leeward side of Lake Algonquin.

6.1.2 HYPOTHESIS 2

Several Paleo-Indian sites in the Great Lakes have yielded evidence of mastodon butchery, with bones containing cut marks, burn marks (Fisher 1981, 1984, 1987) and or being in direct association with chipped stone tools (Mason 1980, Overstreet 1998) suggesting that at least some Paleo-Indian peoples hunted or scavenged mastodon. In addition to the advantages of hunting during the late Pleistocene, pointed out in the previous section, pursuing and successfully exploiting a large game animal such as a mastodon also enabled early Paleo-Indian peoples to gather in larger groups and brought a high level of prestige to those who located or successfully killed such large game (Spiess 1979).

The significant number of mastodon finds in Lower Michigan certainly justifies their consideration as potential species for Paleo-Indians to have hunted. Caribou hunting was still likely the main faunal species hunted during the winter while mastodon would have been the main species hunted throughout the growing season when mastodons frequented and often became trapped in wetlands (Fisher 1981, 1984, 1987, Holman 1995). Michigan mammoth will not be considered in this hypothesis since they primarily occupied open grasslands that would have all but vanished from the study area by the time early Paleo-Indians began to occupy Lower Michigan.

6.1.3 HYPOTHESIS 3

Since many of the stone tools left by early Paleo-Indian peoples were associated with hunting activities and the fact that most of the biological materials from Paleo-Indian sites are the remains of larger game animals, the assumption has been made that early hunter/gatherers primarily relied on a hunting subsistence strategy. This assumption is in some respects premature and misleading because the materials preserved in the archaeological record and the remains that can be recovered through screening or flotation techniques limit archaeological interpretations (Storck 1997). In addition, many of the tools utilized for hunting and game processing, such as projectile points and scrapers, were primarily made of stone; while the tools utilized in gathering, such as baskets and hides, are made of perishable plant materials that have a relatively poor rate of preservation, the archaeological record has become biased toward hunting (Meltzer and Smith 1986). Also, few tools may have been needed to collect and process the available plant materials within a boreal forest ecosystem and there were likely few observable remains left by Paleo-Indian plant collecting and processing. Thus, a perishable assemblage would result in a lack of visible archaeological remains, and thus lead to a misinterpretation of early hunter/gatherer subsistence. Paleo-Indian sites where botanical remains have been located, such as the Shawnee Minisink site in the Upper Delaware Valley and the Michaud site in Maine, indicate that Paleo-Indians occupying a boreal forest setting likely utilized a wide range of the local flora in subsistence (McNett 1985, Meltzer and Smith 1986, Spiess et al. 1998).

Under this third hypothesis, relatively large Gainey and Parkhill Phase sites, such as the Gainey and Leavitt sites, may have been located along ecological transition zones in areas that allowed access to a wide range of plant and animal resources. In addition to migratory caribou, early hunter/gatherers may have hunted moose, muskrat, hare, beaver, giant beaver, woodland caribou, and mastodon from these locations. These animal species are all commonly found in and around wetlands throughout various parts of the year. The Gainey and Leavitt sites are adjacent to wetlands, as are many other early Paleo-Indian sites in southeastern Michigan (Shott 1993, Simons 1997). Although the tool assemblages at both Gainey and Leavitt are dominated by bifaces and scrapers, the plant gathering activities that could have taken place at these sites may not have left much readily observable remains. Meltzer and Smith (1986) suggest that fluted points were often utilized as multipurpose cutting tools used in processing a wide range of resources. Small early Paleo-Indian sites are probably the remnants of logistical task groups undertaking specific activities and specific activity types may have varied significantly from site to site. In summary, rather than representing a singular subsistence strategy, the network of early Paleo-Indian sites across the Lower Great Lakes could be the remnants of a complex adaptive strategy that included hunting, fishing, and gathering (Meltzer and Smith 1986, Shott 1993, Storck 1997).

Within the Great Lakes region, some of the best evidence in support of Hypothesis Three comes from the relatively large Parkhill phase Fisher site in central Ontario (Storck 1997). A detailed use-wear analysis of stone tools at the site indicates that a wide range of foraging activities took place there including the exploitation of fish and immature, or small, mammals. The use-wear analysis also suggests bone, antler, and wood were possibly worked for the construction of tools "...such as harpoons, traps, and or weirs." The Fisher site would have been located along a coastal wetland embayment during Glacial Lake Algonquin and its subsequent lower phases ca. 10,500 B.P. Other Parkhill phase sites along the leeward shore of Lake Algonquin, such as Parkhill and Thedford II, may have had similar activities taking place. Due to the strong prevailing easterly winds (Krist and Schaetzl 2001) and the subsequent lack of coastal wetlands along the western shore of Lake Algonquin, Paleo-Indian groups may well have frequently utilized resources in and around the interior lakes and wetlands across southern Lower Michigan.

6.2 PALEO-INDIAN RESOURCE USE

In order to satisfy food and nonfood needs, Paleo-Indian peoples had to devise an adaptive strategy based on their goals and objectives. The three hypotheses presented above briefly outline alternative adaptive strategies that may have been utilized by early Paleo-Indian groups in Lower Michigan. Each strategy addresses both resource acquisition and settlement issues, the latter to be discussed in the next section.

Behaviors related to early Paleo-Indian resource use across southeastern Michigan were simulated for each hypothesis using the hunter/gatherer behavior model outlined in Chapter 5. Model One will simulate early Paleo-Indian behaviors in the context of Hypothesis One; Model Two for Hypothesis Two, and Model Three for Hypothesis Three. Each model simulates where behaviors related to resource use or settlement would have occurred on the landscape. These cartographic simulations are based on each of the strategies presented in the hypothesis above, and the spatial arrangement of resource patches.

The behavioral model used to simulate each hypothesis assumes that human behaviors are the result of a series of decisions or choices directed toward attaining a set of goals. This assumption requires that the objectives of early Paleo-Indians be identified for each hypothesis prior to implementing the models. Jochim (1976, 1998) has identified several objectives that commonly guide hunter/gatherer choices about resource use, many of which may have guided early Paleo-Indian decision-making:

a) Attainment of a minimum amount of food and manufacturing materials
b) Population aggregation
c) Efficiency in the form of energy and time minimization
d) Risk minimization
e) Attainment of good tasting foods
f) Attainment of a variety of foods
g) Attainment of resources that carry prestige
h) Maintaining differentiation of sex roles

Despite the fact that these goals are commonly found among hunter/gatherers throughout the world, the overall effect each goal has on the decision-making process can vary greatly between cultures and ecosystems (Jochim 1998). In some cases, these goals may not apply to the group of hunter/gatherers under study. In particular, Jochim (1976) pointed out that the desire for good taste, variety, prestige, and the maintenance of sex roles are secondary goals. Secondary goals may often be ignored to satisfy other more important objectives such as the attainment of a minimum amount of food and manufacturing materials for survival, which is thought to be the case for the Paleo-Indian period (Kelly and Todd 1988). Because the desires and goals of Paleo-Indian hunter/gatherers would have been different, particularly between Hypothesis Three and the first two, the objective ratings will vary in each model. The IDRISI GIS software was used to simulate resource use areas for each of the three models presented in this section (Eastman 1999). Appendix D contains both a sample AML and IDRISI Macro Language (IML) program used to simulate resource use areas because ARC/INFO was used to process some of the data prior to its manipulation within IDRISI.

Water was not considered a criterion for the Paleo-Indian resource use models presented in this research. The limited distribution and everyday necessity of water for the human body can significantly affect hunter/gatherer behavior (Kelly 1995). Therefore, the adjacency of resource patches and favorable areas for settlement to sources of water will be considered in the Paleo-Indian settlement model outlined in the latter part of this chapter.

6.2.1 MODEL ONE

The first model, constructed within the context of Hypothesis One, simulated early Paleo-Indian behaviors related to resource use. The objectives, decision rules, and criteria utilized for this model, and the manner in which these information were combined, is outlined in detail below.

6.2.1.1 OBJECTIVES

The first model of Paleo-Indian resource use is constructed around the hypothesis that early hunter/gatherers primarily depended on caribou for their food and nonfood needs (Deller and Ellis 1992, Fisher 1981, 1984, 1987, Jackson 1997, Kelly and Todd 1988, Overstreet 1998, Simons 1997, Storck and Spiess 1994). Under this hypothesis, Paleo-Indian peoples utilized a highly mobile foraging strategy with little concern for energy minimization (Kelly and Todd 1988). Typically, group size consisted of ten to twelve individuals within a single-family unit with infrequent gatherings of no more than fifty to sixty individuals (Jackson 1997).

Keeping these assumptions in mind, efficiency in the form of energy and time minimization played little or no role in resource use and scheduling at residential and logistic sites. However, considerations of how well resources satisfy the minimum necessary sustenance requirement of a group of early Paleo-Indian hunter/gatherers was likely the most important. In other words, Paleo-Indian foragers probably considered the potential yield of resources and likelihood of locating and acquiring a resource prior to making resource use decisions.

Jochim (1998) suggests that risk minimization was a major factor guiding hunter/gatherer decisions. The easiest way for early Paleo-Indians to minimize risk was to utilize resources that were stable and or provided the best short-term reliability. During the Paleo-Indian period, a hunting strategy focused on large migratory herds of caribou was one of the most reliable means of foraging within parts of the Great Lakes because caribou behavior is so predictable (Burch 1972). Therefore, relying on a large game species, such as caribou, minimized the risk of starvation within the relatively unexplored late Pleistocene ecosystem of the Great Lakes region (Kelly and Todd 1988). In addition, with such a low population, there may have been little opportunity for exchange, information sharing, or other strategies that aided hunter/gatherers utilizing unsuccessful subsistence strategies. However, the presence of lithic materials from Southern Ohio at the Gainey and other early Paleo-Indians sites within Lower Michigan suggests some form of exchange and communication was taking place between groups (Simons 1997). The extent of this interaction is unknown. The apparent lack of food storage by early Paleo-Indians suggests that early hunter/gatherers had little to fall back on if a subsistence strategy began to fail (Kelly and Todd 1988). Within Hypothesis One,

risk minimization is the primary force guiding early hunter/gatherer decision-making regarding resource use. Therefore, the desire to select reliable, low risk resources are considered to have had a significant affect on both residential and logistical resource use and was rated accordingly (Appendix B: Tables B.1 - B.2). The attainment of a minimum amount of food and manufacturing materials sufficient to satisfy needs are of equal importance to risk minimization. Hunting large game, in most instances, ensured that resource requirements were met. As a general rule, larger species more likely fulfill resource needs (Jochim 1976, Spiess 1979, 1998). In summary, the key to Paleo-Indian survival under Hypothesis One was the reliance of early hunter/gathers on reliable resources that contained the potential to meet the resource needs of the group.

Early Paleo-Indian groups occasionally gathered into larger groups, indicating that population aggregation probably played a small role in information dissemination and decision-making at residential sites on a periodic basis. However, larger sites, such as Gainey or Parkhill, may represent gatherings of larger groups of people as part of a hunting strategy rather than from a desire to aggregate or socialize. These sites may also be the result of repeated reoccupations by small groups. The potential for this type of repeated activity will be examined with the logistical settlement model presented at the end of this chapter. An aggregation strategy may have worked best for hunting large herds of migratory caribou. Therefore, the goal of population aggregation will receive a low rating, while energy and time minimization is not considered an objective (Appendix B: Table B.1). Population aggregation was not considered an objective used in defining logistical resource use areas because logistical forays were undertaken by small groups of hunter/gatherers often targeting a single resource (Appendix B: Table B.2) (Binford 1980).

The desire for "good" taste, variety, and differentiation of sex roles will not be considered within this first model. Variety and taste were satisfied indirectly by consuming a variety of animal parts and internal organs including the liver, brain, heart, kidney, pancreas, cartilage, unhardened antlers, nasal musculature, and partially digested stomach contents of the caribou (Spiess 1979). Although age and sex role differentiation may affect hunter/gatherer decision making, quantifying these values is difficult and will not be considered here.

Although the attainment of prestige through hunting dangerous or highly prized game can play a significant role in decision making, particularly during seasons when game animals contain a greater fat content, weight, and nonfood yield (Spiess 1979), it will not be considered here. The predictability and relatively small size of caribou, in comparison to mastodon and moose, probably would have given it a low prestige value (Spiess 1979). Prestige hunting placed greater weight on the capture of larger, less predictable or more dangerous game animals, such as mastodon and moose. The assumption that a group primarily hunted caribou suggests that prestige was rarely, if ever, considered. The first hypothesis assumes that mastodon and moose were harvested only as a supplement and were not considered for their prestige value.

6.2.1.2 DECISION RULE

As decision theory points out, the decision rule, or strategy, a group selects to meet their needs is constructed in the context of their goals or objectives (Eastman 1999).

Therefore, under Hypothesis One, the desire to minimize the risk of starvation, through the attainment of resources that provide at least the minimum amount of food and manufacturing materials needed for survival, led early Paleo-Indian hunter/gatherers to the decision that a highly mobile hunting strategy centered around migratory caribou was the best way to meet their resource needs. With this strategy in mind, the criteria for this model were selected, ranked, and combined.

6.2.1.3 CRITERIA

The highly mobile nature and frequent range shifts that were part of the early Paleo-Indian subsistence strategy constrained the number of material possessions that early hunter/gatherers carried. This strategy apparently curtailed the usage of significant standing structures that required significant amounts of bone or wood to construct. Protection from the elements was obtained primarily from the surrounding topography, the clothes worn by an individual, and the potential use of impermanent shelters. The clothing made from caribou skin utilized by the Netsilik and other arctic hunters enables a person to survive very cold weather with little or no shelter for extended periods (Balikci 1970, Mowat 1952). Due to the limited use of non-food items and the fact that wood, for use in fires and possibly to make small shelters, would have been readily available throughout southeastern Michigan, non-food resources will not be considered as criteria for this model. Since the primary source materials in the region, including Bayport chert, of most Paleo-Indian artifacts are located outside the study area, lithic materials will not be considered as criteria for this model (Simons 1997, Voss 1977, Shott 1993).

The spatial distributions of faunal species during the late Pleistocene, presented in Chapter Four, were the main criteria Paleo-Indians considered when choosing resource patches under Hypothesis One. Only the late fall through early spring habitat suitability models constructed in chapter four will be used in this model. According to Hypothesis One, Paleo-Indians primary occupied southeastern Michigan during the dormant season, when migratory caribou were present in their highest numbers. During the growing season hunter/gatherers would have moved into Ontario following migratory herds of caribou (Jackson 1997, 1998). Therefore, floral species will not be considered as criteria because this model focuses on the dormant season and the assumption that Paleo-Indian peoples targeted faunal species (Kelly and Todd 1988).

The potential for resource use at both residential and logistical sites will be evaluated within Model One. Despite the focus on caribou hunting, resource use at residential sites likely included other species as well (Spiess and Storck 1994). To accommodate this assumption, the habitat suitability for caribou, including their migration routes and winter foraging areas, moose, mastodon, muskrat, beaver/giant beaver, and hare are all considered criteria for residential resource use. Therefore, Model One will evaluate how these resources work together to satisfy Paleo-Indian resource use objectives at residential sites. At logistical sites, resource use focused on a single or limited range of resources. As a result, each suitability map was individually ranked based on its ability to satisfy each objective.

For each objective related to residential resource use, each species was assigned a rating within a comparison matrix (Appendix B: Tables B.3 – B.5). Faunal species were given ratings for the first objective, attainment of a minimum amount of food and manufacturing materials, based on their potential yield and or size. Prey size is generally correlated with procurement yield and efficiency when species do not aggregate and the technology used to take advantage of aggregations, such as nets and surrounds, does not exist (Jochim 1998). The prey species examined in this research are general solitary with the exception of migratory caribou that would have been found in large herds throughout the late fall, winter, and early spring in the study area. Despite a lack of direct evidence such as surrounds, stone structures, fences or other means of diverting caribou into natural traps archaeological evidence from the American Southwest (Frison 1973) suggests that early Paleo-Indians were able to take advantage of the herding nature of some species. Based on the assumption that early hunters were able to take advantage of the herding nature of migratory caribou, they are given a higher rating than moose and mastodon despite their smaller size. In addition, Hypothesis One suggests that caribou was the preferred species hunted by early Paleo-Indians indicating that this species was considered the most important resource for fulfilling the first objective, attainment of a minimum amount of food and manufacturing materials (Appendix B: Table B.3). Mastodon was given a moderately less important rating of 1/3, while moose was assigned a strongly less important rating for the first objective. Muskrat and hare were given an extremely less important rating because of their small size. Due to the fairly large size of the giant beaver, about the size of a half-grown bear (Holman 1975), and the high food and non food yield of the modern beaver during the dormant season (Winterhalder 1981b), beaver were given a moderately more important rating than other small game species. Caribou and mastodon were considered strongly more important than moose for population aggregation because of their seasonal abundance and large size respectively

(Appendix B: Table B.4). Beaver was given a strongly less important rating because of their higher fat content and nonfood yield and larger size than muskrat and hare. Muskrat and hare received very strongly and extremely less important ratings respectively.

Migratory caribou are considered a fairly predictable and stable resource that is easy to obtain (Burch 1972) suggesting that a foraging strategy centered on caribou enabled early hunter/gatherers to minimize the risk of starvation. Based on these assumptions, caribou was given the highest rating for satisfying the final objective, risk minimization (Appendix B: Table B.5). Both moose and mastodon had lower population, were more difficult to hunt, and these species are considered less reliable than migratory caribou. In particular, moose can be very difficult to track (Nelson 1973) while hunting a very large game animal such as a mastodon presented a risk of physical injury to the hunter (Spiess 1979). Therefore, these two species were given a strongly less important rating for risk minimization. Due to their small size and frequent fluctuations in population levels, hare and muskrat are much more risky species to depend on for food and or hides (Allen et al. 1984, Janet 1995, Nelson 1973, Snyder 1993). As a result, hare and muskrat received an extremely less important rating for risk minimization. Beaver was assigned a moderately more important rating than hare and muskrat because beaver populations are often fairly stable. Criteria weights were calculated from the ratings within the IDRISI WEIGHT module.

Each species was assigned a percent rank based on the ability to satisfy each objective related to resource use at logistical sites. To keep the individual resource rankings consistent with the ratings generated for the comparison matrix (Appendix B: Tables B.3, B.5), a conversion table was developed (Appendix B: Table B.6). This table provides a means of translating from the 9-point continuous scale to a set of percent ranks, insuring that the ranks are consistent with the assessment of each resources importance to an objective. Appendix B, Tables B.7 and B.8, list the percent ranks by objective for caribou, mastodon, moose, muskrat, beaver, and hare. The suitability values calculated for each species within chapter four were modified by their percent rank using the MULTIPLY option within the SCALAR module in IDRISI.

6.2.1.4 EVALUATION

Using the criteria weights and rankings generated in the previous section, the factors for each objective were combined for residential resource use utilizing a weighted linear combination multi-criterion evaluation (Figure 6.1). Each weighted overlay was performed within the IDIRISI MCE module utilizing the output weight file produced from the comparison matrices shown in Appendix B, Tables B.3 – B.5. The weights for each objective's criteria were generated within the WEIGHT module and are presented in Appendix B, Tables B.9 – B.11. This first series of weighted overlays produced a suitability map for each objective, depicting regions with the greatest potential for satisfying each objective. The MCE evaluation was calculated twice using two sets of order weights (Appendix B: Tables B.12 – B.13). With the first set of order weights, a low risk resource use simulation is produced for each objective while the second set produces a high-risk simulation. The high and low risk suitability maps were subsequently combined within another weighted overlay using the weights produced from the comparison matrix generated for the objectives (Appendix B: Table B.14). Each of the final outputs depicts the suitability of regions for early Paleo-Indian residential

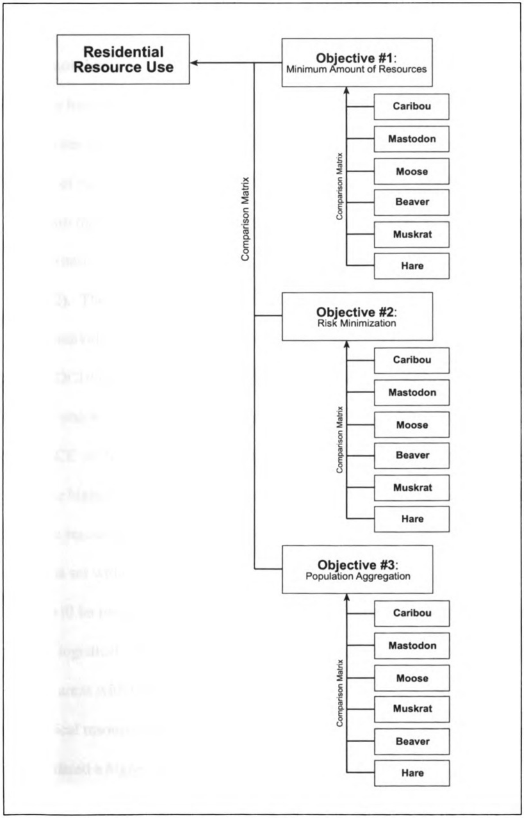

Figure 6.1. Method Of Combining Criteria
To Locate Residential Resource Patches For Model 1

resource use activities based on the ability of resources to satisfy the objectives outlined in Hypothesis One. In other words, areas with the highest suitability values would have been the most likely to satisfy Paleo-Indian resource use objectives. Regions with lower values may have only satisfied some or part of the objectives outlined in Hypothesis One. Suitable areas under the high-risk scenario were less likely to consistently meet the objectives of early hunter/gatherers while low risk regions were much more reliable.

With the weights generated for each objective (Appendix B: Table B.15), the adjusted criteria for logistical resource use were combined within a weighted overlay (Figure 6.2). The weighted overlays produced a series of suitability maps depicting the ability of individual resources to meet the resource use objectives of Paleo-Indians. The IDRISI MDCHOICE module was called upon to produce a summary map depicting the regions in which logistical activities were most likely to have taken place. The MDCHOICE command performs a multi-dimensional choice procedure that was used to identify the highest suitability value occurring at each cell. In other words, MDCHOICE records the resource type with the highest suitability at any one location. A suitability threshold is set within MDCHOICE that represents the minimum value needed before any resource will be recorded for a location. To account for risk taking by Paleo-Indian groups on logistical forays the threshold suitability was set to four and seven respectively to capture areas with both medium and high suitability values for logistical resource use. The logistical resource use map, which included areas with a medium suitability value, was considered a higher risk solution than the suitability map that included only the highest values. These maps will be used to determine where hunter/gatherers focused their efforts during logistical forays. According to Hypothesis One, logistical forays

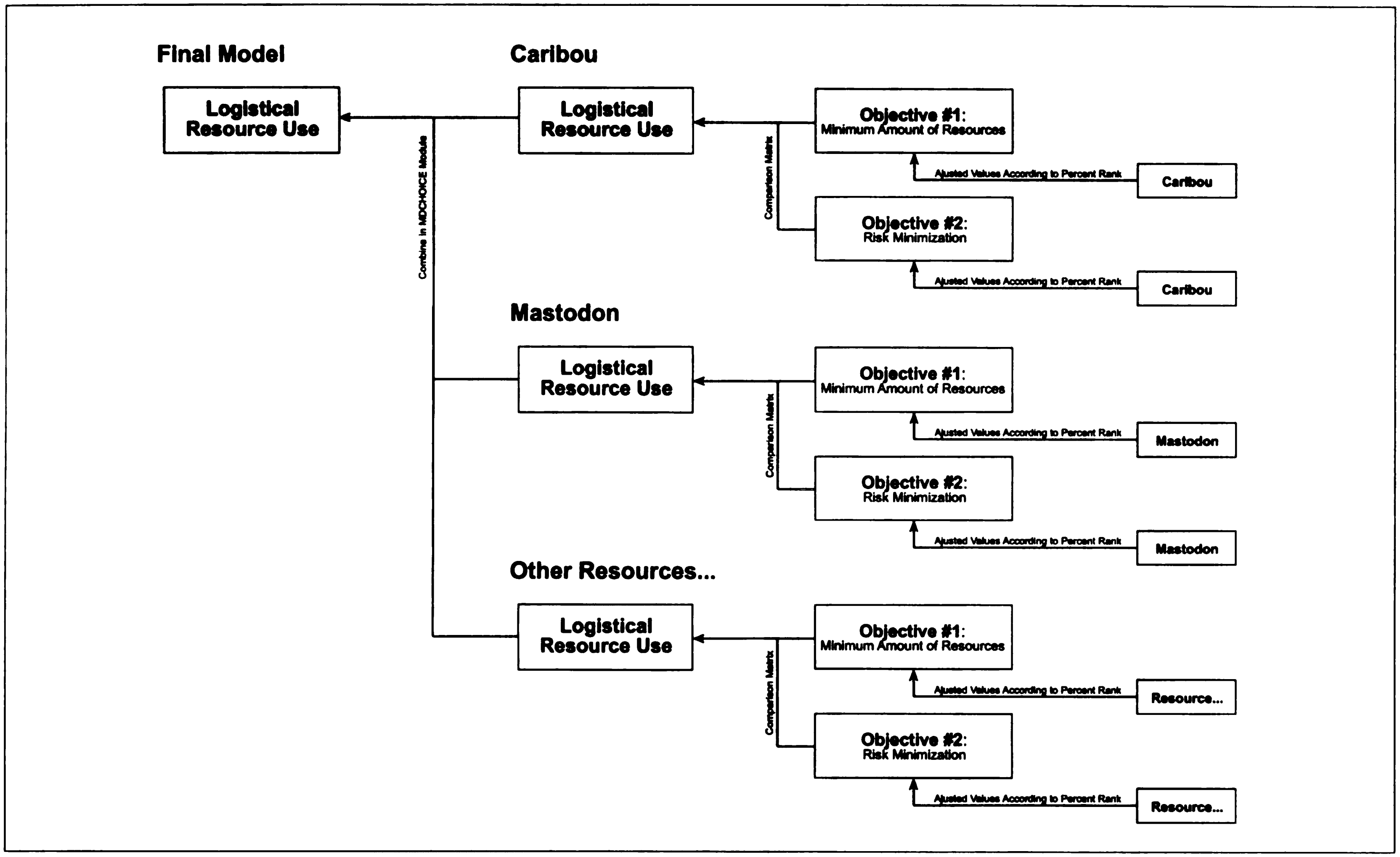

Figure 6.2. Method Of Combining Criteria
To Locate Logistical Resource Patches For Model 1

focused primarily on caribou hunting. Such inferences will be examined in detail within Chapter Seven.

6.2.2 MODEL TWO

Simulations of Paleo-Indian resource use for Model Two were performed for both the dormant and growing seasons. The simulation of winter resource use constructed for Model One was used to represent the dormant season for Model Two as well. Therefore, a dormant season model was not recalculated for Model Two. As a result, only the methods for the growing season simulation of Model Two are presented within this section. This second model, constructed within the context of Hypothesis Two, is very similar to the first, with mastodon being the primary faunal resource utilized by early hunter/gatherers during the late spring and summer. Model Two uses the same criteria and objectives as Model One with the addition of the attainment of prestige as a goal of early hunter/gatherers when choosing resources for the growing season.

6.2.2.1 OBJECTIVES

The second model of Paleo-Indian resource use was developed on the assumption that early hunter/gatherers throughout southeastern Michigan were highly mobile foragers pursuing caribou during the late fall, winter, and early spring, and mastodon during the late spring, summer, and early fall (Deller and Ellis 1992, Fisher 1981, 1984, 1987, Jackson 1997, Kelly and Todd 1988, Overstreet 1998, Simons 1997, Storck and Spiess 1994). Therefore, the same objectives and ratings outlined for Model One are utilized in the second model with the addition of the attainment of prestige as an objective for selecting logistical and residential resources areas during the growing season, and a lowering of the importance of risk when choosing both residential and logistical resource use sites (Appendix B: Tables B.16 – B.17). The reasons for these changes are due to the emphasis of Paleo-Indian foraging on mastodon. Hunting mastodon with thrusting spears at very close range was undoubtedly a dangerous pursuit putting a hunter's health at risk because of its very large size; nearly ten feet tall (Holman 1995). The fact that many potential Paleo-Indian kill sites are often located in wetland areas, where animals are likely stranded or scavenged, suggests Paleo-Indians at least considered the risks involved in hunting mastodon although this may also be a taphonomic phenomenon. As the body weight, fat content, and non-food yield of a species increases so does the prestige value (Jochim 1976, Spiess 1979). Therefore, a group placing primacy on mastodon hunting likely valued the attainment of prestige. An attainment of a minimum amount of food and manufacturing materials received the highest rating (Kelly and Todd 1988) because early hunter/gatherer's concerns still focused on survival. Hypothesis Two is also constructed under the premise that population aggregation played a minimal role in residential resource use decisions.

6.2.2.2 DECISION RULE

Like Hypothesis One, Hypothesis Two suggests early Paleo-Indians relied on terrestrial fauna and utilized resource patches in a short-term and redundant fashion (Kelly and Todd 1988). Unlike Model One, however, Model Two assumes that early Paleo-Indians occupied southeastern Michigan throughout year with their resource use activities centered on migratory caribou during the dormant season and mastodon the remainder of the year. Within the context of this forager strategy, criteria were selected and ranked for Model Two. The criteria discussed in the next section are related to only growing season resource use because the output from Model One represents dormant season resource use under Hypothesis Two.

6.2.2.3 CRITERIA

The habitat potential for mastodon, moose, muskrat, beaver/giant beaver, and hare were all considered criteria for Model Two. Based on the discussion within Section 6.2.1.3, wood and lithic resources were not considered in this model. Suitable areas for caribou habitat and migration were also not regarded as criteria for Model Two based on the assumption that throughout the growing season, migratory caribou resided in northern Lower Michigan or central Ontario where open parkland and tundra ecosystems persisted. Woodland caribou were widely dispersed (Russell 1998) within the spruce ecosystem occupying Lower Michigan making it difficult for early hunter/gatherers to specifically target the species.

The potential for resource use at residential and logistical sites is again evaluated within Model Two. In addition to mastodon, residential resource use is assumed to have potentially included moose, muskrat, beaver, and hare. To a much lesser extent, plant resources could have been utilized. However, because early hunter/gatherers were primarily dependant on fauna (Kelly and Todd 1988), it is assumed that plant resources were rarely targeted at residential and logistical activity areas. Therefore, floral species will not be considered criteria within Model Two.

Each faunal species was assigned a rating within a comparison matrix based on its ability to satisfy an objective related to resource use at residential activity areas. A comparison matrix was developed for each objective's criteria (Appendix B: Tables B.18 – B.21). Because mastodon would have been the preferred species for Paleo-Indian subsistence under Hypothesis Two and likely had the highest return rate of all warm season fauna it was given the highest rating for fulfilling the first objective; attainment of a minimum amount of food and manufacturing materials (Appendix B: Table B.18). Based on their large size, mastodon also satisfied the needs of a small group for an extended period. Moose, another large game species available during the growing season with a high return rate particularly during the spring and late summer (Winterhalder 1981b), was given a moderately less important rating of 1/3 for the first objective. Hare was assigned a very strongly less important rating of 1/7, while muskrat was given an extremely less important rating due to its potentially lower yield during the growing season. Beaver was given a very strongly less important rating because beaver also has a lower yield, smaller body size and thinner fur, during the growing season; it was given a very strongly less important rating. For population aggregation, the largest faunal species were considered the most important with muskrat and hare receiving an extremely less important rating (Appendix B: Table B.19).

Archaeological evidence from the southwestern United States indicates that hunting a very large herbivore, such as mastodon, required the combined effort of more than one person (Holman 1995). Due to the size, mastodon may have been able to frequently escape or injure hunters, making their pursuit both risky and dangerous. Therefore, mastodon received a somewhat unsuitable risk rating of 1/5 (Appendix B:

Table B.20). However, because under Hypothesis Two Paleo-Indians chose to focus on mastodon hunting, they would have considered risk a relatively unimportant objective related to resource use. For this reason, risk as an objective receives a low rating (Appendix B: Tables B.16 – B.17). Since acquiring moose was often a complex process, requiring a variety of hunting techniques (Nelson 1973), it was also assigned a strongly less important risk rating. Due to moderate stability (Winterhalder 1981b) and smaller size, the beaver was assigned a rating of 1/7 while muskrat and hare, were considered the least reliable resources, due to frequent population fluctuations and their small size (Nelson 1973). The weight, fat content, and non-food yield, large bones and tusks that could be used for making tools, of the mastodon made it a very attractive species from which to obtain prestige. The potential danger in hunting large game such as a mastodon undoubtedly added to the prestige value (Appendix B: Table B.21). Although a bull moose can be a very large animal with a formidable temperament, particularly during the rutting season, they are rarely aggressive toward humans (Nelson 1973). This fact, in addition to the somewhat smaller size of the moose, resulted in moose receiving a moderately less important rating for prestige. Muskrat, beaver, and hare were all considered extremely less important for prestige.

Each criterion was also given a percent rank based on the ability to satisfy objectives related to logistical resource use. The conversion table (Appendix B: Table B.6) presented for Model One was to produce percent rankings comparable to the criteria ratings (Appendix B: Tables B.22 – B.24). Since population aggregation was not considered an objective for logistical resource use, rankings were not generated for this objective.

6.2.2.4 EVALUATION

The criteria weights for each objective related to residential resource use, produced using the IDRISI WEIGHT module, were used to adjust the criteria values prior to the weighted overlay the MCE module performs. Order weights were included to simulate high and low risk resource use areas (Appendix B: Tables B.12 – B.13). The weights used for each objective's criteria are presented in Appendix B, Tables B.25 – B.28. Once the weighted overlays were complete, producing a residential resource use suitability map for each objective, these maps were combined within a final weighted overlay using the weights calculated for each objective (Appendix B: Table B.29). To simulate potential logistical resource use for individual species, criteria values were first adjusted according to their percent rankings for every objective (Appendix B: Tables B.22 – B.24). Adjusted values for each species were combined within the MCE module using the weights generated for every objective (Appendix B: Table B.30). This produced a logistical resource use potential map for each resource. The MDCHOICE module was next used to produce two summary maps representing both high and low risk logistical resource use scenarios.

6.2.3 MODEL THREE

The third and final model of resource use, based on Hypothesis Three, is constructed around the premise that early Paleo-Indian peoples depended on a wide range of resources including plants, large and small mammals, and fish (Meltzer and Smith 1986, Storck and Spiess 1994, Kuehn 1998). In many respects, the Paleo-Indian resource use strategy may have been similar to that of the Cree, occupying the boreal forest of northern Ontario (Winterhalder 1981b). Throughout the seasonal round as various resources became available, early Paleo-Indian foragers likely altered their resource use strategy. Therefore, both a growing season and dormant season resource use model were constructed for Hypothesis Two. Thus, Model Three examines which season or seasons early Paleo-Indian foragers most likely occupied Southeastern Michigan.

6.2.3.1 OBJECTIVES

The third model of Paleo-Indian resource use was developed not only under the assumption that early hunter/gatherers depended on a broad spectrum of resources, but also that they addressed a wider range of resource use goals. Hypothesis Three suggests that rather than focusing solely on basic survival needs, early Paleo-Indians had concerns about obtaining both a variety of and "good" tasting food resources as Jochim (1979) and others have suggested is common among modern hunter/gatherers (Egan 1993). Both taste and variety are often a major concern of hunter/gatherers throughout the world. Arctic and sub-arctic hunter/gatherer societies, where individuals focused on caribou hunting, appear to have little concern for taste and dietary variety; peoples consume a variety of animal organs including partially digested stomach contents that of consists of vegetable matter (Spiess 1979). It seems that even hunter/gatherer groups with a narrow resource base have found ways to satisfy their desires for taste and dietary variety. As illustrated in Model Two, prestige and a desire for human aggregation probably also played a role in early Paleo-Indian decision-making, particularly when pursuing larger game, such as moose and mastodon (Jochim 1976, Spiess 1979).

Despite the importance of dietary variety, taste, population aggregation, and the attainment of prestige in resource use decisions, the overarching desire for individual and group survival was still the most important (Jochim 1976). To prevent resource stress, which may have been frequent among early Paleo-Indian societies (Kelly and Todd 1988), the primary goal of early hunter/gatherers may have been the desire to minimize subsistence risks by focusing on reliable resources while ensuring the band had a secure level of food and manufacturing materials. The desire to reduce resource search, handling, and processing costs and minimizing energy expenditures when foraging is also considered a very important goal among modern and prehistoric hunter/gatherers (Egan 1993, Jochim 1976, 1998, Kelly 1995). Therefore, early hunter/gatherers likely considered the efficiency or the ease with which a resource could be obtained and processed prior to pursuing that resource. The frequent utilization of large game and possibly fish (Storck 1997), which are often a highly efficient species to procure (Winterhalder 1981b, Jochim 1998), suggests that early Paleo-Indians had at least some concern for efficiency. As a result, the attainment of a minimum amount of resources, risk minimization, and efficiency were the highest rated residential and logistical resource use objectives for Model Three (Appendix B: Tables B.31 – B.32). All other objectives were given moderately less important ratings. The desire to maintain differentiation of sex roles will not be considered in this model. Population aggregation and dietary variety were not considered objectives for logistical resource use because logistical forays are undertaken by small task groups usually targeting individual resourses (Binford 1980).

6.2.3.2 DECISION RULE

Despite the dependence on a broad spectrum of resources, Model Three assumes that early Paleo-Indians were highly mobile because most resources within the boreal forest are of fairly low density and often scattered in either small or solitary groups (Winterhalder 1981b). A resource use strategy that enabled hunter/gatherers to access a wide range of species was a likely choice because resources are often widely dispersed within a boreal forest ecosystem, depending on the season. The heterogeneous nature of the boreal forest environment favored a forager strategy in which a small group of hunter/gatherers move from one resource use area to another. In addition, utilizing a heterogeneous resource base acts as a risk-reducing strategy (Jochim 1979). Focusing on any single resource for extended periods could have seriously hindered a forager's ability to survive within the boreal forest, where individual resources are often dispersed.

6.2.3.3 CRITERIA

Criteria for Model Three were rated within a comparison matrix (Appendix B: Tables B.33 – B.46) based on their ability to satisfy objectives related to residential resource for the growing (spring, summer, early fall) and dormant (late fall, winter, early spring) seasons during the early Paleo-Indian period. Percent rankings were also generated for individual criteria based on their ability to satisfy objectives associated with logistical resource use (Appendix B: Tables B.47 –B.54). Criteria included the habitat models of moose, mastodon, muskrat, beaver/giant beaver, caribou, hare, chokecherry/serviceberry, thimbleberry, cranberry, and blueberry. Plant materials were considered criteria only for the growing season, while caribou was not included within the growing season model. Similar to Models One and Two, wood and lithic resources were not regarded as criteria in this model.

Based on the assumption that early Paleo-Indians under Hypothesis Three utilized a generalized foraging strategy, no one species was given the highest rating for the first objective, attainment of a minimum amount of food and manufacturing materials. For the growing season, mastodon and moose were assigned the highest rating, while small game species were given a strongly less important rating of 1/5 for the first objective (Appendix B: Table B.33). Caribou, mastodon, and moose were given the highest rating for the dormant season with small game animals receiving a moderately less important rating (Appendix B: Table B.34). Small game was given a higher rating during the dormant season due to their thicker fur and a higher fat content (Nelson 1973, Winterhalder 1981b). Recent research (Egan 1993) indicates that plant materials, during the growing season, can often be as productive as large game animals. Many of the edible plant species within the boreal forest would have required little or no processing prior to consumption and likely were very abundant (Larsen 1980, Rook 1999). Chokecherries, serviceberries, thimbleberries, blueberries, and cranberries, were given a moderately less important rating for the first objective when compared to large game species because they are relatively easy to harvest, were probably very common, and are often found in dense patches they (Appendix B: Table B.33).

Measuring the efficiency of the resources hunter/gatherers utilized can be a complex process, requiring specific measures of prey weight, aggregation size, and mobility (Jochim 1976, 1998). In addition, return rates can vary from person to person and greatly depend on the technology being utilized by a group of foragers. Estimates of efficiency are particularly difficult to generate for prehistoric ecosystems for which archaeologists do not have direct observations and little specific information is usually known about resource characteristics. This research relies on general efficiency rankings because the models presented in this research do not seek quantitative precision but rather examine general relationships between resource distributions and Paleo-Indian activity areas. These general rankings were derived primarily from specific calculations based on Cree hunting and gathering within the boreal forests of northern Ontario (Winterhalder 1981b).

Winterhalder's (1981) work suggests that large game animals, such as moose and caribou, had very high return rates within the boreal forest ecosystem. As a result, mastodon, moose, and migratory caribou were assigned the highest rating for residential resource use efficiency during the dormant and growing seasons (Appendix B: Table B.37 – B.38). During the dormant season, when beaver are fat and their fur is its thickest, return rates for beaver can rival that of larger game. Beaver was assigned a moderately less important rating for the dormant season, while muskrat and hare were given a strongly and very strongly less important rating respectively for the dormant season. The rating for beaver was lowered to 1/7 for the growing season while muskrat and hare were lowered to 1/9. Although densities and, therefore, the biomass of small mammal species is often higher than large game animals, the additional processing and pursuit time required for smaller species lowers their efficiency value (Jochim 1976). Blueberries, cranberries, and thimbleberries were given a moderately less important rating for efficiency because they do not require preparation prior to consumption and are fairly common within the boreal forest ecosystem (Appendix B: Table B.37). Since chokecherries and serviceberries may also have been found in dense thickets, can be consumed without processing, and individual trees and shrubs are capable of producing large amounts of fruit at a single location, these species were given the highest rating for efficiency.

Both fat content and sweetness are positive components of taste (Jochim 1976, Egan 1993). In order to evaluate the ability of resources to meet the objective of taste, each resource was rated based on its fat content and or sweetness. Fat content on faunal species can vary greatly from the dormant to growing seasons. As a result, some species, such as beaver, are targeted more during certain seasons when fat content is highest (Rogers 1972, Jochim 1976, Winterhalder 1981b). During the dormant season mastodon and beaver, the latter only surpassed in fat content by bear within modern boreal forests (Rogers 1972), were given the highest rating for fat content and thus taste. For the growing season, when fat content was its lowest on most mammals, mastodon and beaver were given a strongly less important rating for taste (Appendix B: Table B.41). Moose and caribou were assigned a moderately less important rating for fat content, while muskrat was given a strongly less important rating for the dormant season (Appendix B: Table B.42). During the growing season, moose had little fat and received a very strongly less important rating with muskrat receiving an extremely less important rating for taste. Due to its low fat content, hare is often considered a starvation food by hunter/gatherers (Rogers 1972) and was designated an extremely less important rating for taste during both the dormant and growing seasons. Blueberries were regarded as the sweetest plant food (Barns and Wagner 1981) within Model Three and were given the highest rating for taste during the growing season (Appendix B: Table B.41). Thimbleberries were rated moderately less important for taste while cranberries and choke cherries/service berries were given ratings of 1/7 and 1/9 respectively.

Model Three also assumes that dietary variety is an important objective behind resource use decisions made by early hunter/gatherers (Jochim 1976). In order to simulate variety, each criterion was typically given equal weight for this objective. Rating each resource equally simply generates a suitability map depicting the potential for regions to contain multiple resources. Since mammal species provided early hunter/gatherers with a variety of organs to consume faunal species were given a higher rating than plant materials (Spiess 1979). In particular, caribou, moose, and mastodon were given the highest rating for this objective because the stomach contents of these animals were likely eaten in many instances (Appendix B: Tables B.43 – B.44). Plant species were considered strongly less important because only a single part, the fruiting body, of each plant species was consumed by early hunter/gatherers.

For Model Three, the faunal species ratings for risk minimization and population aggregation generated for Models One and Two were used for the dormant and growing season simulations respectively (Appendix B: Tables B.36, B.40). For the growing season, model plant species were rated based on the reliability and ability to support population aggregations. Since blueberry, cranberry, and thimbleberry production can vary greatly depending on weather and site conditions (Rook 1999) these species were given a relatively low rating of 1/7 for reliability (Appendix B: Table B.35). Chokecherry production on the other hand, is typically regular and viable (Rook 1999) being less affected by weather conditions. Therefore, chokecherry was given the highest rating for risk minimization. Because thimbleberries, cranberries, choke cherries, service berries, and blueberries are often found within dense thickets (Larsen 1980, Rook 1999) these species contain some potential for supporting population aggregation and were thus given a moderately less important rating than mastodon, the highest rated species (Appendix B: Table B.39). In fact, regions with favorable blueberry and thimbleberry habitat that had recently burned were exceptionally productive.

The faunal species prestige ratings generated for Models 1 and 2 were used for the dormant and growing seasons (Appendix B: Tables B.45 – B.46). Migratory caribou was assigned a strongly less important rating than mastodon for prestige because caribou are relatively small and easy to pursue (Spiess 1979). Plant resources were considered extremely less important for satisfying the desire to obtain prestige.

To account for logistical resource use areas, the criteria ratings for each objective, except population aggregation and dietary variety, were converted to percent rankings using Appendix B, Table B.6, as a conversion table. These rankings can be found in Appendix B, Tables B.47 – B.54.

6.2.3.4 EVALUATION

With the IDRISI WEIGHT module, weights for the criteria and objectives related to resource use were produced (Appendix B: Tables B.55 –B.68). The criteria weights were used to combine each objective's factors within the MCE module for both the dormant and growing seasons. The order weights in Appendix B, Tables B.12 and B.13, were included in the MCE evaluation to produce resource use maps that depict high and low risk scenarios. Each set of suitability maps was combined using the objective weights (Appendix B: Table B.69) generating a final map depicting the most suitable regions for early Paleo-Indian residential resource use within the study area. Logistical resource use potential for individual species was simulated from the criteria values that were adjusted using the percent rankings for each factor (Appendix B: Tables B.47 – B.54). The percent rankings, generated for each objective, were derived from the criteria ratings with the aid of Appendix B, Table B.6. Adjusted factor weights for individual resources were combined within the MCE module using the weights produced for every objective (Appendix B: Table B.70). MDCHOICE was used to generate maps representing both high and low risk logistical resource use scenarios. Logistical resource use was simulated for the dormant and growing seasons.

6.3 PALEO-INDIAN SETTLEMENT

Much like choices regarding resource use, decisions about the spatial arrangement of hunter/gatherer settlements are the result of decisions made to meet a set of goals (Jochim 1976). Many of the objectives Jochim outlines in his research likely guided settlement choices made by early Paleo-Indians in southeastern Michigan. The following objectives are considered in this research:

1) Proximity to resources
2) Shelter and protection from the elements
3) Dryness of the ground surface

Since each of the hypotheses presented in this chapter agree that the heterogeneous nature of the boreal forest ecosystem required early hunter/gatherers to utilize a highly mobile short-term settlement strategy, only a single model of settlement is presented in this section. Such a strategy placed primacy on the location of resources when determining settlement placement (Jochim 1976, Kelly and Todd 1988). Even though the settlement model constructed in this section is based on a single set of assumptions, the results will differ based on the resource use maps developed for each three hypothesis presented earlier in this chapter.

Both the ARC/INFO and IDRISI GIS software were used to generate the final settlement maps for this section. Sample AML and IML programs used to simulate Paleo-Indian settlement are included in Appendix D.

6.3.1 SETTLEMENT MODEL

Throughout much of the seasonal round, early Paleo-Indians remained in single-family units targeting individual resource patches (Dent 1995, Jackson 1997, 1998). The small settlements these groups occupied often had characteristics of both residential and logistical camps. These settlements, classed as Type Two by Jackson (1997), resemble logistical camps occupied by small task specific groups with a focus on individual resource patches. Because these settlements are also interpreted as having been residentially occupied by small single-family units, they may have acted as residential base camps as well (Jackson 1997, 1998). Some of these Type Two sites may have been short-term logistical camps also. The large Type One early Paleo-Indian sites, such as Gainey, may represent "true" residential base camps occupied by extended family groups and placed within either very productive resource patches or areas that provided direct access to multiple resources or such sites could simply be the result of repeated residential and logistical activities by small groups (Jackson 1997, Simons 1997). In either case, Type One sites contain multiple activity areas that often overlap, have various stages of fluted point production, and associated unifacial tool activity areas (Jackson

1997). Type One sites are rare within the early Paleo-Indian settlement strategy and could have acted as hubs from which foraging parties ventured out short distances to perform extractive activities which Binford (1980) classifies as location sites. According to Binford (1980) "A *location* is a place where extractive tasks are exclusively carried out." A kill site, which Jackson would classify as Type Three, is an example of early Paleo-Indian location. Small logistical forays were carried out from these base camps as well. These logistical camps resembled Type Two residential settlements.

The goal of this final analysis is to locate areas of potential residential base camps, Type One sites, small logistical and residential settlements, and Type Two and Type Three sites. Residential resource use is assumed to have occurred at Type One sites. A resource use strategy resembling that of logistical resource use is assumed to have been undertaken at Type Two and Type Three settlements. The final output, however, does not necessarily determine which logistical and residential settlement areas were associated with one another. Regions favorable for residential and logistical settlement may overlap.

6.3.1.1 OBJECTIVES

Whether in response to the seasonal movements of migratory caribou, the distribution of lithic materials, or the location of plant and fish resources, decisions early Paleo-Indian peoples made about settlement placement were primarily driven by the spatial arrangement of resources (Curran and Grimes 1989). In fact, Jochim (1976) found that the distribution of economic resources significantly affected the settlement placement of hunter/gatherers throughout the world. Resource availability also affects the duration and type of occupation undertaken. As illustrated earlier in this chapter, two types of resource use modeled in this research correspond to residential and logistical settlements or activity areas. A logistical resource use strategy is not restricted only to logistical settlements, however. In particular, it appears that a logistical resource use strategy, a focus on individual resource patches by small groups, was utilized by early Paleo-Indians at small Type Two residential settlements (Jackson 1998). Because of the significant role resource availability plays on settlement type, location, and duration (Jochim 1976, Murdock 1969), proximity to resources will be assigned a high rating for settlement placement (Appendix B: Tables B.71 – B.72).

The provision for shelter was also likely an important objective for early Paleo-Indians occupying the Great Lakes region, particularly during the winter months for two reasons. First, the highly mobile adaptive strategy utilized by early hunter/gatherers did not allow for the construction and transportation of significant shelters (Ellis and Deller 1990). If early Paleo-Indians had shelters, they were likely portable or temporary, much like the tents used by the Netsilik (Balikci 1970), accommodating their highly mobile foraging strategy. The lack of post molds and other features related to structures at excavated early Paleo-Indian sites tentatively supports these assumptions (Deller and Ellis 1992, Jackson 1998, Shott 1993, Storck 1997). In addition to or instead of structures, early Paleo-Indians could have utilized the natural topography, the thermal cover provided by tree species, such as white spruce, and or multi-layered clothing to help protect them from the elements. When shelter is lacking, multi-layered clothing similar to that utilized by the Netsilik, can provide significant protection from the elements in extreme cold (Baliki 1970). Second, the sedimentology of paleo-spits along the glacial

Lake Algonquin strandline within the Great Lakes region provides evidence of sustained strong east-southeasterly winds in northern Lower Michigan (Krist and Schaetzl 2001) while strong westerly winds would have buffeted Southern Michigan (Muhs and Bettis 2000). If winds were as strong during the winter, early Paleo-Indians may have chosen topographic settings that offered protection from the prevailing winds. Therefore, the desire to place residential settlements in a topographic setting to protect individuals from the elements was given an equal rating to the proximity of resources during the dormant season within Model One and Three and was not considered an objective for the growing season in Model Two and Three (Appendix B: Table B.75). Shelter was assigned a lower rating of 1/5 for dormant season logistical settlement selection because logistical settlements often represent single short-term occupations that were focused on resource extraction and not residential activities (Appendix B: Tables B.71 – B.74) (Jackson 1998).

Hunter/gatherers are concerned with the dryness of the ground when choosing settlement locations (Jochim 1976). The placement of early Paleo-Indian sites throughout the Great Lakes region suggests that early hunter/gatherers considered soil characteristics as well. Most Paleo-Indian sites, both residential and logistical, are on moderately to well-drained soils (Deller and Ellis 1992, Jackson 1998, Shott 1993, Storck 1997, Spiess et al. 1998). Much like the concern for topography, settlement site selection based on soils was probably more of a factor for residential sites because individuals resided in these areas for a longer period. Therefore, the dryness of the ground surface as an objective received a moderately less important rating than the first of objective for growing and dormant season residential site selection, while this same objective received a strongly less important rating for logistical settlement selection (Appendix B: Tables B.71 –B.74).

6.3.1.2 DECISION RULE

In the context of the hypotheses presented in this chapter, early hunter/gatherers in southeastern Michigan chose their settlement locations based primarily on the placement of resource patches. In addition, the highly mobile foraging strategy utilized by early Paleo-Indians limited the type and amount of shelter individuals used. Instead, early hunter/gatherers likely depended on clothes and the topography for shelter. Lastly, Paleo-Indians chose to avoid wet areas, often selecting well-drained uplands for their settlements. With these assumptions in mind, the criteria were derived for this model.

6.3.1.3 CRITERIA

The criteria for the first objective, the proximity to resources, were not based on the location of individual species, but rather the residential and logistical resource use suitability maps generated in the previous sections for each hypothesis. Each of these suitability maps depicts potential resource use areas in the context of different sets of objectives discussed above. The greater the ability of a patch to meet the resource needs or objectives of a group of hunter/gatherers the greater the pull a resource patch has on settlement placement (Jochim 1976). The suitability of patches for residential and logistical resource use provided a means of measuring the pull each patch has on settlement.

The high and low risk logistical resource use maps were combined for each hypothesis to produce a logistical resource use map that included both medium and high suitability values. These logistical resource use layers were then utilized to simulate the location of logistical settlements. In order to evaluate the effect of risk on settlement, regions of low and high logistical resource use risk will be evaluated in relation to archaeological site locations.

In addition to the distribution of white spruce and balsam fir, terrain slope and aspect were the criteria used to model the potential of the landscape to provide shelter for Paleo-Indian settlement. Regions adjacent to fairly steep slopes, with a descent greater than four percent, were considered the best slopes for minimizing the affects of strong winds. With prevailing winds from the west-northwest (Muhs and Bettis 2000) across southern Lower Michigan, slopes with aspects facing east-southeast, or ninety to 135 degrees, were likely preferred by Paleo-Indian peoples occupying southeastern Michigan. Slope was given a moderately more important rating than slope aspect for the second objective because wind directions likely deviated from the prevailing direction during various times of the year (Appendix B: Table B.75). During such episodes, Paleo-Indians likely chose slopes facing other directions in addition to the east-southeast facing slopes. Slope and aspect values were calculated from a USGS 30-meter resolution NED Digital Elevation Model using SURFACE command within IDRISI. To account for thermal cover potential across the landscape, the white spruce and balsam fir suitability models developed within Chapter 4 were used. If sites such as Gainey and Leavitt, located on ridge tops, were occupied during the dormant season thermal cover may have been critical.

Soil drainage, as determined from a base drainage index, was the only criterion for the final objective, dryness of the ground surface. The drainage index values, ranging from ninety-nine for open water to zero for rock, account for both the effects of soil and terrain on the dryness of the ground surface (Schaetzl 1986). The methodology used to generate drainage index values for the study area is introduced within section 4.1.1. Regions wells drained, or drier, were assigned the highest suitability ranking, while the remaining drainage index values were given descending ranks with the FUZZY command. Very poorly drained, or wetter soils, were considered unsuitable for settlement. Since this final objective contained only a single criterion, a comparison matrix was not generated.

The adjacency of suitable areas to a water source was considered a constraint for both residential and logistical settlement placement. A variety of physiographic features, including lakes, intermittent and perennial streams, and permanently flooded, intermittently exposed, semi permanently flooded, and saturated wetlands were assumed to have acted as viable sources of water for early hunter/gatherers. However, the potential portability of water enabled peoples to forage across a large tract of land for an extended period without being tethered to a water source. In addition, the availability of snow during the winter made water available throughout the entire landscape. In this case, water resources should not have been a factor unless little snow was present. As a result, each settlement model was recalculated without including adjacency to water as a constraint.

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6.3.1.4 EVALUATION

With the criteria weights produced from a comparison matrix (Appendix B: Table B.80), the factors related to the objectives shelter and protection from the elements was combined within a multi-criterion evaluation using the IDRISI MCE module (Figure 6.3). A similar series of weighted linear multi-criterion evaluations were used to combine the criteria and objectives related to resources use presented earlier in this chapter. Multi-criterion evaluations were not undertaken for the other two objectives since they are each based on only a single criterion. The suitability maps for each objective were combined within a weighted linear multi-criterion evaluation using the weights generated for residential and logistical settlement during the dormant and growing seasons (Appendix B: Tables B.76 – B.79). The residential and logistical resource use suitability maps generated for Models One, two, and three were used as suitability maps for the first objective. A weighted linear combination was calculated for residential and logistical settlement during the dormant season for Model One, during the growing season for Model Two, and for the dormant and growing season for Model Three.

6.4 SUMMARY

The spatial distribution of behaviors related to early Paleo-Indian resource use and settlement were simulated. These simulations predict where behaviors related to residential and logistical resource use, and settlement should have occurred based on the goals and objectives of early hunter/gatherers, and the characteristics of the late Pleistocene environment in Lower Michigan. A set of simulations was generated for each of the three hypotheses presented at the beginning of this chapter. Both low and high-risk

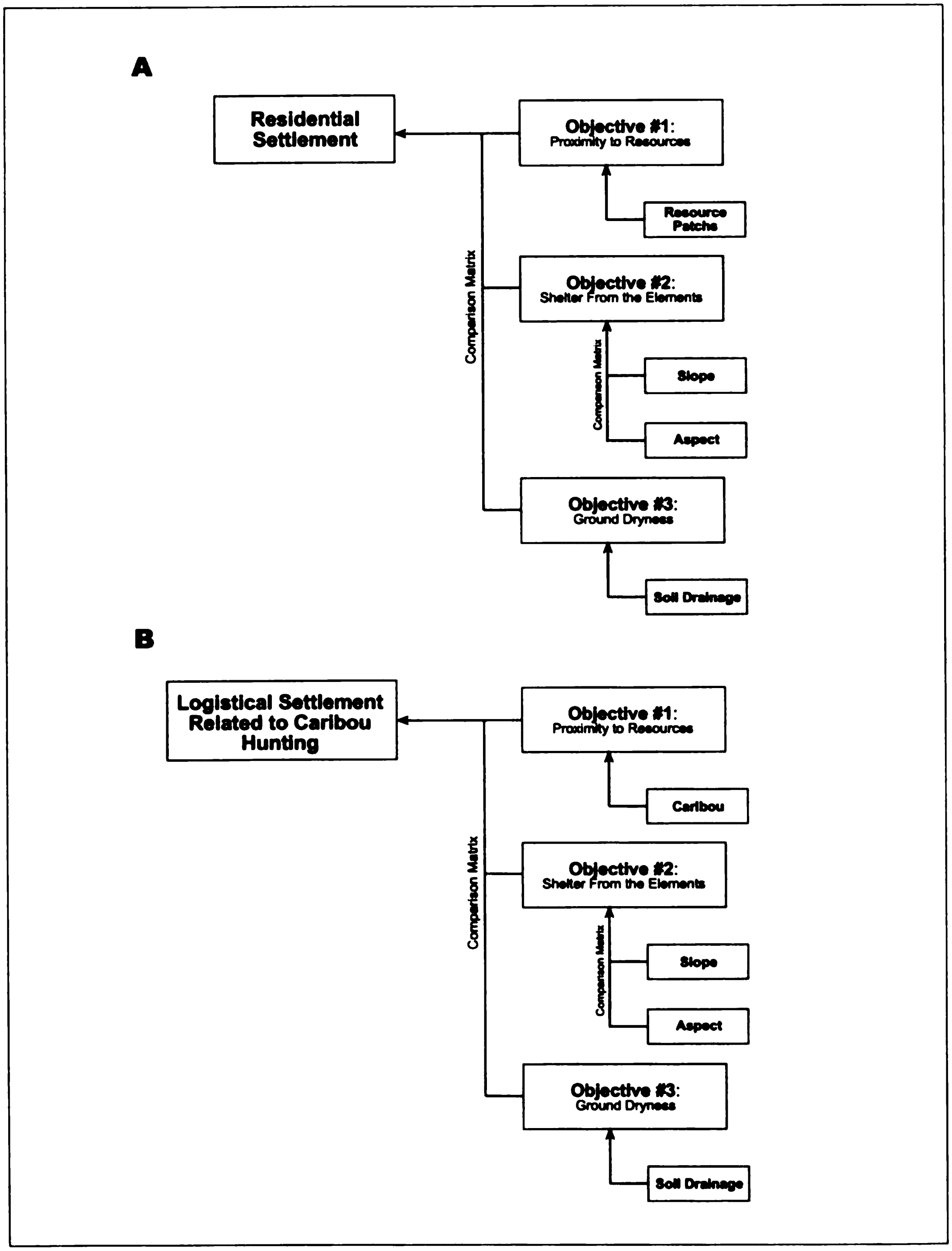

Figure 6.3. Method Of Combining Criteria To Locate Residential (A) And Logitical (B) Settlements

scenarios were calculated for every hypothesis. The simulations produced within this chapter will be compared to the distribution of early Paleo-Indian sites across Southeastern Michigan.

Chapter VII

MODEL SIMULATIONS IN COMPARISON TO THE ARCHAEOLOGICAL RECORD

The goal of this chapter is to evaluate the relationship between the archaeological data presented in Chapter 3 and the behavioral simulations generated in Chapter 6. Such a comparison will identify some of the behaviors in which hunter/gatherers engaged while occupying Lower Michigan during the late Pleistocene. The likely adaptive strategy, or strategies, utilized by early Paleo-Indians will also be pinpointed. In addition, the early Paleo-Indian settlement distribution across Southeastern Michigan will be evaluated relative to the distribution of floral and faunal species, using the simulations produced in Chapter 4, to assess how these species may have affected the early hunter/gatherer decision-making process.

To accomplish these goals, a summary of the settlement suitability map generated for each model and resource use type was produced for an area falling within a 200-meter buffer around each Paleo-Indian site. The buffer enables the results to be evaluated in and around each site. A 200-meter buffer was selected to account for errors in the placement of sites because many of the archaeological sites used in this study were mapped using a 40-acre legal description. By summarizing values using a 200-meter buffer, an overview of the landscape suitability immediately adjacent to each site was also obtained.

Summarizing the suitability values for each site's buffer requires three steps. First, buffers around each site were calculated in ArcView GIS software. Second, the size of the suitable settlement region, if any, within each buffer was calculated with the

ARC/INFO ZONALSTATS function. All areas with high (7 –10) and medium (4 – 6.9) suitability values were considered suitable for settlement. High, medium, and unsuitable are used in place of exact values when examining the results. As archaeologists and natural scientists gather additional information about the late Pleistocene environment, measures that are more precise can be generated. The mean value of the suitable areas falling within each buffer was also calculated with the ARC/INFO ZONALSTATS function. By calculating the mean, an overall measure of the suitability at each site was estimated. Third, to account for the size of each suitable region, the suitable area calculated within the ZONALSTATS function was divided by the total area of each buffer. This produced a percent value that was multiplied by the mean suitability value in the final step. The mean suitability was reduced according to the size of each area, thus eliminating the possibility that the suitable region within a buffer was not so small that it would be of little use to early peoples occupying the site. The results for each site contained a value ranging from 0 – 10, which was subsequently divided into high, medium, and unsuitable classes. For each settlement model, the values were averaged producing a single value from which the overall results for every model could be compared.

The co-occurrence of an early Paleo-Indian settlement and a region modeled as highly suitable for settlement indicates that the hypothesized strategy was a viable option for hunter/gatherers occupying that location. Although co-occurrence does not confirm that a hypothesized settlement strategy was utilized by a group of hunter/gatherers, unsuitable values do eliminate settlement strategies that were not viable.

In order to assess the effect of individual species on the early hunter/gatherer decision-making process, a buffering process similar to the one used for settlement was used, but with an increase in the buffer size. The increased buffer size accounts for the fact that resource extraction likely occurred away from settlement locations, particularly for Type 1 and 2 sites that may have acted as staging areas or residential locales. One kilometer and ten kilometer buffer sizes were chosen to summarize the habitat suitability of key floral species adjacent to Type 1 and Type 2 sites in addition to the 200-meter buffer. A 200-meter and a one-kilometer buffer were used around Type 3 sites because these sites are likely the remnants of individual resource extraction activities (Jackson 1997, Shott 1993,). Currently, it is unclear at what distance resources may have affected Paleo-Indian settlement choices; therefore, two buffer sizes were used. If the buffers become too large, resource summaries are more likely to become similar, eliminating their interpretive potential.

In order to account for the costs of traversing the landscape one-kilometer and ten kilometer buffers were constructed from anisotropic cost-distance surfaces simulated around each early Paleo-Indian site. With a GIS based anisotropic cost-distance model the effects of terrain on human movement, which depend on the direction of travel, can be more accurately accounted for (Krist 2001). In addition, buffers can be constructed based on the amount of calories required to traverse the landscape rather than with measures of Euclidean distance. Although prehistoric peoples did not have the means of precisely measuring caloric expenditures they were likely well aware of the differences in traversing various terrain features such as side hills, up hills, down hills, wetlands, etc.

To construct the anisotropic cost-distance models for this research, friction surfaces of caloric expenditure extending out from and to each Paleo-Indian site were generated. Once calculated the region around the archaeological sites that fall within 116 kcal and 1160 kcal, the roundtrip cost to traverse 1 km and 10 km on a level surface at a walking speed of 100 meters/minute, is identified. Cost-distance modeling was not used for the estimation of 200-meter buffers because these depict regions within or adjacent to every archaeological site.

Prior to the assembling the friction surfaces, slope and aspect values were calculated from a DEM using ARC/INFO GRID software. Aspect values were used to determine the extent to which gradients are up slopes, down slopes, or side slopes. The direction that a descending or ascending slope faces (aspect) is dependent on the direction of travel. For this research, the general orientation toward each archaeological site, calculated with the GRID EUCDIRECTION function, is used to determine which aspects represent up hills, down hills, and side hills. For example, an ascending gradient on a north/south trending axis will have an aspect of 180 degrees if the direction of travel is north. To model side slopes, up hills, and down hills according to the direction of travel, the following equation was used to alter the gradients within the GRID software:

$$\text{Aslope} = \text{slope} * \cos(\text{Taspect} - \text{Saspect})$$

Where Aslope is the adjusted slope value and slope is the original slope value, Taspect is the direction toward or away from a site, and Saspect is the slope aspect. Taspect is calculated with the GRID EUCDIRECTION function. The latter half of the equation generates a number ranging from 1 to –1. A value of 1 represents ascending slopes, a value of –1 represents descending slopes, and a value of 0 represents side slopes. Multiplying these numbers by the corresponding terrain slope adjusts the gradient according to the direction of travel by assigning negative values to descending slopes and lowering the effect of side slopes that may act as level terrain, when traveling along them, providing little resistance. In the case of very steep gradients, side slopes could have provided significant resistance. However, it was assumed that the slopes found across the study area would not have been steep enough to deter travel.

To estimate the direction moving away from every archaeological site the direction toward each site, calculated with the EUCDIRECTION function, is reversed. This can be accomplished by assigning a value of 180 to all values from 0 to 180, and a value of -180 to all values from 180 up to 360, and a value of 0 to all values from -1 up to 0 to the EUCDIRECTION output. The adjusted grid is then added to the first grid, subsequently reversing the directions on the first grid.

Altered slope values were entered into the following equations, borrowed from McDonald (1961), using ARC/INFO GRID software to perform the calculations:

For slopes from -40 to –20:

$$F1 = (-0.00415 * V + 0.000049 * V * V) + (-0.13276 * G) + (-0.004692 * G * G) + (-0.00005213 * G * G * G) + (-0.0003257 * V * G + 0.000002036 * V * V * G) + (-0.8588)$$

For slopes from -20 to +5:

$$F2 = (0.00202 * V + 0.000021 * V * V + 0.0256 * G + 0.00154 * G * G + 0.000044 * V * G) + (-0.00000314 * V * G * V) + (0.3515)$$

For slopes from +5 to Highest:
F3 = (0.00275 + 0.049 * (SIN(SLOPEDEG DIV DEG))) * V * (COS(SLOPEDEG DIV DEG)) + (0.00002 + (-0.00033 * (SIN(SLOPEDEG DIV DEG)))) * V * V * (COS(SLOPEDEG DIV DEG)) * (COS(SLOPEDEG DIV DEG)) + (0.396 + 0.17 * (SIN(SLOPEDEG DIV DEG)))

Where V is the walking speed and G represents the altered slope values. The walking speed is based on the average speed for most humans, which is approximately 100 m/min or 3.72 mph. F1, F2, and F3 are the final friction maps generated from each equation. Each friction map represents the cost, in kcal (kilocalories), to move through each 30-meter pixel. It should be noted that slope values, represented by SLOPEDEG, are entered into the third equation as degrees instead of percent rise. The following equation was used to convert slope values to degrees:

SLOPEDEG = (ATAN(SLOPE/100)) * DEG

Where ATAN is the inverse tangent and DEG is a built-in constant utilized by the GRID software. Once the three friction maps were combined, the resultant map was divided by 0.3, the time required to move through a 30-meter pixel at a speed of 100 m/min, to determine the cost in kcal per minute of traversing each pixel.

Hydrologic features likely played a significant role in the travel of early hunter/gatherers. The National Wetlands Inventory (NWI) maps were used to identify regions that likely contained standing water and would have been impediments to land travel. All wetlands with NWI water regime modifiers of semipermanently flooded, intermittently exposed, and permanently flooded, which includes lakes, were considered barriers to travel. Recall that within the beaver, mastodon, moose, and muskrat habitat models presented in Chapter 4 (Appendix A: Table A.12, A.14, A.15, and A.16) these areas were given a high likelihood of having standing water during the Paleo-Indian period. Other wetlands were treated as impediments to travel rather than barriers. Seasonally flooded and saturated/semipermanent/seasonal wetlands were given a friction of 0.15, nearly three times the cost to walk across a 30-meter portion of flat terrain. The remaining wetlands with seasonally flooded/saturated water regime modifiers were given a friction of 0.1.

Once the barriers and the costs of traversing wetland areas were overlayed onto each friction surface the friction maps were combined. Two friction models were generated for each archaeological site under the assumption that travel from an activity area was bi-directional. Using the archaeological sites as start and end points and the friction models as input, the cost to move planimetrically through every cell was calculated with the GRID function COSTDISTANCE. The resultant cost-distance maps were used to identify the 1km and 10km buffers. The process of summarizing the model results for each buffer, presented at the beginning of this chapter, was repeated with the buffers derived from the cost-distance surfaces. In regions with more extensive topographic relief or wetlands, the cost-distance buffers differed significantly from the original circular buffers (Figure 7.1).

A chi-square test was preformed in order to determine the probability that an association between early Paleo-Indian site locations and regions suitable for settlement is due to random occurrence. By calculating a chi-square, the null hypothesis, that there is not an association between archaeological site locations and suitable areas, was tested for each settlement model. The null hypothesis was rejected at a probability of less than or equal to 0.1, where 90 times out of 100 the correspondence between archaeological

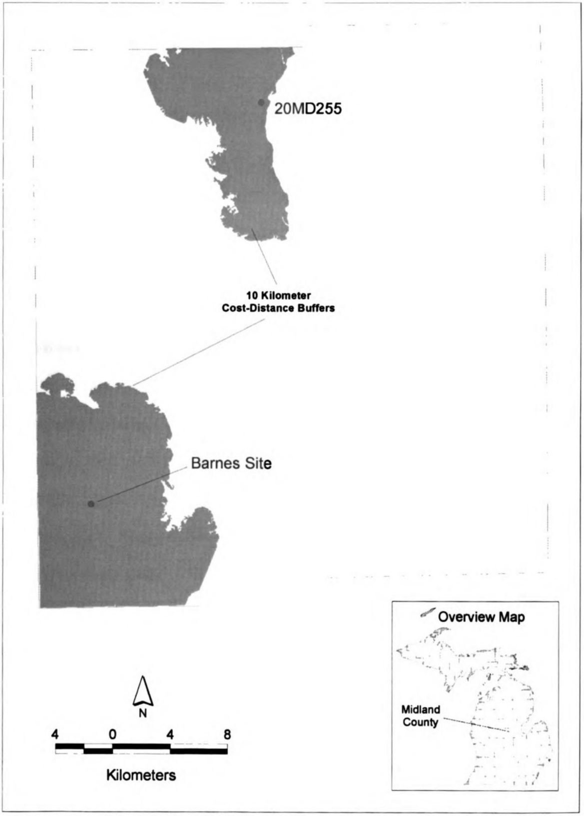

Figure 7.1. One Kilometer Cost-Distance Buffers For Two Paleo-Indian Sites In Midland County

site locations and suitable areas is not due to random occurrence. A number of separate chi-square tests were preformed for each settlement model based on the following groups: Type 1 and 2 sites, Type 3 sites, and all site types. Due to a small sample size, groupings were generated to produce more reliable chi-square results. Random points for the chi- square analysis were generated within the IDRISI SAMPLE module. A 200-meter buffer was calculated around the random points and the settlement values were summarized as described above.

The co-occurrence, or adjacency, of an archaeological site to a suitable habitat indicates the species was accessible from the site. General archaeological assemblage characteristics are then used to verify the use of a particular species. For example, an archaeological site yielding implements utilized for hunting that is adjacent to a region highly suitable for caribou habitat, suggests the site might have served as a staging area for caribou hunting. A fluted point find spot located within a region suitable for caribou habitat might suggest a caribou kill site. Unfortunately, facets of resource procurement and use may not be readily visible within a Paleo-Indian assemblage, nor do all activities produce preservable artifacts. Therefore, "…it is questionable to assume that the size and composition of a single site's assemblage accurately reflects the kinds and frequencies of activities that occurred at the site…" (Shott 1993). Shott also points out that some tool types, such as fluted projectile points, have a wide range of functions. As a result, the presence of such an artifact does not necessarily mean that hunting activities occurred at the site. The advantage of the approach outlined here is that it pinpoints a set of behaviors that are likely to have occurred in and around a settlement without being limited to our assumptions or biased interpretations about archaeological assemblages. In regions where detailed assemblage information is lacking, like the early Paleo-Indian of the Great Lakes, this approach is particularly useful.

A visual inspection was also conducted between archaeological site locations and various model simulations produced in Chapter 6. To accomplish this, the early Paleo-Indian settlement locations were brought into the ArcView GIS software and overlayed onto the cartographic simulations created within Chapters 4 and 6. With the aid of the ArcView Spatial Analyst extension, the spatial relationship between the grid based suitability models and the Paleo-Indian assemblage distributions can be easily examined.

Although few early Paleo-Indian sites across Southern Lower Michigan have undergone detailed lithic studies and only the Leavitt site has yielded floral remains, therefore, conclusive testing of the results generated in Chapter 6 is lacking. As additional early Paleo-Indian subsistence data become available, the models can again be tested and objective and criteria ratings used to produce the results improved.

7.1 PALEO-INDIAN SETTLEMENT

Thirty-two simulations of settlement suitability were calculated based on the three hypothesis presented in Chapter 6. These simulations included high and low risk scenarios, the presence and absence of water as a resource, and both growing and dormant season models. As expected, most of the simulations did not correspond to the early Paleo-Indian settlement pattern found across Southeastern Michigan. In particular, the simulations based on the low risk residential resource use strategies outlined in Chapter 6, showed little or no correspondence to the archaeological record across Lower

Michigan. Therefore, simulations of settlement suitability based on the low risk residential resource use models will not be discussed in detail in the next section.

Prior to moving on to the next section, a trend related to risk will be discussed. The simulations for residential settlement, calculated using the residential resource use layers based on low and intermediate levels of risk, showed little or no correspondence to the early Paleo-Indian settlement pattern recorded in Southeastern Michigan. In order to account for various levels of risk, order weights were generated for each residential resource use model (Appendix B: Tables B.12 – B.13). In a high-risk scenario, greater weight is placed on the resource with the highest suitability. The result is a final suitability map that is primarily driven by highly suitable resource patches. As a result, within the framework presented in this research, a residential settlement strategy based on a high-risk resource use strategy had the individual resources characteristics of a logistical settlement model that guided settlement choices. Residential settlement models based on high-risk resource use presented here are not identical to the logistical settlement models. In fact, if a region contains only a single highly suitable resource with a value of 10, all other criteria related to settlement would require a value of 10 for the outcome to be a highly suitable value for settlement of 7. This situation is unlikely and therefore, areas receiving highly suitable values for residential settlement probably do so because these regions likely allowed access to more than one resource type.

Without correspondence between simulated settlement patterns constructed from moderate to low risk resource use models and the existing archaeological record, a tentative conclusion that early Paleo-Indians, as Kelly and Todd (1988) have suggested, placed little emphasis on risk reduction when choosing an adaptive strategy. This does not mean that early hunter/gatherers did not choose reliable and easily obtainable species, such as caribou (Spiess 1979), but rather the strategy they used to harvest these resources was not necessarily the most risk adverse based on our current understanding of the late Pleistocene. On the other hand, within a boreal forest ecosystem that often contained regions with few overlapping resource patches or species habitats, Paleo-Indians may have had to rely on the best individual resource patches to survive. In this instance, a strategy that appeared to be risk taking might have been a risk adverse one. The remainder of the settlement discussion will focus on settlement models that show correspondence with the archaeological record. Risk taking as it relates to logistical settlement will be discussed in the latter part of this chapter.

7.1.1 MODEL ONE

Under Model 1, it was hypothesized that early Paleo-Indians in pursuit of migratory caribou occupied Lower Michigan primarily during the dormant season (Jackson 1997, Simons 1997). Using this hypothesis, early hunter/gatherers utilizing a rather focal or narrow-spectrum adaptive strategy were mainly concerned with obtaining enough resources for survival. Although risk may have been a concern, and therefore the focus on a relatively easily obtainable resource such as caribou (Spiess 1979), it was given no more weight than any other objective (Appendix B: Tables B.1 – B.15, B.72, B.74 – B.75, B.77, B.79). Therefore, settlement locations were generally in regions with highly suitable caribou habitat. In addition, cover and the dryness of the ground would also have played a minor role.

Of the simulations generated for Hypothesis One, the logistical settlement model, without the inclusion of water as a resource best fit the settlement pattern across the study area (Figure 7.2, Table 7.1). Although obtaining slightly lower ranks, the logistical settlement model with the inclusion of water as a factor was not significantly lower than the logistical settlement model without water. Within the study area, regions in and

Table 7.1. Model 1: Logistical Settlement Rankings within 200 Meters of Each Paleo-Indian Site

Site	**Name**	**Type**	**Phase**	**Rank Without Water**	**Rank Without Water**	**Rank With Water**
20GS49	Gainey	Type 1	Gainey	High	10	
20OK36	N/A	Type 3	Gainey	High	8.74	
20OK394	Shelton Mastodon	Type 3	Unknown	High	8.48	
20MD255	N/A	Type 3	Parkhill	High	7.7	
20SA211	Kralosky	Type 3	Unknown	High	7.18	
20SA196	Lux	Type 3	Enterline	Medium	6.81	
20MR582	Meiring	Type 3	Unknown	Medium	6.7	
20MD423	N/A	Type 3	Gainey	Medium	6.29	
20CL81	Leavitt	Type 2	Parkhill	Medium	6.22	
20MD81	N/A	Type 3	Gainey	Medium	5.7	
20SA1000	Burk 71	Type 3	Parkhill	Medium	5.7	
20MR7	Corcoran	Type 3	Gainey	Medium	5.54	
20MD445	N/A	Type 3	Gainey	Medium	5.19	
20MD124	Porter 1	Type 3	Gainey	Medium	4.75	4.58
20MD328	Kruger	Type 3	Parkhill	Medium	4.61	4.44
20MR296	Petteys d-1	Type 3	Unknown	Medium	4.57	
20GS69	N/A	Type 3	Unknown	Medium	4.13	
20MR122	Gethsemane Cemetery	Type 3	Gainey	Medium	4.04	4.00
20MD472	Varner Site	Type 3	Gainey	Unsuitable	3.17	
20GS104	Butler	Type 2	Gainey	Unsuitable	2.69	
20OK135	N/A	Type 2	Gainey	Unsuitable	2.6	
20MD1	Barnes	Type 2	Parkhill	Unsuitable	2.51	2.39
20MR131	N/A	Type 3	Gainey	Unsuitable	0.34	0.00
				Mean	**5.377**	**5.34**

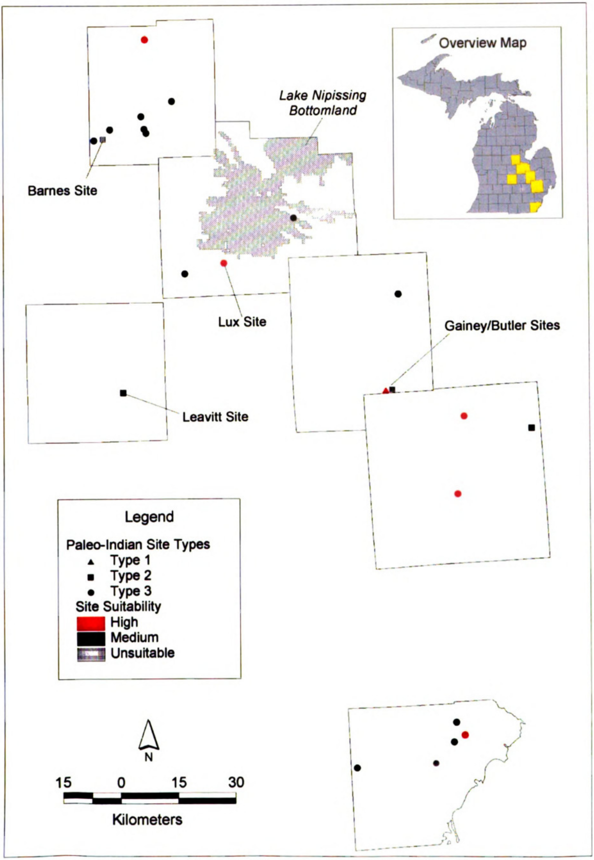

Figure 7.2. Model 1: Logistical Settlement Suitability Without Water By Site

around eighteen of the twenty-three early Paleo-Indian sites received a suitable ranking for this simulation. In particular, the Type 1 and Type 3 sites received the highest rankings. The Gainey site, from which it has been hypothesized that caribou hunting took place (Jackson 1997, Simons 1997), had a ranking of ten, the highest of any site. The adjacency of the Gainey site to caribou migration corridors, generated in Chapter 4, indicate that the site was particularly well suited for the interception of caribou during the spring and fall as large herds moved into and exited the region (Figure 7.3). These results indicate that caribou hunting, utilizing a logistical resource use and settlement strategy was a viable option for early hunter/gatherers occupying Lower Michigan during the dormant season. It should be noted, however, that this model also reveals that moose and mastodon also played a significant role in the settlement choices early peoples made. The results further suggest that water played a minor role in Paleo-Indian settlement choices, while spruce, as a thermal cover, may also have been considered when choosing a settlement. Nearly all the sites received an unsuitable ranking for the models that included water as a resource. Paleo-Indians may have utilized snow or carried water with them during the dormant season. In addition, the much wider distribution of water would have made it relatively easy for early hunter/gatherers to obtain water at will.

Type 1 and Type 2 sites received suitable rankings for the settlement model based on a strategy of high risk residential resource use and settlement under Hypothesis One (Table 7.2, Figure 7.4). Six Type 3 archaeological sites were located within favorable areas for residential settlement. Because resources are typically targeted from logistical settlements (Binford 1980), these camps could have been placed in regions with direct access to one or more resources, although is not required for the placement of a logistical

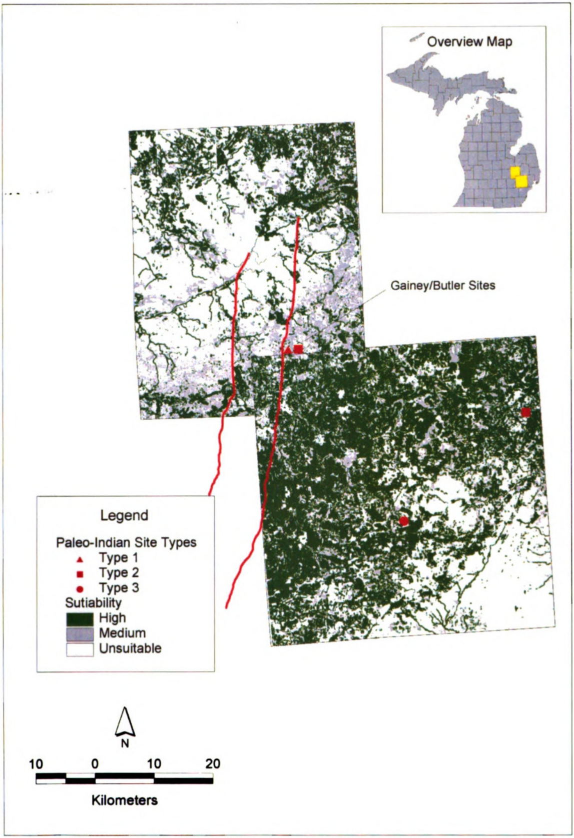

Figure 7.3. Caribou Habitat and Migration Corridors In Relation to The Gainey and Butler Sites

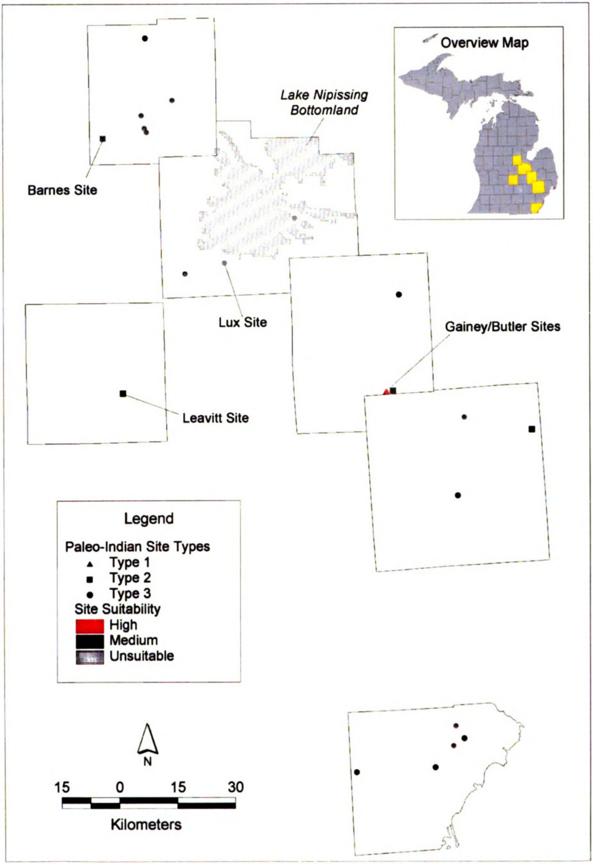

Figure 7.4. Model 1: Residential Settlement Suitability Without Water By Site

Table 7.2. Model 1: High Risk Residential Settlement Rankings Within 200 Meters Of Each Paleo-Indian Site

Site	Name	Type	Phase	Rank Without Water	Rank Without Water
20GS49	Gainey	Type 1	Gainey	High	8.39
20CL81	Leavitt	Type 2	Parkhill	Medium	6.65
20OK135	N/A	Type 2	Gainey	Medium	6.06
20GS104	Butler	Type 2	Gainey	Medium	5.12
20MD1	Barnes	Type 2	Parkhill	Unsuitable	1.03
				Mean	**5.45**

site. For example, a small group of hunter/gatherers targeting caribou may have found themselves occupying regions favorable for blueberries as well. If Type 2 early Paleo-Indian settlements did act as residential camps, then it can be expected that such sites were located in regions that allowed multiple resource access. This appears be the case with Type 2 sites, which faired better as a group under the residential settlement model (Tables 7.3 – 7.4). In particular, Gainey Phase Type 2 settlements received unsuitable rankings for all the logistical models. Although the Gainey and Leavitt sites received a slightly lower ranking for residential settlement under Model 1, the rank was not significantly different from that of the logistical model, indicating the site was located in a setting suitable for both logistical and residential strategy behaviors. The Barnes site, which received unsuitable rankings for both logistical and residential settlement, may have acted as a staging area located on the fringe of multiple resource patches. The site's position, on the western edge of a highly suitable region for resource use, will be explored further in the latter part of this chapter.

A high-risk residential strategy appears advantageous because highly suitable habitats overlapped within the boreal forest ecosystem. As a result, Paleo-Indians likely placed more weight on locating the habitats of individual species rather than regions,

Table 7.3. Logistical Settlement Rankings Within 200 Meters Of Each Paleo-Indian Site For Model 1, 2, And 3

Site	Name	Type	Phase	Log1d_No	Log1d_W	Log2g_No	Log2g_W	Log3d_No	Log3d_W	Log3g_No	Log3g_W
20GS49	Gainey	Type 1	**Gainey**	**High**	**High**			**High**	**High**	Medium	Medium
20GS104	Butler	Type 2	Gainey						3.94		Medium
20OK135	N/A	Type 2	Gainey					Medium	Medium		
20SA196	Lux	Type 3	Enterline	Medium	Medium	Medium	Medium	**High**	**High**		
20MD81	N/A	Type 3	Gainey	Medium	Medium	Medium	Medium	Medium	Medium		
20MD124	Porter 1	Type 3	Gainey	Medium	Medium			Medium	Medium	Medium	Medium
20MD472	Varner Site	Type 3	Gainey					Medium	Medium		
20MD445	N/A	Type 3	Gainey	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
20MD423	N/A	Type 3	Gainey	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
20OK36	N/A	Type 3	Gainey	**High**	**High**			**High**	**High**	**High**	**High**
20MR7	Corcoran	Type 3	Gainey	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
20MR131	N/A	Type 3	Gainey								
20MR122	Gethsemane Cemetery	Type 3	Gainey	Medium	Medium	Medium	Medium	Medium	Medium		
20CL81	Leavitt	Type 2	Parkhill	Medium	Medium			Medium	Medium		Medium
20MD1	Barnes	Type 2	Parkhill						3.39		
20MD255	N/A	Type 3	Parkhill	**High**	**High**	Medium		**High**	**High**	**High**	Medium
20MD328	Kruger	Type 3	Parkhill	Medium	Medium	Medium		Medium	Medium		
20SA1000	Burk 71	Type 3	Parkhill	Medium	Medium	Medium		Medium	Medium	Medium	Medium
20OK394	Shelton Mastodon	Type 3	Unknown	**High**	**High**			**High**	**High**	**High**	**High**
20GS69	N/A	Type 3	Unknown	Medium	Medium			Medium	Medium	Medium	Medium
20SA211	Kralosky	Type 3	Unknown	**High**	**High**			Medium	Medium		
20MR582	Meiring	Type 3	Unknown	Medium	Medium	**High**	**High**	**High**	**High**	**High**	Medium
20MR296	Petteys d-1	Type 3	Unknown	Medium	Medium			Medium	Medium	Medium	

Key: **Log1d_No** = Logistical Settlement, Model 1, Dormant Season, Without Water

Table 7.4. High Risk Residential Settlement Rankings Within 200 Meters Of Each Paleo-Indian Site For Model 1, 2, And 3

Site	Name	Type	Phase	Res1d_No	Res1d_W	Res2g_No	Res2g_W	Res3d_No	Res3d_W	Res3g_No	Res3g_W
20GS49	Gainey	Type 1	Gainey	**High**	**High**			**High**	Medium	Medium	Medium
20GS104	Butler	Type 2	Gainey	Medium				Medium			
20OK135	N/A	Type 2	Gainey	Medium	Medium			Medium	Medium	Medium	Medium
20SA196	Lux	Type 3	Enterline			Medium				Medium	
20MD81	N/A	Type 3	Gainey			Medium					
20MD124	Porter 1	Type 3	Gainey							Medium	Medium
20MD472	Varner Site	Type 3	Gainey								
20MD445	N/A	Type 3	Gainey			Medium	Medium			Medium	Medium
20MD423	N/A	Type 3	Gainey			Medium	Medium			Medium	Medium
20OK36	N/A	Type 3	Gainey	Medium	Medium	Medium	Medium	Medium	Medium	**High**	**High**
20MR7	Corcoran	Type 3	Gainey					Medium		Medium	Medium
20MR131	N/A	Type 3	Gainey	Medium				Medium			
20MR122	Gethsemane Cemetery	Type 3	Gainey			Medium		Medium			
20CL81	Leavitt	Type 2	Parkhill	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
20MD1	Barnes	Type 2	Parkhill								
20MD255	N/A	Type 3	Parkhill	Medium	Medium	Medium	Medium	Medium	Medium	**High**	Medium
20MD328	Kruger	Type 3	Parkhill								
20SA1000	Burk 71	Type 3	Parkhill			Medium				Medium	Medium
20OK394	Shelton Mastodon	Type 3	Unknown			Medium	Medium			**High**	**High**
20GS69	N/A	Type 3	Unknown	Medium	Medium			Medium	Medium		
20SA211	Kralosky	Type 3	Unknown								
20MR582	Meiring	Type 3	Unknown	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
20MR296	Petteys d-1	Type 3	Unknown	Medium	Medium			Medium	Medium		

Key: **Res1d_No** = Residential Settlement, Model 1, Dormant Season, Without Water which contained multiple resources. Therefore, as Jackson (1998) has suggested, early Paleo-Indian residential settlements may have characteristics of logistical camps. Much like a logistical strategy, the high-risk residential settlement model discussed here has highly suitable resource patches that are given greater weight using order weights (Appendix B: Tables B.12 – B.13). Risk, as it relates to logistical settlement, will be examined within the resource use discussion of this chapter.

The chi-square results for Model 1 indicate that some of the co-occurrence between suitable regions and site locations may be the result of random processes (Appendix C: Tables C.1 – C.4). However, the null hypothesis may be rejected for the residential settlement model (Appendix C: Table C.4). This supports the notion that the Type 1 and 2 sites, in particular the Gainey site, may have been utilized as residential camps from which caribou were hunted.

7.1.2 MODEL TWO

The simulations produced for Model 2 were designed to test Hypothesis Two. Under Hypothesis Two, early Paleo-Indians utilized a settlement strategy that gave them access to mastodon and moose habitat during the growing season (Appendix B: Tables B.16 – B.30, B.72, B.73, B.76, B.78). It was assumed that if early Paleo-Indians occupied Lower Michigan during the dormant season that the strategy put forth within Model 1 would apply. Regions in and around nine of the archaeological sites received a medium suitability ranking for logistical settlement without water as a factor while one site obtained a high ranking (Table 7.5). Although the co-occurrence between the second settlement model is not as striking when examining the entire study area, it does suggest that species other than caribou affected early Paleo-Indian settlement decisions. Of particular interest is the distribution of archaeological sites receiving suitable rankings. Suitable settlement values occurring in the northern and southern parts of the study area suggest an alternative settlement and subsistence strategy in these regions (Figure 7.5). The central portion of the study area was favorable for dormant season caribou hunting, while the northern and southern portions were suitable for growing season mastodon and moose hunting. The Gainey site, located in the center of the study area, received the lowest unsuitable ranking, further supporting the assumption that activities occurring

Table 7.5. Model 2 Growing: Logistical Settlement Rankings within 200 Meters of Each Paleo-Indian Site

Site	**Name**	**Type**	**Phase**	**Rank Without Water**	**Rank WithoutWater**
20MR582	Meiring	Type 3	Unknown	High	8.04
20MR7	Corcoran	Type 3	Gainey	Medium	6.47
20MD423	N/A	Type 3	Gainey	Medium	6.14
20SA196	Lux	Type 3	Enterline	Medium	5.74
20MD81	N/A	Type 3	Gainey	Medium	5.7
20MD445	N/A	Type 3	Gainey	Medium	4.36
20MR122	Gethsemane Cemetery	Type 3	Gainey	Medium	4.3
20MD328	Kruger	Type 3	Parkhill	Medium	4.13
20MD255	N/A	Type 3	Parkhill	Medium	4.06
20SA1000	Burk 71	Type 3	Parkhill	Medium	4.01
20MD124	Porter 1	Type 3	Gainey	Unsuitable	3.84
20GS104	Butler	Type 2	Gainey	Unsuitable	3.15
20MD472	Varner Site	Type 3	Gainey	Unsuitable	2.91
20MD1	Barnes	Type 2	Parkhill	Unsuitable	2.81
20OK135	N/A	Type 2	Gainey	Unsuitable	2.73
20SA211	Kralosky	Type 3	Unknown	Unsuitable	2.66
20OK394	Shelton Mastodon	Type 3	Unknown	Unsuitable	2.17
20OK36	N/A	Type 3	Gainey	Unsuitable	2.07
20CL81	Leavitt	Type 2	Parkhill	Unsuitable	1
20MR296	Petteys d-1	Type 3	Unknown	Unsuitable	0.79
20MR131	N/A	Type 3	Gainey	Unsuitable	0.34
20GS69	N/A	Type 3	Unknown	Unsuitable	0.07
20GS49	Gainey	Type 1	Gainey	Unsuitable	0
				Mean	**3.369**

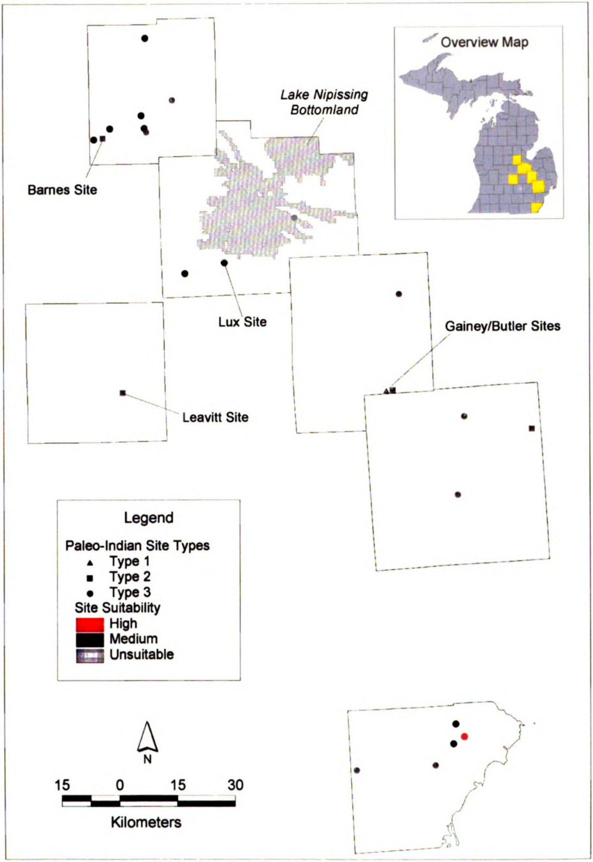

Figure 7.5. Model 2: Logistical Settlement Suitability Without Water By Site

at the site were related to dormant season caribou hunting. This pattern will be discussed further in the latter part of this chapter. The viability of this model in parts of the study area also indicates that prestige may have been a supporting factor in early hunter/gatherer decision-making within some regions. With the exception of the Leavitt site, which obtained a medium ranking, Type 1 and Type 2 sites are located in unsuitable areas for residential settlement. The Shelton Mastodon site, a potential growing season scavenging site, received an unsuitable ranking for logistical settlement, but a medium ranking for residential settlement indicating that the location was much more suitable when other resources were also considered. This is due to the fact that the region adjacent to the site is only moderately suitable for mastodon hunting. Therefore, a scavenging scenario is more likely because Paleo-Indians may have passed through the region in search of other resources and came upon a stranded or dead animal. Unfortunately, no diagnostic artifacts were recovered from the Shelton Mastodon site, nor is there evidence of butchery (Fisher 1988), therefore, assumptions drawn about the site remain tentative at best.

Based on the chi-square results for Model 2, the null hypothesis could be rejected for each simulation (Appendix C: Tables C.5 – C.8). Therefore, the patterns isolated for Model 2 do not appear to be due to chance.

7.1.3 MODEL THREE

The simulations generated for Model 3 were constructed to test Hypothesis Three. Early Paleo-Indian settlement, under this hypothesis, was guided by a desire to utilize a generalized foraging strategy in which a variety of resources, including several plant species during the growing season, were targeted (Appendix B: Tables B.31 – B.79).

Of the three sets of simulations generated for this research, (Figure 7.6, Table 7.6) the dormant season logistical settlement model for Model 3, with a mean suitability value of approximately six and lacking water as a criterion, most closely matched the early Paleo-Indian settlement pattern located across Southeastern Michigan. All but three archaeological sites received suitable values. Two of the sites are Type 2, one, the Butler site, received a suitable ranking for residential settlement without the inclusion of water. The second, the Barnes site with a ranking of 3.51, was most suitable under the dormant season logistical model (Tables 7.3 – 7.4). Of the remaining Paleo-Indian sites, nine received highly suitable rankings while fourteen have a medium settlement suitability ranking. It should be noted that the results for the logistical model that included water as a criterion was not significantly different from the logistical model that did not include water as a factor.

The results from Model 3 indicate that although early hunter/gatherers seem to have preferred a short-term logistical settlement strategy, they did not rely on a single resource, such as caribou, but utilized a wide range of resources or "generalized" foraging strategy as Meltzer and Smith have indicated (1986). Thirteen sites obtained suitable rankings for the growing season residential settlement model (Table 7.7), reinforcing this assumption. During the growing season, a wider range of resources would have been available, enabling Paleo-Indians to target regions with multiple resources. However, despite the availability of additional resource types, the productivity

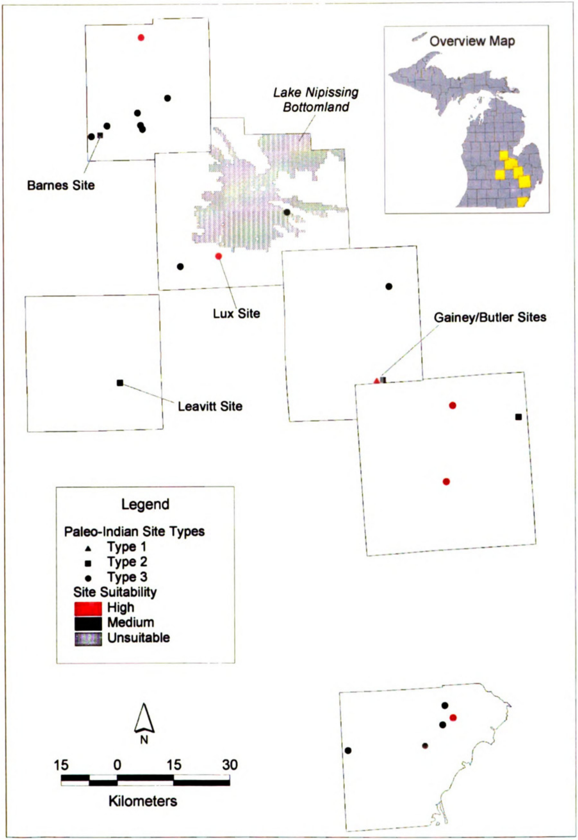

Figure 7.6. Model 3 Dormant Season: Logistical Settlement Suitability Without Water By Site

of these additional species may not have been very high. As a result, an adaptive strategy targeting individual patches, which were the most productive, may have continued to be the most suitable strategy during the growing season as indicated by the thirteen suitable rankings derived from a settlement model based on a high risk residential resource use strategy. This hypothesis will be examined in detail in the latter part of this chapter. The fact that Model 3 seems to fit the best early Paleo-Indian settlement pattern seen throughout Southeastern Michigan indicates that population aggregation, taste, prestige

Table 7.6. Model 3 Dormant: Logistical Settlement Rankings within 200 Meters of Each Paleo-Indian Site

Site	Name	Type	Phase	Rank Without Water	Rank Without Water	Rank With Water
20GS49	Gainey	Type 1	Gainey	High	9.83	
20MR582	Meiring	Type 3	Unknown	High	9.61	
20MD255	N/A	Type 3	Parkhill	High	9.55	
20OK36	N/A	Type 3	Gainey	High	9.36	
20OK394	Shelton Mastodon	Type 3	Unknown	High	9.26	
20SA196	Lux	Type 3	Enterline	High	7.16	
20CL81	Leavitt	Type 2	Parkhill	Medium	6.88	
20MR7	Corcoran	Type 3	Gainey	Medium	6.75	
20SA1000	Burk 71	Type 3	Parkhill	Medium	6.56	
20MD81	N/A	Type 3	Gainey	Medium	6.36	
20MR122	Gethsemane Cemetery	Type 3	Gainey	Medium	6.36	6.32
20MD423	N/A	Type 3	Gainey	Medium	6	
20SA211	Kralosky	Type 3	Unknown	Medium	6	
20MD124	Porter 1	Type 3	Gainey	Medium	5.61	5.41
20MD328	Kruger	Type 3	Parkhill	Medium	4.96	4.79
20MD472	Varner Site	Type 3	Gainey	Medium	4.86	
20MR296	Petteys d-1	Type 3	Unknown	Medium	4.57	
20MD445	N/A	Type 3	Gainey	Medium	4.5	
20GS69	N/A	Type 3	Unknown	Medium	4.13	
20OK135	N/A	Type 2	Gainey	Medium	4.1	
20GS104	Butler	Type 2	Gainey	Unsuitable	3.94	
20MD1	Barnes	Type 2	Parkhill	Unsuitable	3.51	3.39
20MR131	N/A	Type 3	Gainey	Unsuitable	0.34	0
				Mean	**6.096**	**6.058**

and dietary variety were also likely objectives of early peoples. Each objective was given equal weight within Model 3 (Appendix B: Table B.31). The lack of early Paleo-Indian sites adjacent to resources that received low ratings for these objectives, such as hare and muskrat, also supports this premise.

Table 7.7. Model 3 Growing: High Risk Residential Settlement Rankings within 200 Meters of Each Paleo-Indian Site

Site	**Name**	**Type**	**Phase**	**Rank Without Water**	**Rank Without Water**
20OK394	Shelton Mastodon	Type 3	Unknown	High	8.41
20OK36	N/A	Type 3	Gainey	High	7.89
20MD255	N/A	Type 3	Parkhill	High	7.42
20MR582	Meiring	Type 3	Unknown	Medium	6.64
20MD423	N/A	Type 3	Gainey	Medium	6.14
20SA1000	Burk 71	Type 3	Parkhill	Medium	6.1
20GS49	Gainey	Type 1	Gainey	Medium	6
20OK135	N/A	Type 2	Gainey	Medium	6
20SA196	Lux	Type 3	Enterline	Medium	5.74
20CL81	Leavitt	Type 2	Parkhill	Medium	4.72
20MD124	Porter 1	Type 3	Gainey	Medium	4.46
20MD445	N/A	Type 3	Gainey	Medium	4.36
20MR7	Corcoran	Type 3	Gainey	Medium	4.16
20MR122	Gethsemane Cemetery	Type 3	Gainey	Unsuitable	3.48
20GS104	Butler	Type 2	Gainey	Unsuitable	3.31
20GS69	N/A	Type 3	Unknown	Unsuitable	3.26
20MD472	Varner Site	Type 3	Gainey	Unsuitable	2.91
20SA211	Kralosky	Type 3	Unknown	Unsuitable	2.78
20MD1	Barnes	Type 2	Parkhill	Unsuitable	2.4
20MD328	Kruger	Type 3	Parkhill	Unsuitable	2.26
20MD81	N/A	Type 3	Gainey	Unsuitable	1.39
20MR296	Petteys d-1	Type 3	Unknown	Unsuitable	0.47
20MR131	N/A	Type 3	Gainey	Unsuitable	0.34
				Mean	**4.376**

Although early Paleo-Indian settlement patterns seem to indicate that they occupied the region primarily during the dormant season, the placement of sites such as 20OK135, 20OK36, and 20MD255 suggest that to a lesser extent early groups probably inhabited Lower Michigan throughout the growing season (Tables 7.6 – 7.7). The likelihood that gathering activities could have taken place at these sites will be explored further in this chapter.

The correspondence between the archaeological record in Lower Michigan and the simulated regions for dormant season settlement are not the result of chance. The null hypothesis can be rejected for each of the logistical and residential settlement models calculated in Model 3 (Appendix C: Tables C.9 – C.12). The correlations between the growing season models and the archaeological record on the other hand, may be partially explained by chance. The null hypothesis could only be rejected for the residential growing season model for Type 1 and 2 sties (Appendix C: Tables C.13 – C.16).).

7.2 CRITERIA

One of the primary advantages of the approach advocated within this research is the ability to easily examine the components that make up each suitability model, the resultant criteria, and objective maps. These maps can provide valuable insights into why a correspondence between modeled results and the archaeological record exists. In other words, rather than taking the results at face value, the effects of each criterion can be further evaluated.

7.2.1 RESOURCE USE

When evaluating the potential resource use patterns in and around the early Paleo-Indian sites using 200 meter, 1 kilometer, and 10-kilometer buffers, several patterns arise with respect to the residential and logistical resource use simulations generated in

Chapter 6. The most obvious pattern is that a resource use strategy focused on highly suitable resource patches would have been the most likely for early Paleo-Indians to utilize (Tables 7.8 – 10). With relatively few overlapping patches within the boreal forest ecosystem, the residential resource use simulations based on a strategy of moderate risk, in which regions with access to multiple resources were rated higher, received much lower rankings while regions in and around each site received much higher rankings under the risk-taking strategy. Relying on individual resource patches can be risky due to "Cyclic, or periodic but irregular, population fluctuations known to occur in all species..." within the boreal forest (Winterhalder 1981b). To counterbalance this reliance on such a risky strategy, Paleo-Indians could have used a generalized foraging strategy. By utilizing a generalized strategy, early hunter/gatherers would move from patch to patch in search of a wide range of species. Support for this assertion is seen in early Paleo-Indian settlement patterns across Lower Michigan, which closely corresponds to the generalized foraging settlement model, Model 3, presented in the previous section. The presence of both large and small game at Paleo-Indian sites within the Great Lakes region also supports a generalized strategy (Storck and Spiess 1994).

A second pattern of resource use that emerges, particularly at the Barnes and Butler sites, is the placement of settlement locations in unproductive areas on the edge of resource patches. The rankings for both the Barnes and Butler sites increased when the buffer around each site was set to 10 km (Tables 7.8 – 7.13). The Barnes site saw the greatest increase from a medium to high value under every model, indicating that this site, in particular, was used as a staging area at which little or no resource extraction or processing took place. The assemblage from the Barnes site also supports this assertion

Table 7.8. Model 1: Dormant Season Residential Resource Use Based on High And Intermediate Risk Strategies

Site	Name	Type	Phase	Inter. Risk 200m	Inter. Risk 1km	Inter. Risk 10km	High Risk 200m	High Risk 1km	High Risk 10km
20MD81	N/A	Type 3	Gainey	1.39	1.19 (1.03)		5.70	4.86 (4.63)	
20MD124	Porter 1	Type 3	Gainey	3.80	5.16		5.37	6.31	
20SA196	Lux	Type 3	Enterline	2.13	1.11 (0.96)		7.16	5.79 (5.74)	
20MD255	N/A	Type 3	Parkhill	4.77	4.79 (3.96)		8.28	7.03 (6.46)	
20MD472	Varner Site	Type 3	Gainey	0.83	3.57 (3.50)		3.29	6.14 (5.99)	
20MD445	N/A	Type 3	Gainey	6.88	5.45 (4.42)		7.57	5.92 (5.59)	
20MD328	Kruger	Type 3	Parkhill	2.71	5.11		3.33	5.75	
20MD423	N/A	Type 3	Gainey	6.46	7.25		6.46	7.28	
20SA211	Kralosky	Type 3	Unknown	7.18	6.42 (6.39)		7.29	7.16 (7.15)	
20SA1000	Burk 71	Type 3	Parkhill	4.47	5.30 (5.28)		7.57	7.06 (7.12)	
20GS69	N/A	Type 3	Unknown	2.51	3.79 (3.78)		2.57	5.02 (5.00)	
20OK394	Shelton Mastodon	Type 3	Unknown	5.30	5.02 (5.49)		8.48	7.53 (9.46)	
20OK36	N/A	Type 3	Gainey	5.39	3.97 (3.39)		6.52	5.56 (4.92)	
20MR582	Meiring	Type 3	Unknown	4.64	2.03		6.70	4.25	
20MR7	Corcoran	Type 3	Gainey	5.35	1.68 (1.79)		5.54	3.71 (3.77)	
20MR131	N/A	Type 3	Gainey	0.0	1.26 (0.70)		0.0	1.38 (0.55)	
20MR122	Gethsemane Cemetery	Type 3	Gainey	3.26	3.56 (3.50)		3.83	4.78 (4.64)	
20MR296	Petteys d-1	Type 3	Unknown	3.49	1.33		4.57	2.25	
20MD1	Barnes	Type 2	Parkhill	2.30	4.26 (2.95)	6.06 (5.58)	2.30	5.03 (3.92)	7.15 (7.36)
20GS104	Butler	Type 2	Gainey	2.93	3.34 (1.67)	3.94 (2.16)	3.26	3.93 (2.16)	5.43 (4.85)
20GS49	Gainey	Type 1	Gainey	5.96	4.34 (4.42)	3.97 (2.16)	6.00	5.88 (5.92)	5.3 (4.85)
20CL81	Leavitt	Type 2	Parkhill	0.96	2.12 (1.99)	2.07 (0.95)	4.22	4.92 (4.75)	3.97 (3.66)
20OK135	N/A	Type 2	Gainey	0.99	4.06 (3.88)	4.57	3.02	4.83 (4.62)	6.19

Key: ( ) = Values Calculated With Buffers Generated From Cost-Distance Models

Table 7.9. Model 3: Dormant Season Residential Resource Use Based on High and Intermediate Risk Strategies

Site	Name	Type	Phase	Inter. Risk 200m	Inter. Risk 1km	Inter. Risk 10km	High Risk 200m	High Risk 1km	High Risk 10km
20MD81	N/A	Type 3	Gainey	1.39	1.17		6.36	5.11	
20MD124	Porter 1	Type 3	Gainey	3.48	4.81		4.95	6.48	
20SA196	Lux	Type 3	Enterline	2.13	0.98		7.16	5.67	
20MD255	N/A	Type 3	Parkhill	4.99	4.05		8.22	6.72	
20MD472	Varner Site	Type 3	Gainey	0.57	3.14		3.29	6.31	
20MD445	N/A	Type 3	Gainey	5.22	4.9		7.57	6.33	
20MD328	Kruger	Type 3	Parkhill	2.43	4.92		4.73	6.08	
20MD423	N/A	Type 3	Gainey	6.29	6.63		6.57	7.52	
20SA211	Kralosky	Type 3	Unknown	2.37	3.06		7.32	7.48	
20SA1000	Burk 71	Type 3	Parkhill	3.58	3.63		6.71	7.13	
20GS69	N/A	Type 3	Unknown	0.16	1.9		2.51	4.37	
20OK394	Shelton Mastodon	Type 3	Unknown	5.26	3.64		5.96	5.84	
20OK36	N/A	Type 3	Gainey	2.14	2.36		6.35	4.86	
20MR582	Meiring	Type 3	Unknown	4.64	2.13		8.63	4.91	
20MR7	Corcoran	Type 3	Gainey	5.35	1.73		6.75	4.14	
20MR131	N/A	Type 3	Gainey	0.0	1.32		0.34	1.74	
20MR122	Gethsemane Cemetery	Type 3	Gainey	3.48	3.62		6.22	5.88	
20MR296	Petteys d-1	Type 3	Unknown	3.06	1.16		4.14	2.1	
20MD1	Barnes	Type 2	Parkhill	2.41	4.21	5.68	3.36	5.4	7.35
20GS104	Butler	Type 2	Gainey	3.31	2.81	2.29	3.58	4.15	4.98
20GS49	Gainey	Type 1	Gainey	0.0	1.52	2.31	6.00	5.52	4.94
20CL81	Leavitt	Type 2	Parkhil	0.17	0.97	1.1	4.22	4.79	3.77
20OK135	N/A	Type 2	Gainey	1.04	0.87	2.15	3.11	4.74	5.45

Table 7.10. Model 3: Growing Season Residential Resource Use Based on High and Intermediate Risk Strategies

Site	Name	Type	Phase	Inter. Risk 200m	Inter. Risk 1km	Inter. Risk 10km	High Risk 200m	High Risk 1km	High Risk 10km
20MD81	N/A	Type 3	Gainey	0.0	0.16		6.00	4.66	
20MD124	Porter 1	Type 3	Gainey	2.42	3.76		4.72	6.97	
20SA196	Lux	Type 3	Enterline	2.13	0.92		7.38	6.01	
20MD255	N/A	Type 3	Parkhill	3.22	2.96		8.10	6.46	
20MD472	Varner Site	Type 3	Gainey	0.57	2.21		3.29	5.95	
20MD445	N/A	Type 3	Gainey	4.36	3.83		6.59	6.13	
20MD328	Kruger	Type 3	Parkhill	1.46	3.33		4.54	6.28	
20MD423	N/A	Type 3	Gainey	6.00	5.69		6.77	7.83	
20SA211	Kralosky	Type 3	Unknown	2.46	3		4.07	5.04	
20SA1000	Burk 71	Type 3	Parkhill	2.89	2.56		7.19	6.15	
20GS69	N/A	Type 3	Unknown	1.22	2.59		3.29	6.2	
20OK394	Shelton Mastodon	Type 3	Unknown	3.26	3.05		8.03	8.46	
20OK36	N/A	Type 3	Gainey	3.57	1.47		8.09	5.07	
20MR582	Meiring	Type 3	Unknown	2.35	1.03		6.84	4.43	
20MR7	Corcoran	Type 3	Gainey	2.29	0.69		4.24	3.57	
20MR131	N/A	Type 3	Gainey	0.0	0.86		0.38	2.25	
20MR122	Gethsemane Cemetery	Type 3	Gainey	0.0	0.78		4.04	3.6	
20MR296	Petteys d-1	Type 3	Unknown	0.47	0.31		1.40	1.34	
20MD1	Barnes	Type 2	Parkhill	1.63	2.91	4.02	3.53	5.8	7.47
20GS104	Butler	Type 2	Gainey	1.53	1.38	1.85	3.93	4.37	5.78
20GS49	Gainey	Type 1	Gainey	0.0	0.84	1.79	3.76	5.54	5.58
20CL81	Leavitt	Type 2	Parkhil	0.04	0.19	0.83	4.94	6.24	4.38
20OK135	N/A	Type 2	Gainey	047	1.7	2.6	6.35	7.35	7.39

by indicating the primary activity at the site was the manufacture of extractive implements, particularly projectile points (Voss 1977). The Barnes site is located along the edge of a highly productive region in which a number of early Paleo-Indian find-spots have been located (Figure 7.7). Two of these sites belong to the Parkhill phase and may be related to the Barnes site, while the remaining five sites belong to the Gainey Phase (Figure 3.15). A "worn out" Barnes type projectile point was reported from 20MD255 and a Barnes type point base was recovered from 20MD328. Although a lithic analysis is needed to determine if these sites are contemporaneous with the Barnes site, their location within a highly suitable region for resource extraction and the worn point indicate these sites were related to extractive activities. Rather than being placed in a location allowing direct access to resources, the Barnes site, situated along a small well-drained ridge, was placed in a region of very favorable terrain. In addition, the Barnes site was located in a white spruce forest (Figure 7.7). White spruce provides excellent thermal cover during the dormant season.

Upon the examination of the logistical settlement models, some clear trends emerge. Based on the logistical resource use criteria rankings (Appendix B: Tables B.7 – B.8) for Model 1, caribou would have been the primary resource utilized by early hunter/gatherers while mastodon and moose would have been secondary resources. Beaver, muskrat and hare were probably rarely used under this model (Table 7.11). After adjusting criteria values according to their rankings, the pursuit of caribou and to a limited extent moose and mastodon would have been the only low risk logistical resource use strategy for early Paleo-Indian groups under Model 1 (Table 7.11, Figure 7.8). Including higher risk resources significantly expands the region that was likely exploited

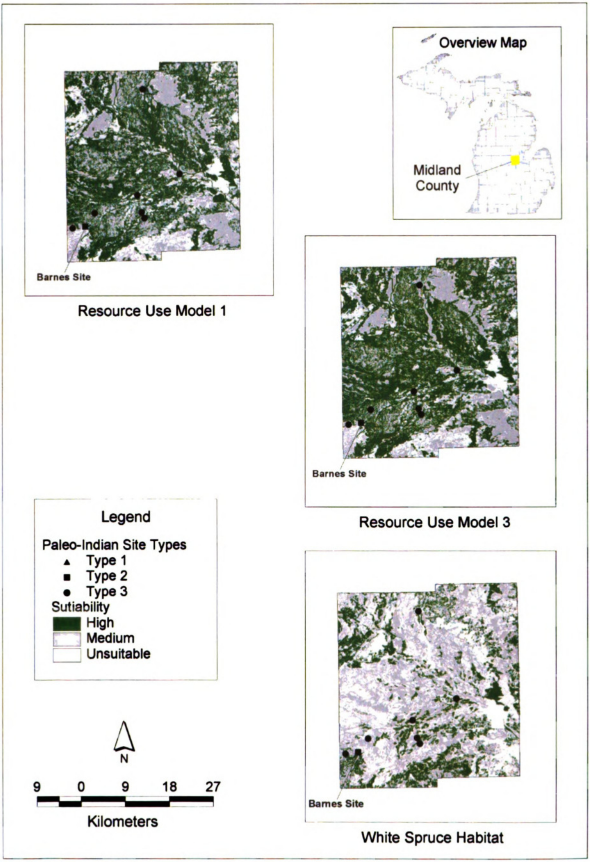

Figure 7.7. Resource Use And White Spruce In Relation To The Barnes Site

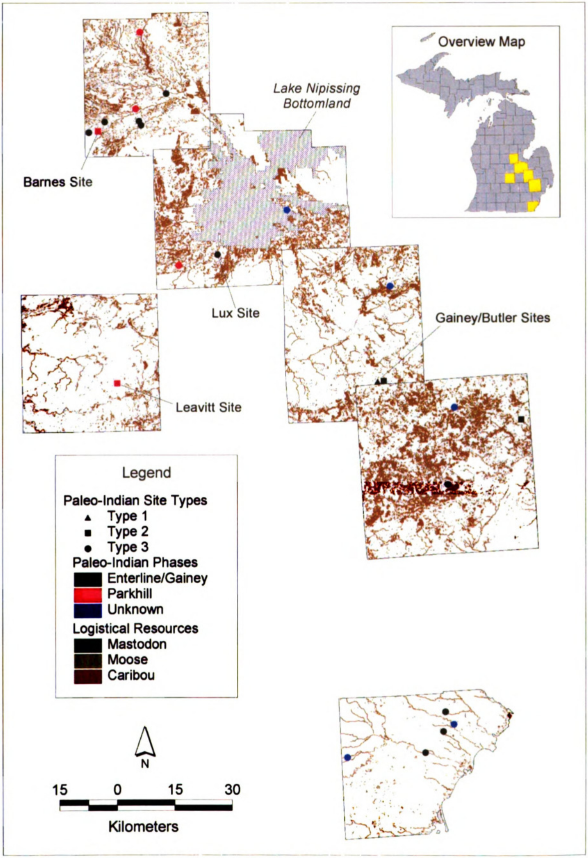

Figure 7.8. Model 1: Low Risk Logistical Resource Use Areas

Table 7.11. Model 1: Dormant Season High Risk Logistical Resource Use Summed By Square Meters of Habitat For Each Species Within a 200 Meter Buffer

Site	Name	Type	Phase	Species	Area (Square Meters)
20SA196	Lux	Type 3	Enterline	Caribou	44100
20SA196	Lux	Type 3	Enterline	Moose	69300
20GS49	Gainey	Type 1	Gainey	Caribou	125100
20GS104	Butler	Type 2	Gainey	Caribou	9900
20GS104	Butler	Type 2	Gainey	Moose	38700
20OK135		Type 2	Gainey	Caribou	4500
20OK135		Type 2	Gainey	Moose	46800
20MD124	Porter 1	Type 3	Gainey	Caribou	47700
20MD124	Porter 1	Type 3	Gainey	Mastodon	14400
20MD124	Porter 1	Type 3	Gainey	Moose	17100
20MD423	N/A	Type 3	Gainey	Caribou	18000
20MD423	N/A	Type 3	Gainey	Moose	108000
20MD445	N/A	Type 3	Gainey	Caribou	69300
20MD445	N/A	Type 3	Gainey	Mastodon	2700
20MD445	N/A	Type 3	Gainey	Moose	18900
20MD472	Varner Site	Type 3	Gainey	Caribou	11700
20MD472	Varner Site	Type 3	Gainey	Moose	48600
20MD81	N/A	Type 3	Gainey	Caribou	28800
20MD81	N/A	Type 3	Gainey	Moose	89100
20MR122	Gethsemane Cemetery	Type 3	Gainey	Caribou	63900
20MR122	Gethsemane Cemetery	Type 3	Gainey	Moose	19800
20MR131	N/A	Type 3	Gainey	Moose	7200
20MR7	Corcoran	Type 3	Gainey	Caribou	79200
20MR7	Corcoran	Type 3	Gainey	Moose	6300
20OK36		Type 3	Gainey	Caribou	98100
20OK36		Type 3	Gainey	Mastodon	900
20OK36		Type 3	Gainey	Moose	19800
20CL81	Leavitt	Type 2	Parkhill	Caribou	64800
20CL81	Leavitt	Type 2	Parkhill	Moose	20700
20MD1	Barnes	Type 2	Parkhill	Caribou	17100
20MD1	Barnes	Type 2	Parkhill	Mastodon	9000
20MD1	Barnes	Type 2	Parkhill	Moose	26100
20MD255	N/A	Type 3	Parkhill	Caribou	63000
20MD255	N/A	Type 3	Parkhill	Mastodon	7200
20MD255	N/A	Type 3	Parkhill	Moose	51300
20MD328	Kruger	Type 3	Parkhill	Caribou	36000
20MD328	Kruger	Type 3	Parkhill	Moose	44100
20SA1000	Burk 71	Type 3	Parkhill	Caribou	72900
20SA1000	Burk 71	Type 3	Parkhill	Moose	4500
20OK394	Shelton Mastodon	Type 3	Unknown	Caribou	78300
20OK394	Shelton Mastodon	Type 3	Unknown	Moose	45000
20GS69	N/A	Type 3	Unknown	Caribou	51300
20MR296	Petteys d-1	Type 3	Unknown	Caribou	57600
20MR582	Meiring	Type 3	Unknown	Caribou	78300
20MR582	Meiring	Type 3	Unknown	Moose	50400
20SA211	Kralosky	Type 3	Unknown	Caribou	125100

by early peoples (Figure 7.9). With a better overall correspondence to the Paleo-Indian settlement pattern found in Lower Michigan, Model 3 primarily relies on moose and mastodon in addition to caribou during the dormant season. Beaver, muskrat and hare would have acted as secondary resources. After adjusting the dormant season criteria values according to their rankings for Model 3 (Appendix B: Tables B.48, B.50, B.52, B.54), the pursuit of caribou, moose, and mastodon would have provided a low risk logistical resource use strategy for early Paleo-Indian groups (Table 7.12, Figure 7.10). When regions of higher risk are included, caribou, moose, and mastodon are still the primary resources. However, the region from which early hunter/gatherers could utilize them significantly increases (Figure 7.11). During the growing season hunting/harvesting mastodon, moose, and cherry/serviceberry would have provided the lowest risk resource use strategy (Table 7.13). However, the limited distribution of highly suitable regions during the growing season may help to explain why the settlement pattern found in Lower Michigan does not correspond as well with the growing season model results (Figure 7.12). When higher risk, or secondary resources, such as blueberry and cranberry, is included, a much larger region becomes suitable during the growing season. Since sites such as 20OK135 and 20OK36, with high suitability values for growing season logistical settlement (Table 7.3) are located in a region of higher risk for logistical resource use, the notion that early hunter/gatherers did not regard risk aversion as a very high priority is supported (Figure 7.13).

Another distinct pattern arises when viewing the regions for logistical resource use. In the northern and southern parts of the study area, the suitability of these regions is

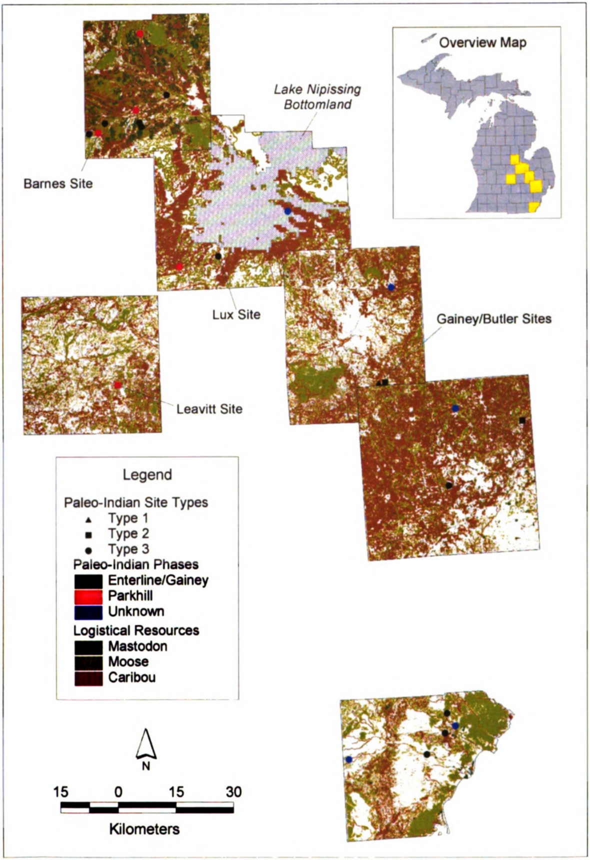

Figure 7.9. Model 1: High/Low Risk Logistical Resource Use Areas

Table 7.12. Model 3: Dormant Season High Risk Logistical Resource Use Summed By Square Meters of Habitat For Each Species Within a 200 Meter Buffer

Site	Name	Type	Phase	Species	Area
20SA196	Lux	Type 3	Enterline	Moose	118800
20GS49	Gainey	Type 1	Gainey	Caribou	125100
20GS104	Butler	Type 2	Gainey	Caribou	9900
20GS104	Butler	Type 2	Gainey	Moose	38700
20OK135		Type 2	Gainey	Caribou	4500
20OK135		Type 2	Gainey	Moose	46800
20MD124	Porter 1	Type 3	Gainey	Caribou	22500
20MD124	Porter 1	Type 3	Gainey	Moose	56700
20MD423	N/A	Type 3	Gainey	Moose	126000
20MD445	N/A	Type 3	Gainey	Moose	90900
20MD472	Varner Site	Type 3	Gainey	Moose	60300
20MD81	N/A	Type 3	Gainey	Moose	117900
20MR122	Gethsemane Cemetery	Type 3	Gainey	Moose	83700
20MR131	N/A	Type 3	Gainey	Moose	7200
20MR7	Corcoran	Type 3	Gainey	Caribou	4500
20MR7	Corcoran	Type 3	Gainey	Moose	81000
20OK36		Type 3	Gainey	Caribou	98100
20OK36		Type 3	Gainey	Moose	20700
20CL81	Leavitt	Type 2	Parkhill	Caribou	64800
20CL81	Leavitt	Type 2	Parkhill	Moose	20700
20MD1	Barnes	Type 2	Parkhill	Moose	52200
20MD255	N/A	Type 3	Parkhill	Caribou	47700
20MD255	N/A	Type 3	Parkhill	Moose	73800
20MD328	Kruger	Type 3	Parkhill	Caribou	10800
20MD328	Kruger	Type 3	Parkhill	Moose	69300
20SA1000	Burk 71	Type 3	Parkhill	Caribou	40500
20SA1000	Burk 71	Type 3	Parkhill	Mastodon	4500
20SA1000	Burk 71	Type 3	Parkhill	Moose	68400
20GS69	N/A	Type 3	Unknown	Caribou	50400
20GS69	N/A	Type 3	Unknown	Moose	900
20MR296	Petteys d-1	Type 3	Unknown	Caribou	47700
20MR296	Petteys d-1	Type 3	Unknown	Moose	9900
20MR582	Meiring	Type 3	Unknown	Caribou	12600
20MR582	Meiring	Type 3	Unknown	Moose	116100
20OK394	Shelton Mastodon	Type 3	Unknown	Caribou	78300
20OK394	Shelton Mastodon	Type 3	Unknown	Moose	45000
20SA211	Kralosky	Type 3	Unknown	Caribou	75600
20SA211	Kralosky	Type 3	Unknown	Moose	49500

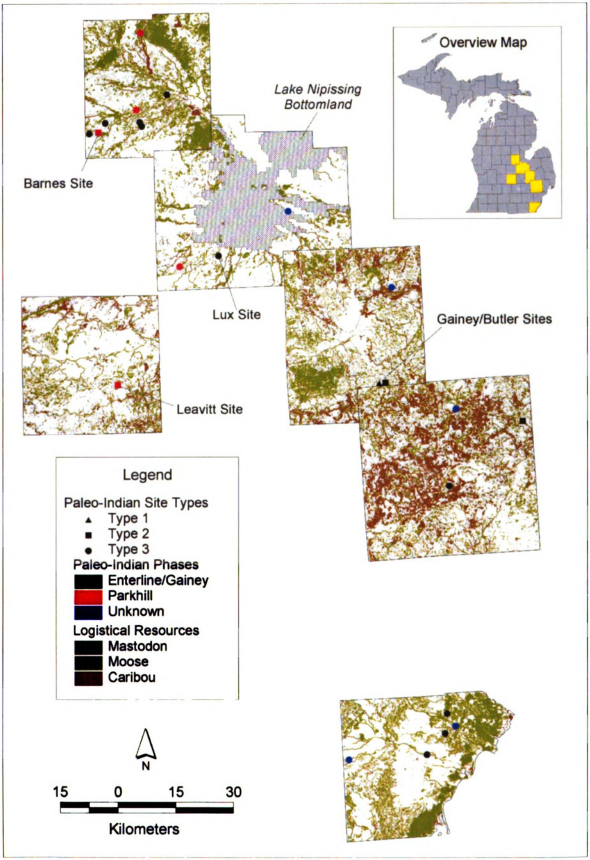

Figure 7.10. Model 3 Dormant Season: Low Risk Logistical Resource Use Areas

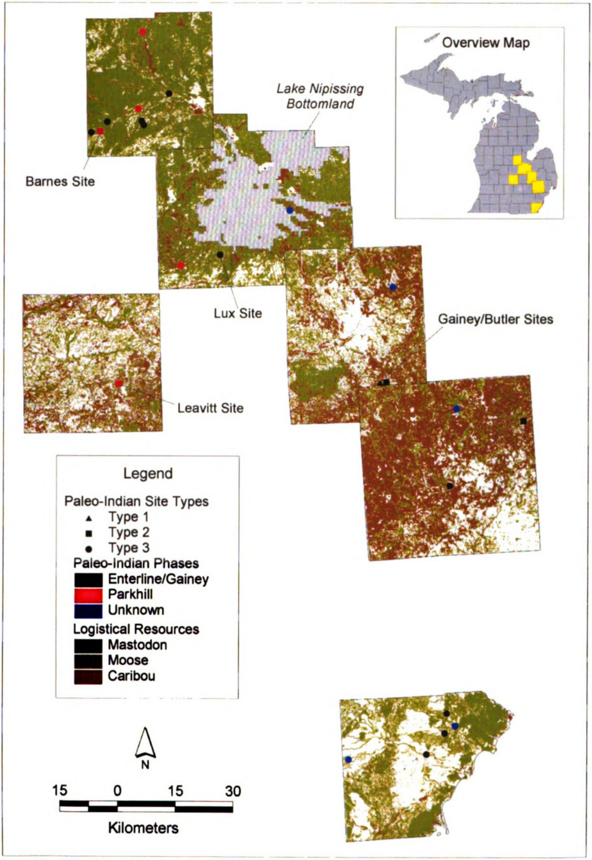

Figure 7.11. Model 3 Dormant Season: High/Low Risk Logistical Resource Use Areas

Table 7.13. Model 3: Growing Season High Risk Logistical Resource Use Summed By Square Meters of Habitat For Each Species Within a 200 Meter Buffer

Site	Name	Type	Phase	Species	Area
20SA196	Lux	Type 3	Enterline	Moose	44100
20GS49	Gainey	Type 1	Gainey	Moose	78300
20GS104	Butler	Type 2	Gainey	Cranberry	18900
20GS104	Butler	Type 2	Gainey	Mastodon	19800
20GS104	Butler	Type 2	Gainey	Moose	11700
20OK135		Type 2	Gainey	Cranberry	36000
20OK135		Type 2	Gainey	Mastodon	8100
20OK135		Type 2	Gainey	Moose	81000
20MD124	Porter 1	Type 3	Gainey	Cherry	7200
20MD124	Porter 1	Type 3	Gainey	Mastodon	30600
20MD124	Porter 1	Type 3	Gainey	Moose	14400
20MD423	N/A	Type 3	Gainey	Mastodon	101700
20MD423	N/A	Type 3	Gainey	Moose	24300
20MD445	N/A	Type 3	Gainey	Mastodon	52200
20MD445	N/A	Type 3	Gainey	Moose	38700
20MD472	Varner Site	Type 3	Gainey	Cranberry	48600
20MD472	Varner Site	Type 3	Gainey	Moose	11700
20MD81	N/A	Type 3	Gainey	Moose	28800
20MR122	Gethsemane Cemetery	Type 3	Gainey	Mastodon	14400
20MR122	Gethsemane Cemetery	Type 3	Gainey	Moose	57600
20MR7	Corcoran	Type 3	Gainey	Cherry	36000
20MR7	Corcoran	Type 3	Gainey	Mastodon	49500
20OK36		Type 3	Gainey	Cherry	900
20OK36		Type 3	Gainey	Cranberry	42300
20OK36		Type 3	Gainey	Mastodon	900
20OK36		Type 3	Gainey	Moose	76500
20CL81	Leavitt	Type 2	Parkhill	Cranberry	20700
20CL81	Leavitt	Type 2	Parkhill	Moose	17100
20MD1	Barnes	Type 2	Parkhill	Mastodon	30600
20MD1	Barnes	Type 2	Parkhill	Moose	1800
20MD255	N/A	Type 3	Parkhill	Blueberry	49500
20MD255	N/A	Type 3	Parkhill	Cranberry	35100
20MD255	N/A	Type 3	Parkhill	Mastodon	18000
20MD255	N/A	Type 3	Parkhill	Moose	18000
20MD328	Kruger	Type 3	Parkhill	Cherry	5400
20MD328	Kruger	Type 3	Parkhill	Mastodon	17100
20MD328	Kruger	Type 3	Parkhill	Moose	10800
20SA1000	Burk 71	Type 3	Parkhill	Blueberry	27900
20SA1000	Burk 71	Type 3	Parkhill	Cranberry	7200
20SA1000	Burk 71	Type 3	Parkhill	Mastodon	4500
20SA1000	Burk 71	Type 3	Parkhill	Moose	27900
20GS69	N/A	Type 3	Unknown	Moose	51300
20MR296	Petteys d-1	Type 3	Unknown	Mastodon	8100
20MR296	Petteys d-1	Type 3	Unknown	Moose	1800
20MR582	Meiring	Type 3	Unknown	Cherry	35100
20MR582	Meiring	Type 3	Unknown	Cranberry	31500
20MR582	Meiring	Type 3	Unknown	Mastodon	35100
20MR582	Meiring	Type 3	Unknown	Moose	27000
20OK394	Shelton Mastodon	Type 3	Unknown	Cherry	7200
20OK394	Shelton Mastodon	Type 3	Unknown	Cranberry	32400
20OK394	Shelton Mastodon	Type 3	Unknown	Moose	70200
20SA211	Kralosky	Type 3	Unknown	Moose	51300

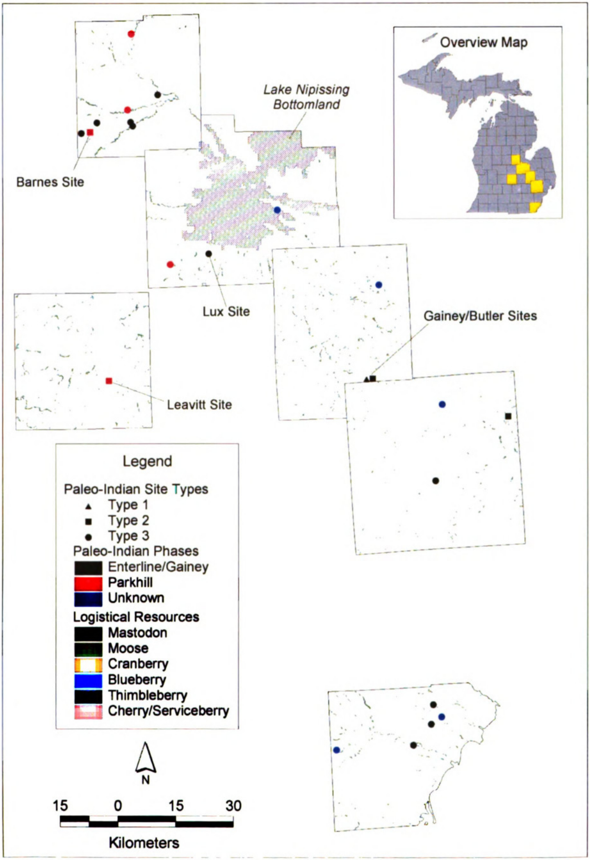

Figure 7.12. Model 3 Growing Season: Low Risk Logistical Resource Use Areas

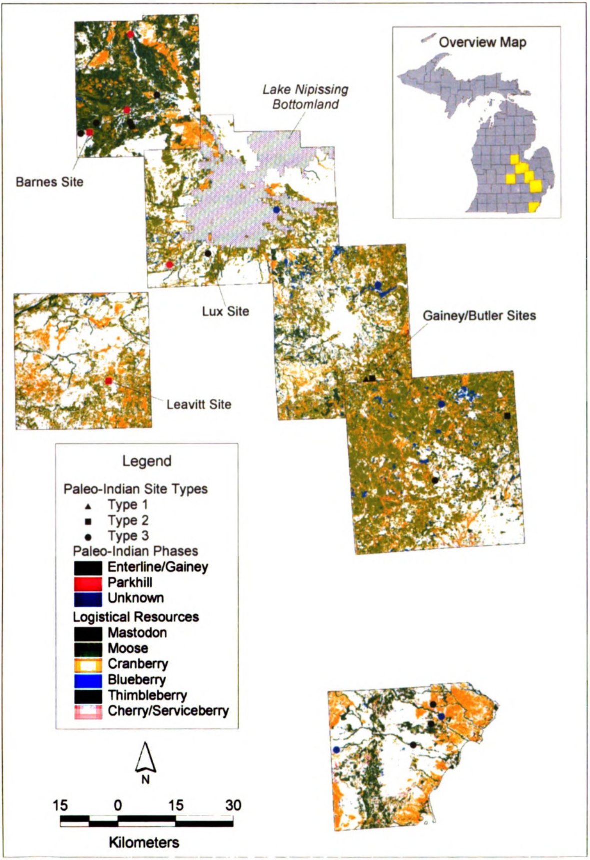

Figure 7.13. Model 3 Growing Season: High/Low Risk Logistical Resource Use Areas

driven by the presence of moose habitat during the growing season for Model 1 and especially for Model 3 (Figure 7.9 – 7.11). This suggests that a logistical adaptive strategy with an emphasis on moose hunting in the northern and southern reaches of the study area and an emphasis on caribou in the center was possible.

Interestingly the buffers generated from the cost-distance models did not generate significantly different summary results. A sample of these results is presented in Table 7.8. The primary reason for this may be the fact that the terrain across the study area is rather mundane in many areas. The results for early Paleo-Indian sites in regions with more significant variations in topographic relief yielded some of the greatest discrepancies between the circular and cost-distance buffers. For example, the Butler, Gainey, and Shelton Mastodon sites all had variations greater than one. Another likely explanation is that the heterogeneous distribution of resource patches is highly patterned in parts of the study area. Across Midland County, for example, resource patches are small and evenly interspersed. Therefore, regardless of the buffer's shape the result will be similar each time. Similar results would be derived in a completely homogenous environment.

Conclusions drawn about resource use using 1 kilometer and 10 kilometer buffers are tentative due to the lack of understanding about early Paleo-Indian mobility. Both buffer size and shape are in question. The circular nature of buffers implies that peoples always moved outward in all directions from an archaeological site. For example, the Barnes, Butler, and Gainey sites appear to be along the edge of regions with extensive resources from which early peoples would have accessed by traveling along a limited set of directions. In the case of the Barnes site, for instance, a buffer extending to the northeast of the site may better depict the actual region exploited by peoples occupying the site (Figure 7.14). Until Paleo-Indian adaptive strategies are better understood, utilizing multiple buffers will be the best means of examining the resource base within regions adjacent to activity areas.

7.2.2 INDIVIDUAL RESOURCES

Figures 7.15 – 7.21 depict the distribution of seven faunal habitats; beaver/giant beaver; dormant season caribou habitat; hare; mastodon; growing and dormant season moose habitat; and muskrat; and five floral habitats; blueberry; cherry/serviceberry; cranberry; thimbleberry; and white spruce that may have directly affected early Paleo-Indian resource use and settlement. To assess the habitat potential on and adjacent to each site, a 200 and 1-kilometer (km) buffer was used to summarize the habitat suitability for each site and species. Because Type 1 and 2 sites may have acted as residential base camps, a 10 km buffer was also used to summarize the habitat suitability around these sites. The 200-meter buffer size is also useful for evaluating the potential that an archaeological site was positioned adjacent to species that can survive in particularly small habitat patches, such as hare, that has a modern home range of "...only a few hundred yards in dense woods..." (Carreker 1985). The results generated from the cost-distance buffers are virtually identical to those calculated from the circular buffers. Therefore the summaries derived from the cost-distance buffers are not included in this discussion.

Although moose habitat appears to have been the most widespread of all game animal habitats during the late Pleistocene, the number of individuals per suitable region

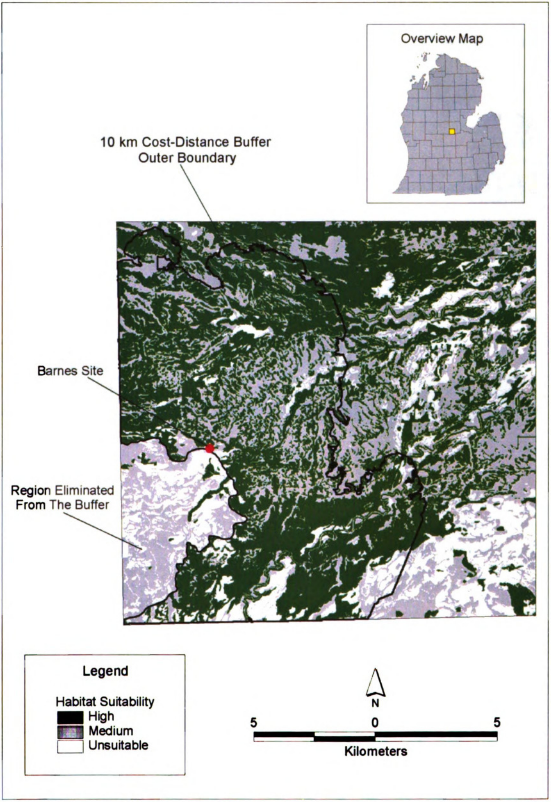

Figure 7.14. Adjusted 1 Kilometer Cost-Distance Buffer Around The Barnes Site

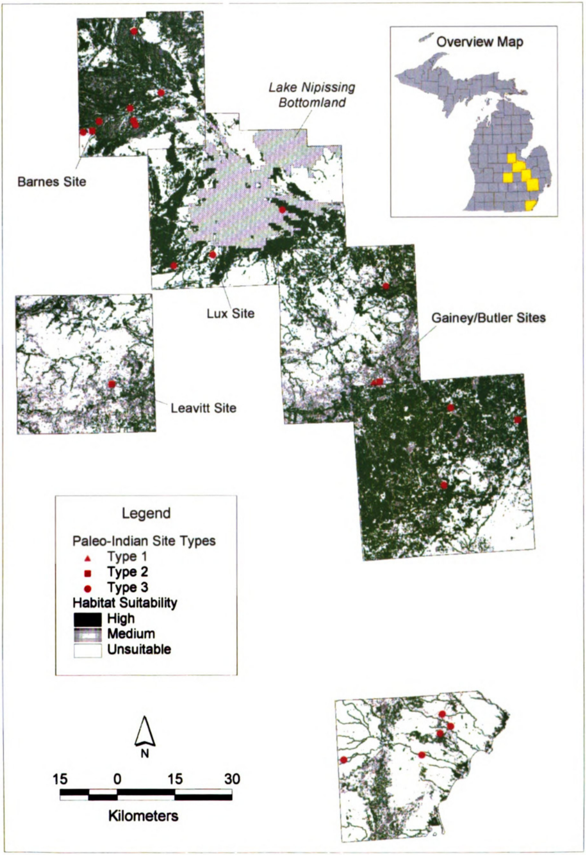

Figure 7.15. Caribou Habitat Suitability In Relation To Paleo-Indian Sites

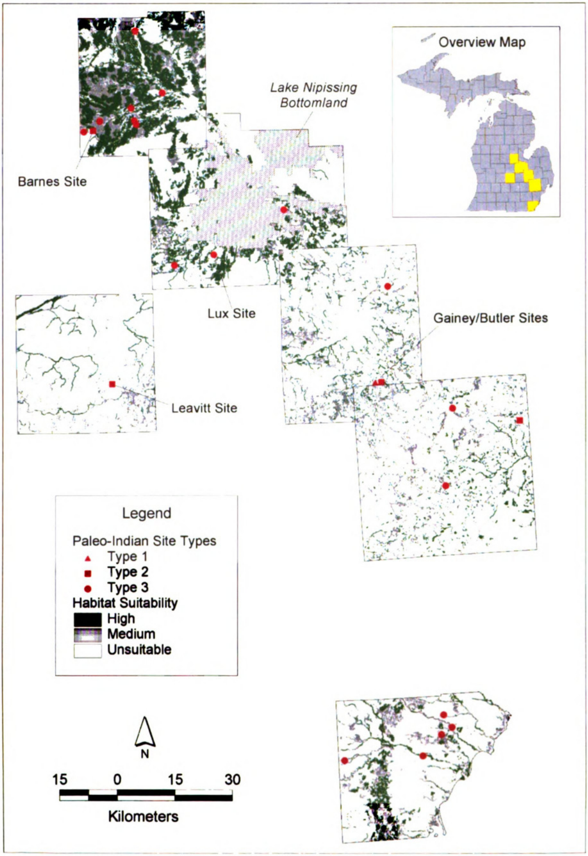

Figure 7.16. Mastodon Habitat Suitability In Relation To Paleo-Indian Sites

would have been much lower than caribou (Figure 7.17 – 7.18). Within modern boreal forests, the year-round density of moose is generally about two individuals per square kilometer (Allen et al. 1987). In addition, moose are often fairly solitary during the growing season and difficult to hunt (Nelson 1973). With the wide availability of thermal cover, moose would have been widely scattered throughout the winter as well. With over fifteen Paleo-Indian sites located in and around suitable dormant and growing season moose habitat, each with a value higher than four, moose were a likely subsistence choice for peoples occupying these sites and may have played some role in early hunter/gatherer subsistence (Table 7.14). However, there is little doubt that the survival of early Paleo-Indians required the utilization of other resources for subsistence.

Caribou, with their much higher densities and predictable behavior, were likely targets of early Paleo-Indian groups (Figure 7.15) (Spiess 1979, Storck and Spiess 1994, Jackson 1997, Simons 1997). Nearly the same numbers of Paleo-Indian sites were adjacent to favorable caribou habitat as they were to moose habitat (Table 7.14). With the much higher density of caribou during the dormant season and based on Simons' (1997) and Jackson's (1997) interpretations, it is highly likely that caribou hunting played a significant role in decisions related to early Paleo-Indian settlement and subsistence. The dormant season caribou habitat model, produced in Chapter 4, suggests that the northeasterly trending interlobate region occupying the central part of the study area fits into Skoog's (1968) description of a "center of habitation" for migratory caribou (Figure 7.15). Simons (1997) explanation of the Gainey site as a location from which caribou were intercepted appears to be correct. However, the Gainey site is also located within a region that would have been favorable for moose hunting (Table 7.14); explaining why

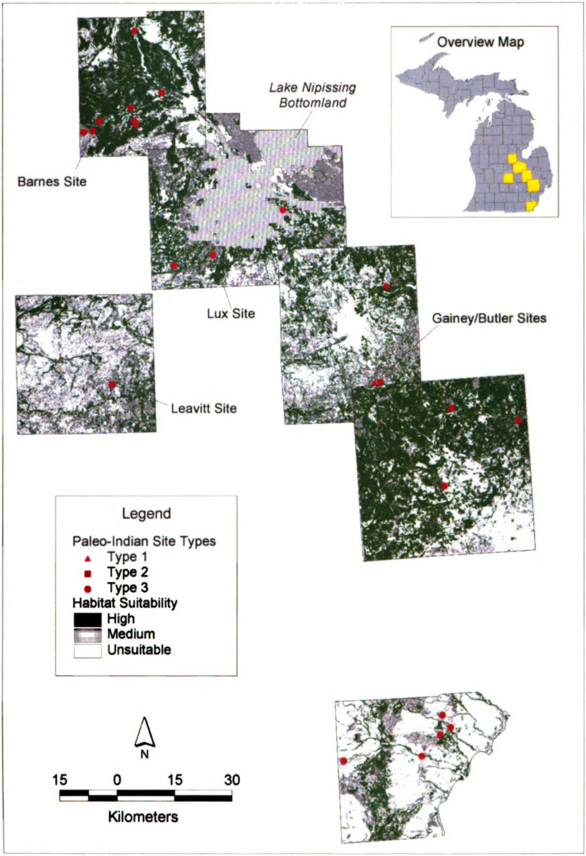

Figure 7.17. Summer Moose Habitat Suitability In Relation To Paleo-Indian Sites

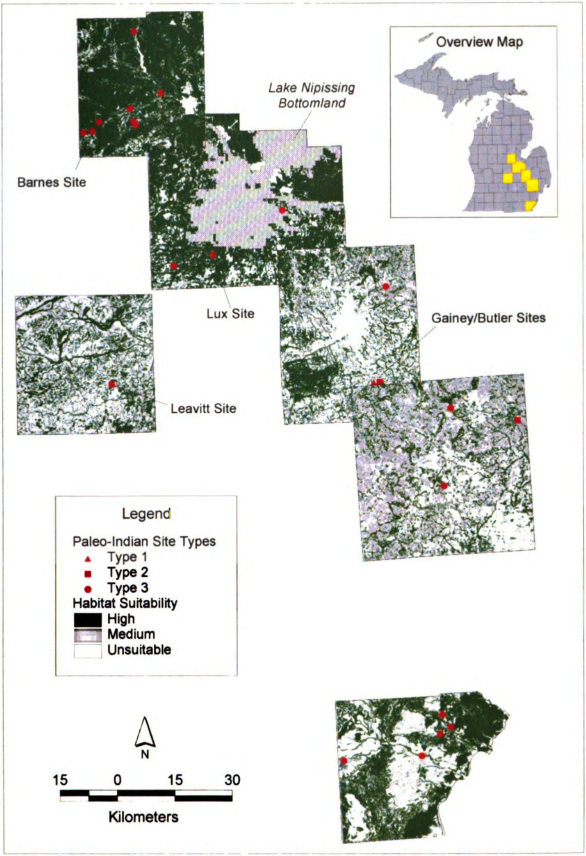

Figure 7.18. Winter Moose Habitat Suitability In Relation To Paleo-Indian Sites

Table 7.14. Large Game Habitat Suitability Rankings within 200 Meters, and 1 and 10 Kilometers of Each Paleo-Indian Site

Site	Name	Type	Phase	Caribou 200m	Caribou 1km	Caribou 10km	Mastodon 200m	Mastodon 1km	Mastodon 10km	Moose Sum. 200m	Moose Sum. 1km	Moose Sum. 10km	Moose Win. 200m	Moose Win. 1km	Moose Win. 10km
20GS49	Gainey	Type 1	Gainey	7.5	6.06	5.62	0	1.11	1.53	3.76	5.72	5.49	0	2.44	3.7
20GS104	Butler	Type 2	Gainey	2.91	3.83	5.76	3.09	2.24	1.38	3.47	4.11	5.75	3.71	3.32	3.75
20CL81	Leavitt	Type 2	Parkhil	3.91	4.81	3.33	0	0.07	0.59	3.72	5.25	4.23	2.23	4.79	3.81
20MD1	Barnes	Type 2	Parkhill	2.21	4.53	6.53	2.79	4.54	6.32	3.51	5.87	7.61	4.14	6.7	8.66
20OK135	N/A	Type 2	Gainey	1.08	6.28	7.36	0.73	0.44	0.89	4.62	7.39	8.07	6.85	5.48	5.33
20SA196	Lux	Type 3	Enterline	3.55	1.66		0	0.43		7.16	5.75		9.83	8.82	
20MD81	N/A	Type 3	Gainey	2.32	1.86		0	0.79		5.7	4.49		9.8	7.51	
20MD124	Porter 1	Type 3	Gainey	4.91	6.13		3.48	6.29		5.52	7.47		5.71	7.64	
20MD472	Varner Site	Type 3	Gainey	0.94	3.84		0.94	3.32		0.94	4.86		4.86	7.77	
20MD445	N/A	Type 3	Gainey	7.57	5.86		5.44	5.73		5.6	6.15		7.27	7.09	
20MD423	N/A	Type 3	Gainey	6.57	7.48		6	5.96		6.77	7.76		10	9.93	
20OK36	N/A	Type 3	Gainey	7.89	6.44		0.96	1.51		7.89	6.23		5.87	6.32	
20MR7	Corcoran	Type 3	Gainey	5.24	2.12		3.97	0.68		4.1	1.95		6.69	5.69	
20MR131	N/A	Type 3	Gainey	0	1.4		0	1.54		0.34	1.87		0.57	2.08	
20MR122	Gethsemane Cemetery	Type 3	Gainey	5.14	4.81		0.7	2.16		4.04	3.52		6.74	5.59	
20MD255	N/A	Type 3	Parkhill	5.64	5.81		2.93	4.23		6.07	6.21		8.33	8.46	
20MD328	Kruger	Type 3	Parkhill	3.05	5.45		2.31	5.56		5.09	6.32		6.39	6.64	
20SA1000	Burk 71	Type 3	Parkhill	5.83	7.17		2.59	3.55		6.98	5.58		6.96	6.89	
20SA211	Kralosky	Type 3	Unknown	10	9.94		3.31	3.74		4.1	5.12		4.04	5.02	
20GS69	N/A	Type 3	Unknown	3.29	6.06		0.04	0.56		3.29	6.2		1.25	3.7	
20OK394	Shelton Mastodon	Type 3	Unknown	7.88	8.03		1.54	0.71		8.53	8.88		5.22	5.8	
20MR582	Meiring	Type 3	Unknown	4.35	2.02		3.94	1.39		7.16	2.76		9.61	6.47	
20MR296	Petteys d-1	Type 3	Unknown	4.57	1.63		1.4	0.64		0.79	1.13		0.79	1.58	

the Gainey site received high rankings for both Models One and Three. Although Gainey has been interpreted as a large residential camp (Jackson 1997), it appears possible that the site represents the remnants of repeated reoccupation by small groups, possible family units, utilizing a logistical resource use strategy in pursuit of caribou and moose (Tables 7.3 – 7.4).

So little is known about the behavior of mastodon that the limited distribution of its habitat estimated by the habitat model constructed for this research may be greatly underestimating their true habitat extent (Figure 7.16). The simulated habitat distribution probably more accurately reflects the setting in which mastodon remains are more likely to be preserved and recovered than the entire habitat selection by the mastodon. In all likelihood, mastodon could have utilized coniferous vegetation (Holman 1995) that would have greatly expanded its habitat range across the study area. However, if aspen and birch leaves and twigs were indeed the preferred species of the mastodon, as there dental structure seems to indicate (Holman 1975, 1995), Midland County would have been a primary region in which to pursue the species. Six of the eight early Paleo-Indian sites identified in Midland County, including the region adjacent to the Barnes site, received suitable rankings for mastodon habitat indicating that mastodon was a viable game species in this region (Table 7.14). Unfortunately, none of the mastodon discoveries from Midland County have yielded evidence of either butchery or scavenging by early hunters. The fact that many mastodon finds lack precise provenances (Abraczinskas 1993) and that the overwhelming majority of recoveries were not conducted using systematic excavations, (Fisher 1986) suggests there is relatively little evidence from which to test assumptions made about hunter/gatherer utilization of the species.

Due to its outstanding hide quality and fat content, beaver was often sought by hunter/gatherer groups that occupied the boreal forest (Rogers 1972, Winterhalder 1981b). Based on ethnographic accounts, it seems likely that early Paleo-Indians would have utilized the modern beaver and its significantly larger relative, the giant beaver. In addition, the discovery of beaver remains at the Bull Brook site in Massachusetts supports the notion that early Paleo-Indians occupying the Great Lakes Region may have utilized this species (Spiess et al. 1985). Simulations for Midland County indicate the region would have been highly favorable for aspen and birch forests, the preferred food niches of the modern beaver. In addition, the large number of wetlands in the region supports the assumption that Midland County had very favorable habitats for both modern and giant beaver during the late Pleistocene (Figure 7.19). Both 20MD445 and 20MD423, located in southern Midland County, obtained high rankings for beaver habitat (Table 7.15).

Although hare is considered starvation food by some hunter/gatherers (Rogers 1972), early Paleo-Indian utilization of the species was likely in the Great Lakes region. Fragmentary remains of hare, possibly snowshoe or arctic hare, were recovered from the Udora site located in Central Ontario (Storck and Spiess 1994). Although the extent to which hare was a part of Paleo-Indian subsistence is unknown, the remains located at Udora, which also included arctic fox (Alopex lagopus), do indicate that small game were viable resources for early hunter/gatherers occupying the Great Lakes region. Despite the wide distribution of potential hare habitat throughout the study area, the regions in and

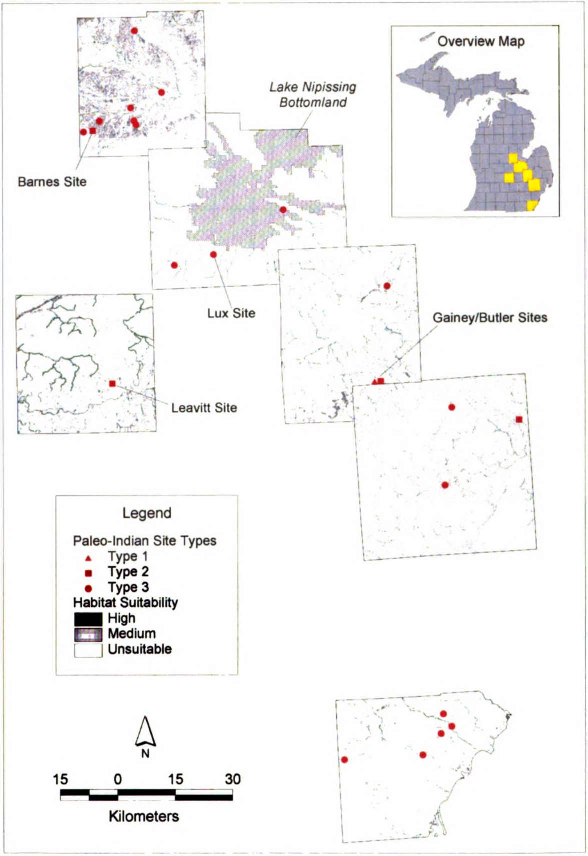

Figure 7.19. Beaver Habitat Suitability In Relation To Paleo-Indian Sites

Table 7.15. Small Game Habitat Suitability Rankings within 200 Meters, and 1 and 10 Kilometers of Each Paleo-Indian Site

Site	Name	Type	Phase	Beaver 200m	Beaver 1km	Beaver 10km	Hare 200m	Hare 1km	Hare 10km	Muskrat 200m	Muskrat 1km	Muskrat 10km
20GS49	Gainey	Type 1	Gainey	0	1.06	1.23	0	0.99	1.4		1.81	1.4
20GS104	Butler	Type 2	Gainey	2.44	1.8	1.09	2.53	2.14	1.4	2.41	1.66	1.26
20CL81	Leavitt	Type 2	Parkhil	0	0.06	0.49	1	1.43	1.1	0.33	0.98	0.85
20MD1	Barnes	Type 2	Parkhill	2.64	4.68	5.9	1.46	1.25	2.1	0.47	1.11	1.09
20OK135	N/A	Type 2	Gainey	0.73	0.27	0.56	2.59	1.05	1.3	0.86	0.57	0.76
20SA196	Lux	Type 3	Enterline	0	0.28		0	0.04			0	
20MD81	N/A	Type 3	Gainey	0	0.1		1.39	1.06			0	
20MD124	Porter 1	Type 3	Gainey	2.89	5.32		1.69	1.76		1.76	1.46	
20MD472	Varner Site	Type 3	Gainey	0	1.8		2.35	3.02			0.3	
20MD445	N/A	Type 3	Gainey	8.26	6.21		2.5	2.48			0.85	
20MD423	N/A	Type 3	Gainey	10	9.52		4.84	3.16		5.87	3.63	
20OK36	N/A	Type 3	Gainey	0.96	1.15		2	2.64		1.56	2.67	
20MR7	Corcoran	Type 3	Gainey	1.29	0.47		3.96	2.93			0	
20MR131	N/A	Type 3	Gainey	0	0.93		0.43	2.7			0.59	
20MR122	Gethsemane Cemetery	Type 3	Gainey	0	1		3.48	3.45			0.22	
20MD255	N/A	Type 3	Parkhill	1.7	3.48		3.12	3.04		0.65	1.51	
20MD328	Kruger	Type 3	Parkhill	2.13	5.2		0.51	1.2		0.09	0	
20SA1000	Burk 71	Type 3	Parkhill	0.86	2.54		0.35	0.48			0.35	
20SA211	Kralosky	Type 3	Unknown	0	0.53		0	0			0.07	
20GS69	N/A	Type 3	Unknown	0	0.55		0.04	0.27			0.06	
20OK394	Shelton Mastodon	Type 3	Unknown	1.52	0.57		1.59	1.28		2.45	1.24	
20MR582	Meiring	Type 3	Unknown	0.56	0.89		4.69	3.44		0.56	0.59	
20MR296	Petteys d-1	Type 3	Unknown	1.4	0.65		3.69	1.77			0	

around only two sites received suitable rankings for the species (Figure 7.20, Table 7.15). Hare may have been used as a secondary resource that was harvested while in pursuit of other species because of its low fat content and small size. This trend seems to indicate that more intangible objectives, such as taste, played a role in the resource choices of Paleo-Indians.

Only site 20MD423, located in southern Midland County, was located adjacent to a significant region of suitable muskrat habitat (Figure 7.21, Table 7.15). Much like the hare, muskrat would have had a relatively low subsistence value due to its small size and lack of fat. However, the region may have been highly favorable for a diverse subsistence economy because early Paleo-Indian sites in Midland County obtained suitable rankings for all game species examined in this research.

Although cherry and serviceberry were likely common during the late Pleistocene in Lower Michigan, few Paleo-Indian sites were located adjacent to or within these cover types (Figure 7.22, Table 7.16). Thimbleberry, on the other hand, received suitable rankings at nine Paleo-Indian sites (Table 7.16). These rankings may be misleading, however, because although widely distributed throughout the study area as an understory (Figure 7.23), the species is not very productive in regions with competition (Rook 1999). Throughout much of the study area, thimbleberry was probably more critical for moose habitat than Paleo-Indian subsistence because the leaves of the plants are eaten by moose (Allen et al. 1987). Despite the fairly wide distribution of blueberry (Figure 7.24), Paleo-Indian sites received very low rankings for this species (Table 7.17). Due to the overall basic nature of the soils across the study area, blueberry production may have been relatively low, thereby making the resource less appealing. After fires passed through

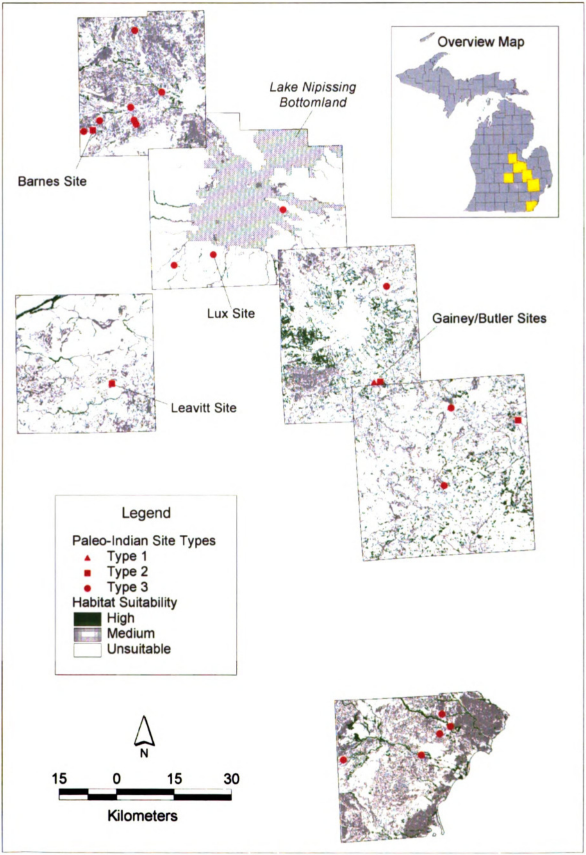

Figure 7.20. Hare Habitat Suitability In Relation To Paleo-Indian Sites

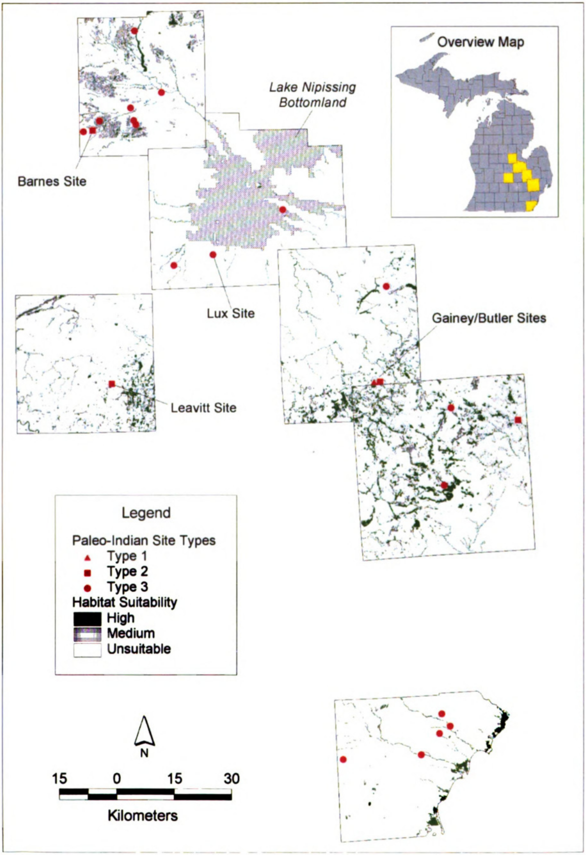

Figure 7.21. Muskrat Habitat Suitability In Relation To Paleo-Indian Sites

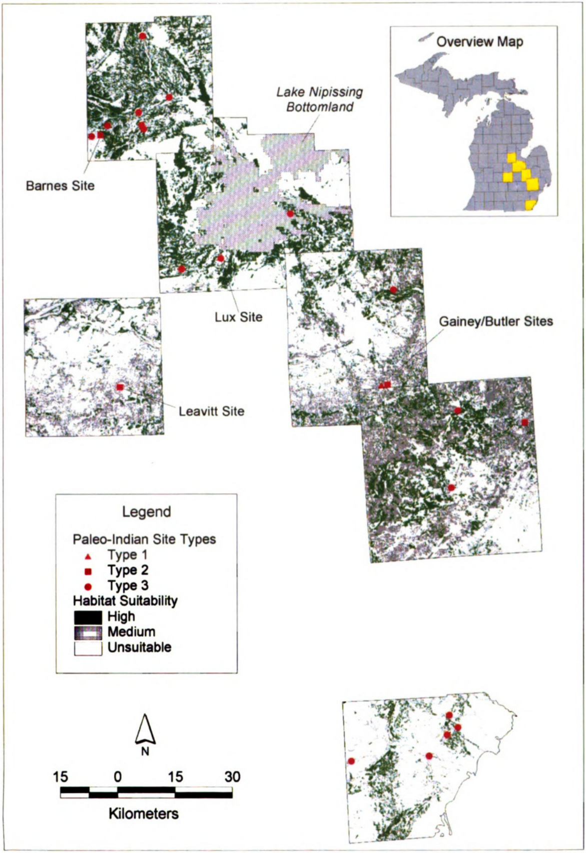

Figure 7.22. Cherry/Serviceberry Habitat Suitability In Relation To Paleo-Indian Sites

Table 7.16. Tree/Shrub Habitat Suitability Rankings within 200 Meters, and 1 and 10 Kilometers of Each Paleo-Indian Site

Site	Name	Type	Phase	Cherry/SB 200m	Cherry/SB1km	Cherry/SB 10km	Thimble. 200m	Thimble. 1km	Thimble. 10km
20GS49	Gainey	Type 1	Gainey	3.76	4.54	3.63	3.76	4.65	4.39
20GS104	Butler	Type 2	Gainey	0.95	1.89	3.86	4.12	4.02	4.42
20CL81	Leavitt	Type 2	Parkhil	3.17	3.09	2.3	5	4.61	4.97
20MD1	Barnes	Type 2	Parkhill	1.09	3.37	4.22	5.61	3.97	3.13
20OK135	N/A	Type 2	Gainey	3.76	4.49	4.98	3.76	5.06	4.35
20SA196	Lux	Type 3	Enterline	3.55	1.38		3.87	5.09	
20MD81	N/A	Type 3	Gainey	0	0.22		6	5.83	
20MD124	Porter 1	Type 3	Gainey	2.05	4.33		4.84	3.44	
20MD472	Varner Site	Type 3	Gainey	0.94	2.13		3.09	3.08	
20MD445	N/A	Type 3	Gainey	3.09	2.78		4.14	3.98	
20MD423	N/A	Type 3	Gainey	1.93	4.72		4.84	2.86	
20OK36	N/A	Type 3	Gainey	3.93	3.03		3.7	3.39	
20MR7	Corcoran	Type 3	Gainey	2.88	1.4		3.63	3.78	
20MR131	N/A	Type 3	Gainey	0.34	0.67		6	5.11	
20MR122	Gethsemane Cemetery	Type 3	Gainey	0.57	1.13		5.61	5.57	
20MD255	N/A	Type 3	Parkhill	3.68	3.31		0.39	1.95	
20MD328	Kruger	Type 3	Parkhill	3.83	4.29		5.16	3.65	
20SA1000	Burk 71	Type 3	Parkhill	3.93	4.08		2.76	3.19	
20SA211	Kralosky	Type 3	Unknown	4.1	5.11		3.54	2.93	
20GS69	N/A	Type 3	Unknown	2.54	4.92		5.87	5.15	
20OK394	Shelton Mastodon	Type 3	Unknown	5.94	6.16		3.49	4.47	
20MR582	Meiring	Type 3	Unknown	4.34	1.6		2.6	3.08	
20MR296	Petteys d-1	Type 3	Unknown	0.47	0.33		5.53	5.73	

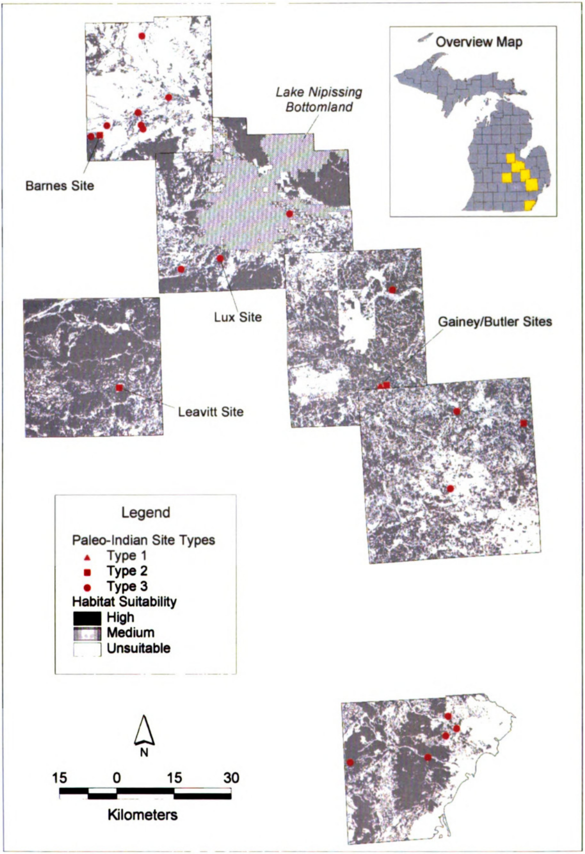

Figure 7.23. Thimbleberry Habitat Suitability In Relation To Paleo-Indian Sites

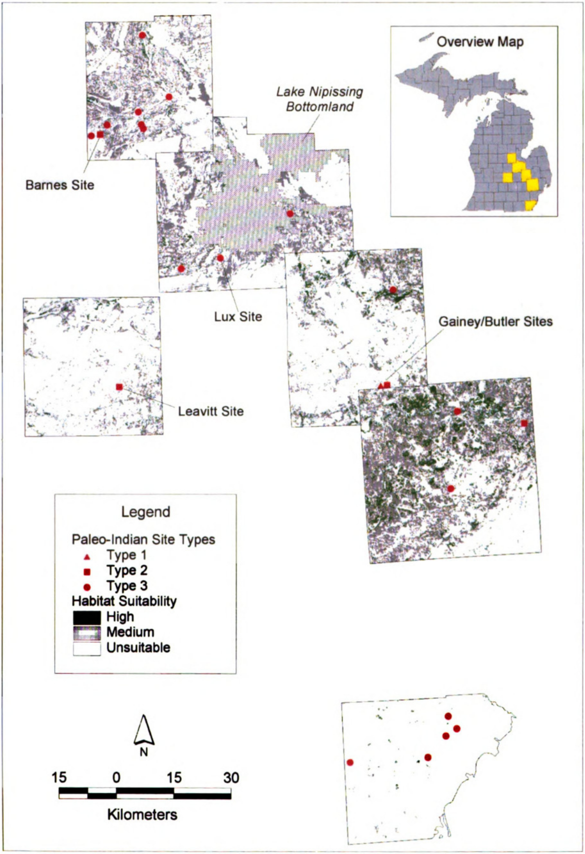

Figure 7.24. Blueberry Habitat Suitability In Relation To Paleo-Indian Sites

Table 7.17. Shrub Habitat Suitability Rankings within 200 Meters, and 1 and 10 Kilometers of Each Paleo-Indian Site

Site	Name	Type	Phase	Blueber. 200m	Blueber. 1km	Blueber. 10km	Cranber. 200m	Cranber. 1km	Cranber. 10km
20GS49	Gainey	Type 1	Gainey	2.24	0.88	1.99		1.64	1.92
20GS104	Butler	Type 2	Gainey	0.57	1.18	2.13	3.14	2.45	1.9
20CL81	Leavitt	Type 2	Parkhil	0.83	1.59	0.84	1.84	3.04	2.53
20MD1	Barnes	Type 2	Parkhill	0.09	1.93	2.46	1.66	2.04	3.02
20OK135	N/A	Type 2	Gainey	0	3.24	4.12	3.74	1.53	1.86
20SA196	Lux	Type 3	Enterline	2.13	1.01		3.87	4.72	
20MD81	N/A	Type 3	Gainey	0	0.1		6	4.47	
20MD124	Porter 1	Type 3	Gainey	1.16	2.37		2.53	2.29	
20MD472	Varner Site	Type 3	Gainey	0.57	1.06		3.91	4.78	
20MD445	N/A	Type 3	Gainey	1.86	1.63		2.5	2.89	
20MD423	N/A	Type 3	Gainey	1.16	2.81		4.84	3.39	
20OK36	N/A	Type 3	Gainey	3.43	1.89		3.33	4.14	
20MR7	Corcoran	Type 3	Gainey	0	0		3.96	3.98	
20MR131	N/A	Type 3	Gainey	0	0			1.6	
20MR122	Gethsemane Cemetery	Type 3	Gainey	0	0		3.74	2.88	
20MD255	N/A	Type 3	Parkhill	4.72	2.21		3.9	4.5	
20MD328	Kruger	Type 3	Parkhill	0.79	2.16		1.05	1.49	
20SA1000	Burk 71	Type 3	Parkhill	3.78	2.49		3.08	2.12	
20SA211	Kralosky	Type 3	Unknown	2.46	3.07				
20GS69	N/A	Type 3	Unknown	1.23	3.33		0.07	0.49	
20OK394	Shelton Mastodon	Type 3	Unknown	4.41	4.61		3.26	2.29	
20MR582	Meiring	Type 3	Unknown	0	0		5.66	4.85	
20MR296	Petteys d-1	Type 3	Unknown	0	0		0.79	1.09	

portions of Lower Michigan, thimbleberry and blueberry production would have increased significantly (Rook 1999), allowing Paleo-Indians to more actively pursue these species. Five archaeological sites received suitable values for cranberry habitat (Table 7.17), which has a wider distribution (Figure 7.25). This species appears a viable resource Paleo-Indians utilized across the central and southern regions of the study area.

The low rankings that nearly all the sites in this study obtained for cherry, serviceberry, and blueberry may be deceiving because tools, in particular projectile points, used primarily for hunting activities, were used to definitively assign archaeological sites to the early Paleo-Indian period for this research. As a result, further survey work is needed in regions favorable for gathering to identify potential sites that may be related to plant processing. Unfortunately, this may be a difficult, or impossible, task because as noted previously, the tools utilized in gathering, such as baskets or hide containers, may have long since vanished.

A final intriguing pattern uncovered during this study was the correlation between archaeological site distribution and white spruce habitat (Figure 7.26). All the Type 2 sites were located within, on the edge of, or were surrounded by pure stands of spruce (Table 7.18). With the exception of two Type 3 sites, remaining Paleo-Indian activity areas were also located within, or on the edge of pure and or mixed stands of white spruce. White spruce provides important thermal cover for faunal species such as moose and was likely used by humans during the dormant season. The placement of many sites within pure spruce stands that are generally unproductive suggests that these locations may have been chosen for their thermal cover, in addition to the resource patches to which they were adjacent. White spruce was given the highest rating when simulating

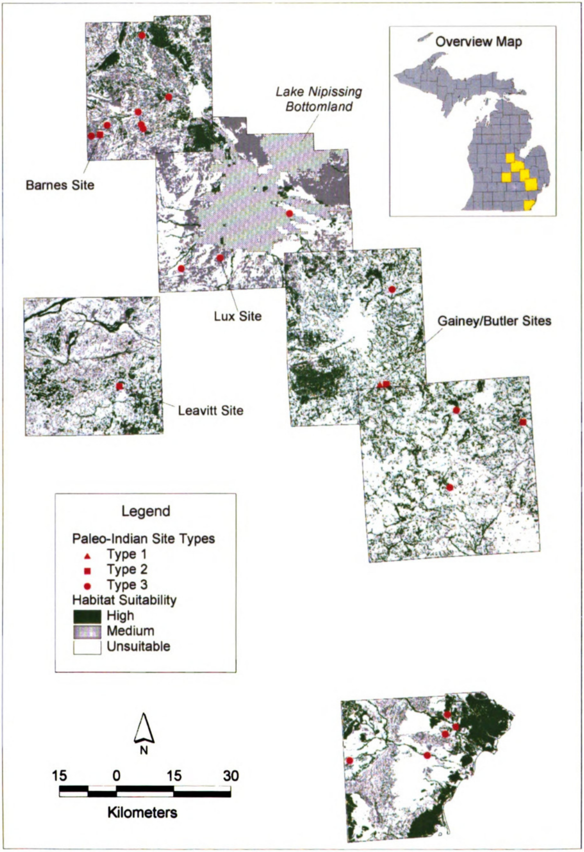

Figure 7.25. Cranberry Habitat Suitability In Relation To Paleo-Indian Sites

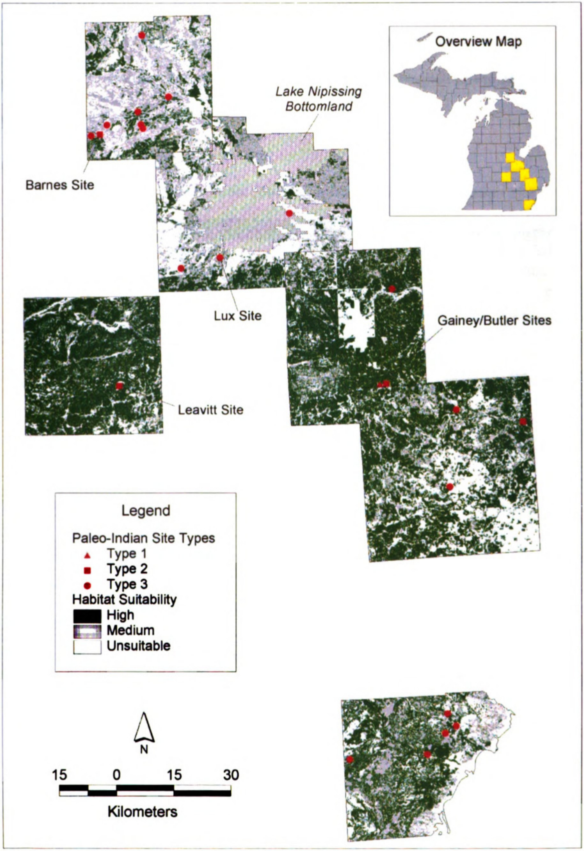

Figure 7.26. White Spruce Habitat Suitability In Relation To Paleo-Indian Sites

the potential for shelter (Appendix B: Table B.75) within the logistical and residential dormant season settlement models. The large number of sites in or near spruce stands also supports the assertion that early Paleo-Indians primarily occupied Lower Michigan during the dormant season.

Table 7.18. White Spruce Stand Quality Located At Each Paleo-Indian Site

Site	Name	Type	Phase	White Spruce
20GS49	Gainey	Type 1	Gainey	Surrounded
20OK135	N/A	Type 2	Gainey	Edge/Pure
20GS104	Butler	Type 2	Gainey	Mixed/Pure
20CL81	Leavitt	Type 2	Parkhill	Pure
20MD1	Barnes	Type 2	Parkhill	Pure
20SA196	Lux	Type 3	Enterline	Mixed
20MR131	N/A	Type 3	Gainey	Pure
20OK36	N/A	Type 3	Gainey	Pure
20MD445	N/A	Type 3	Gainey	Pure
20MD124	Porter 1	Type 3	Gainey	Pure
20MD472	Varner Site	Type 3	Gainey	Edge/Pure
20MR122	Gethsemane Cemetery	Type 3	Gainey	Mixed
20MR7	Corcoran	Type 3	Gainey	Mixed
20MD423	N/A	Type 3	Gainey	Mixed
20MD81	N/A	Type 3	Gainey	Mixed
20MD328	Kruger	Type 3	Parkhill	Pure
20SA1000	Burk 71	Type 3	Parkhill	Edge/Mixed
20MD255	N/A	Type 3	Parkhill	No
20OK394	Shelton Mastodon	Type 3	Unknown	Mixed/Pure
20MR582	Meiring	Type 3	Unknown	Mixed
20MR296	Petteys d-1	Type 3	Unknown	Edge/Pure
20GS69	N/A	Type 3	Unknown	Pure
20SA211	Kralosky	Type 3	Unknown	No

Spruce was recovered from a feature at the Leavitt site in Clinton County, confirming the use of this species by Paleo-Indians for firewood (Egan 1993). Although a large portion of the region within 1000 meters of Leavitt site would have been highly favorable for white and black spruce, there are a number of mixed spruce stands including an area devoid of spruce within this buffer. The mixed nature of some of these stands would account for the basswood (*Tilia* spp.) and oak (*Quercus* spp.) also located at the site. Despite its poor burning qualities, spruce may have been used as firewood at the Leavitt site because white and black spruce was indeed the dominant species in the area. The poor burning quality of spruce also indicates that early Paleo-Indian sites were probably not located within or adjacent to spruce stands because it provided access to wood for burning. Spruce may have been used in the construction of spear shafts and small shelters, although evidence is lacking, however, it seems more likely that spruce, and particularly white spruce, would have been utilized for its thermal cover characteristics.

7.3 SUMMARY

After examining the simulations produced within Chapters 4 and 6, several conclusions can be made about the behaviors that most likely occurred in Lower Michigan at documented early Paleo-Indian activity areas or sites (Figure 7.27):

1) Early Paleo-Indians appear to have utilized a somewhat generalized foraging strategy, harvesting mainly large game and to a lesser extent utilizing small game such as beaver and possibly plant resources. Although the region in and around 20OK135, Gainey, Butler, and Leavitt would have supported longer term residential settlement (Table 7.4), early Paleo-Indian settlement patterns across Lower Michigan probably was made up of mainly: a) logistical extraction areas or "locations" (Binford 1980), Type 3 sites, b) small logistical camps, Type 2 sites, and c) longer term logistical camps, such as the Leavitt site, and locales with repeated longer term occupation, the Gainey site. These sites were logistical in nature in that peoples moved to the resource patches and resource extraction activities probably took place at the sites. This assumption is supported by the higher rankings for residential settlement models constructed around a resource use strategy that placed higher weight on individual patches.
2) Lower Michigan was primarily occupied during the dormant season with limited activity occurring during the growing season. During the growing season many

early peoples may have moved into southern and central Ontario in pursuit of caribou and other resources (Figure 7.27).

3) Caribou hunting most likely occurred across the central part of the study area with moose hunting possibly dominating in the northern and southern reaches of the region. Thus, the strategies across the study area may not necessarily have been uniform, and a single model interpretation may be inappropriate.
4) The region in and around Midland County would have been very productive for a wide range of species during the late Pleistocene. Within this region a generalized foraging strategy most likely occurred.
5) White spruce, with its ability to provide thermal cover, may have been a driving force behind choices about settlement placement during the dormant season. This also supports the notion that early peoples occupied the region primarily during the dormant season.
6) Water was a minor factor in settlement placement. This may be, in part, because water, in the form of snow, would have been readily available during the winter if peoples primarily occupied the region during the dormant season. Water would have been more widely distributed during the growing season as well. In addition, Paleo-Indians may have carried water with them in some manner.
7) Paleo-Indian hunter/gatherers appear to have minimized risk-taking within a heterogeneous boreal forest ecosystem by utilizing multiple resources, while often coupling this with the utilization of a reliable and easily obtainable resource such as caribou.
8) In general, the results presented in this chapter indicate that early Paleo-Indians who occupied Lower Michigan adopted a dynamic foraging strategy. Both logistic and residential settlement strategies were utilized, while groups may have focused on a single resource, such as caribou, in the central portion of the study area. The results indicate that a diverse economy was supported in the northern part of the study area.
9) Lastly, the chi-square results (Appendix C) demonstrate that many of the settlement patterns observed within this research are not due to chance alone.

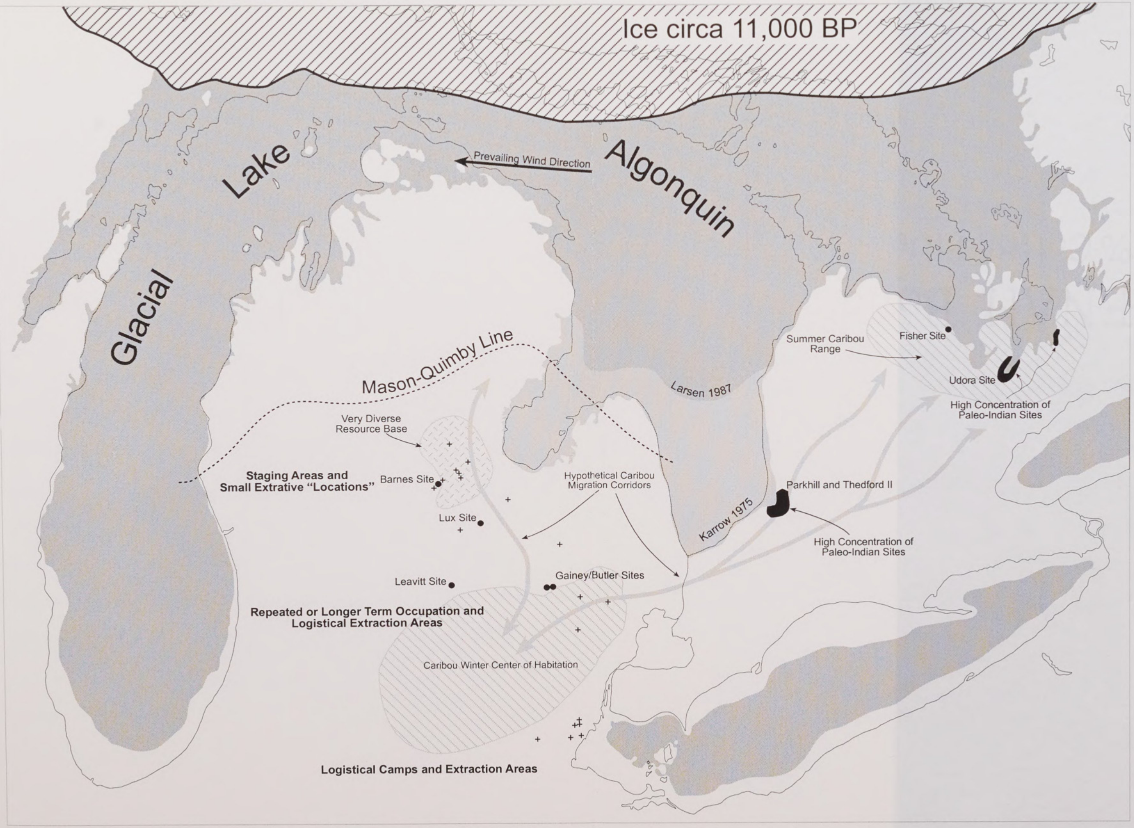

Figure 7.27. Early Paleo-Indian Archaeological Site Locations In Relation to Key Resource Areas (Note: The Presence of Multiple Mobility Strategies in Southeastern Michigan)

Chapter VIII

CONCLUSIONS

Great Lakes Paleo-Indian research has demonstrated that early hunter/gatherers throughout the region utilized a mix of large and small game including caribou, hare, arctic fox, and possibly mastodon and fish (Cleland 1965, Fisher 1986, Storck and Spiess 1994, Storck 1997, Jackson 1997, Simons 1997). However, systematic studies that examine the extent to which these and other potential resources were utilized are lacking (Jackson and McKillop 1991). In addition, very little is known about the adaptive strategy early Paleo-Indians employed while procuring resources. To address these issues a decision based hunter/gatherer behavioral model was developed and used to simulate the location of activity areas based on three alternate hypothesis of subsistence and settlement behavior for the Gainey and Parkhill phases of the early Paleo-Indian period in Southeastern Lower Michigan. The first two hypotheses propose that during the dormant season, migratory caribou was the primary resource being utilized by early hunter/gatherers. The second hypothesis proposes that early peoples also occupied Southeastern Lower Michigan during the growing season when their subsistence strategy shifted toward a primary reliance on mastodon. Under the third hypothesis, early Paleo-Indians are assumed to have adopted a rather generalized foraging strategy in which both large and small games were harvested during the dormant season. In addition to large and small game, during the growing season plant resources would also have been harvested by Paleo-Indians.

Although not required, the simulations produced for each hypothesis were generated within the context of a Geographic Information System (GIS). The ability of the IDRISI GIS environment to simulate human decision-making based on the goals and objectives of a set of decision makers made it a logical choice to implement a spatially based hunter/gatherer behavioral model (Eastman et al. 1995, Eastman 1999). With its ability to combine multiple layers of spatial information, the GIS environment was also used to generate detailed paleoenvironmental reconstructions of the late Pleistocene. These data were then employed as input into the behavioral model, producing a series of models depicting the spatial distribution of hunter/gatherer activity areas based on each of the three hypothesis outlined in this research.

Once simulated, these activity areas were compared to the location of archaeological sites attributed to the early Paleo-Indian period. It was assumed that correspondence between simulated activity areas and the archaeological record provided a viable, but inconclusive explanation of the range of activities that took place at the site. A close match was identified between the archaeological record and the simulations generated for the dormant season for Hypotheses One and Three (Table 7.1, 7.6). However, the correspondence for the third hypothesis was slightly better. Although there was a fairly poor correspondence between the archaeological record and the growing season model within Hypothesis Two (Table 7.5), the growing season model for Hypothesis Three (Table 7.7) was better. These comparisons indicate that a somewhat generalized foraging strategy, centered on caribou and moose hunting, likely took place. The simulations also demonstrate that early Paleo-Indian resource use and settlement activities, although limited, probably did take place during the growing season as well.

During the growing season, moose and mastodon hunting may have been the primary activities while cranberry, blueberry, thimbleberry, cherry, and serviceberry gathering probably took place. Due to the lack of archaeological data, no definitive conclusions can be made regarding the use of plant materials. Many sites are located in regions that allowed access to plant resources (Figure 7.19 – 7.22), however, without further study conclusions about plant resource use are premature. In addition, with data lacking on water quality, estimations of fish resources during the late Pleistocene in streams and lakes could not be generated. Based on recent discoveries made at the Shelton Mastodon site (Shoshani and Smith 1996), Dutchess Cave (Spiess et al. 1985), Shawnee-Minisink (McNett 1985), and recent use wear analysis conducted by Tomenchuk (1997) at the Fisher site, the suggestion that early Paleo-Indians utilized fish resources seems plausible.

The results presented in the previous chapter also suggest that a logistical resource use strategy, in which small groups of foragers moved to individual resource patches, may have been preferred (Table 7.3 – 7.4). Such a strategy would enable foragers to take advantage of the heterogeneous nature of the boreal forest ecosystem. Type 1 and 2 sites did, however, receive higher rankings under the residential settlement model indicating that some Paleo-Indian sites may have acted as residential camps from which multiple resources could be acquired on logistical forays. The high-risk residential models had the highest rankings, suggesting that regions in around Type 1 and 2 sites were probably limited in their ability to provide access to a diverse set of resources. As a result, many of these larger activity areas my have acted as long term logistical camps at which multiple resources could be extracted without extended logistical forays. The Gainey site, located in a region with access to migratory and resident caribou herds (Figure 7.12), an easily attainable and reliable resource (Spiess 1979) during the dormant season, would have been the most likely area for long-term residential activities to take place. With access to large herds of caribou, early hunter/gatherers could also have gathered in larger groups.

8.1 IMPLICATIONS FOR FUTURE PALEO-INDIAN RESEARCH

This research has demonstrated how a detailed description of late Pleistocene ecosystems can be easily generated using a GIS. Such models have the power to alleviate stereotypes about Paleo-Indian resource use and settlement by providing an independent means through which to evaluate the archeological record. Detailed paleoenvironmental reconstructions can aid in limiting the range of possible subsistence choices. They also provide a very unique picture of the distribution of late Pleistocene ecosystems. In addition, the models presented throughout this research may provide the building blocks for the continued development of paleoenvironmental models. As other data sets become available, such as water quality, additional models can be constructed and other hypotheses tested.

8.2 CONTRIBUTION TO ANTHROPOLOGY

The behavioral model presented in this research provides a means to study the goals and objectives of a group of hunter/gatherers. In addition to its applicability to the study of prehistoric societies, the model can also aid research on modern hunter/gatherers. For example, within a modern culture, where the goals and objectives are not clearly understood, the model may be run and re-run to determine which results match the observed patterns found within a culture. Anthropologists can objectively reevaluate cultural data recorded in the ethnographic record. Once a firm set of criteria and objectives are generated for a culture, the model may be used as a tool for evaluating the affects of environmental and cultural change on indigenous cultures that may occur in the future. Such an approach may be particularly useful in regions where significant ecological and cultural changes are taking place.

The results presented in this research demonstrate that hunter/gatherers were flexible, utilizing a wide range of adaptive strategies, even within a relatively small region such as Lower Michigan. The suggestion that early peoples were able to switch between a logistical and residential settlement strategy, as the results from Model 1 and 3 indicate (Table 7.4), is evidence of this hypothesis. In addition, early hunter/gatherers occupied regions that would have allowed them to focus on a single reliable resource, such as migratory caribou, and a diverse set of resources including beaver, moose, and muskrat. The Barnes site was a likely staging area from which a diverse set of resources was harvested, while the Gainey site was a likely camp from which caribou were harvested. This pattern provides evidence that early hunter/gatherers utilized a flexible economy choosing both a diverse and focal strategy within the same region. As new subsistence data become available, these hypotheses may be further tested.

8.3 EVALUATION OF THE METHODOLOGY

The overarching methodology behind the behavioral model outlined within this work is rigorous for several reasons. First, the model is relatively easy to implement and is repeatable. Second, the approach is flexible and can accommodate a wide range of data. This flexibility also allows the model to be used at any scale, from site level to the regional level. Data with different units of measure, such as taste and soil dryness can be incorporated into a single model. Upon review, or due to new evidence, criteria scores and rankings may be changed and the model recalculated to produce updated results. Third, the data being entered into the model need not be highly accurate. In other words, the model can be run using different levels of accuracy bearing in mind that the final output will be no more accurate than the least accurate data set. Fourth, the model was designed to accommodate the hunter/gatherer decision-making process. In implementation, the design of the model enables the incorporation of the goals and desires of a group of hunter/gatherers being studied. Fifth, although relatively simple, the model can incorporate an unlimited amount of data layers. With the development of GIS, it has become increasingly easy to incorporate a large number of criteria, goals, and objectives into a model such as the one presented here. Lastly, once a set of criteria and objectives have been tested and entered into the behavioral model, the model can be used to predict the location of various activity areas on a landscape that has not undergone archaeological survey. This will aid archaeologists in the practical aspects of resource management by pinpointing regions that should be avoided during destructive land altering activities.

There are two primary limitations to the model presented here. First, the accuracy of the results is of course limited by the least accurate dataset entered into the model. As a result, it is recommended that great care be spent in developing factor weights and rankings, and that the data representing these criteria are well understood. Second, results generated within a multi-criterion approach are subject to the affects of error propagation. When uncertainty exists within the data entered into the model, error will propagate throughout the analysis (Eastman 1999). In addition, inaccuracies from different layers will combine, compounding the errors within the final output. This is a particularly acute problem for archaeologists who utilize data collected about the past, which frequently possess some degree of uncertainty (Jochim 1998). Compounding this shortcoming, testing the output of such models is frequently difficult because there is little data for comparison. To minimize the affects of error propagation, the output values can be reclassified into more generalized classes such as the high, medium, and low categories used to evaluate the results in this analysis. Error propagation has been encountered within this analysis of the early Paleo-Indian period, which has little floral or faunal evidence left to compare with the modeled results. Despite these limitations, the model developed for this study is able to provide new lines of evidence from which research strategies can be developed for the Paleo-Indian period. Lastly, further testing is needed to determine the full potential of the model.

APPENDICES

APPENDIX A:

Floral And Faunal Habitat Criteria For The Late Pleistocene

Table A.1. Black Spruce Overstory Habitat Model Criteria

Criteria	% Influence	Value Description	Value	Scaled Value
Soil Texture	50			
Textures		clay	C	6
		cobbly loam	CB-L	0
		cobbly loamy sand	CB-LS	0
		cobbly sandy loam	CB-SL	0
		clay loam	CL	5
		channery fine sandy loam	CN-FSL	0
		channery sandy loam	CN-SL	0
		fine sand	FS	0
		fine sandy loam	FSL	0
		gravelly loam	GR-L	0
		gravelly loamy sand	GR-LS	0
		gravelly sandy clay loam	GR-SCL	4
		gravelly sandy loam	GR-SL	0
		very gravelly sandy loam	GRV-SL	0
		loam	L	0
		loamy fine sand	LFS	0
		loamy sand	LS	0
		loamy very fine sand	LVFS	0
		loamy very fine sand, silt loam, very fine sandy loam	LVFS SIL VFSL	0
		mucky fine sand	MK-FS	8
		mucky loamy fine sand	MK-LFS	8
		mucky loamy sand	MK-LS	8
		mucky sand	MK-S	8
		mucky silty clay loam	MK-SICL	9
		mucky silt loam	MK-SIL	9
		mucky sandy loam	MK-SL	8
		muck	MUCK	10
		peat	PEAT	10
		sand	S	0
		sandy clay loam	SCL	4
		silty clay	SIC	6
		silty clay loam	SICL	5
		silt loam	SIL	5
		sandy loam	SL	0
		stony loam	ST-L	0
		variable	VAR	0
		very fine sandy loam	VFSL	0
Soil Moisture	50			
Drainage		well drained (DI ≤ 40)	W	0
		very poorly drained (DI ≥ 90)	VP	10

Table A.2. White Spruce Overstory Habitat Model Criteria

Criteria	% Influence	Value Description	Value	Scaled Value
Soil Texture	50	clay	C	10
Textures		cobbly loam	CB-L	10
		cobbly loamy sand	CB-LS	6
		cobbly sandy loam	CB-SL	8
		clay loam	CL	10
		channery fine sandy loam	CN-FSL	8
		channery sandy loam	CN-SL	8
		fine sand	FS	0
		fine sandy loam	FSL	8
		gravelly loam	GR-L	10
		gravelly loamy sand	GR-LS	6
		gravelly sandy clay loam	GR-SCL	9
		gravelly sandy loam	GR-SL	8
		very gravelly sandy loam	GRV-SL	8
		loam	L	10
		loamy fine sand	LFS	6
		loamy sand	LS	6
		loamy very fine sand	LVFS	6
		loamy very fine sand, silt loam, very fine sandy loam	LVFS SIL VFSL	6
		mucky fine sand	MK-FS	5
		mucky loamy fine sand	MK-LFS	5
		mucky loamy sand	MK-LS	5
		mucky sand	MK-S	5
		mucky silty clay loam	MK-SICL	5
		mucky silt loam	MK-SIL	5
		mucky sandy loam	MK-SL	5
		muck	MUCK	0
		peat	PEAT	0
		sand	S	0
		sandy clay loam	SCL	9
		silty clay	SIC	10
		silty clay loam	SICL	10
		silt loam	SIL	10
		sandy loam	SL	8
		stony loam	ST-L	10
		Variable	VAR	0
		very fine sandy loam	VFSL	8
Soil Moisture	50	excessively well drained (DI ≤ 20)	E	0
Drainage		well drained (DI 40)	W	10
		poorly – very drained (DI ≥ 80)	VP	0
Direct Competition	Constraint			
		reduce white spruce suitability values by black spruce potential		

Table A.3. Jack Pine Overstory Habitat Model Criteria

Criteria	% Influence	Value Description	Value	Scaled Value
Soil Texture	50			
Textures		clay	C	0
		cobbly loam	CB-L	8
		cobbly loamy sand	CB-LS	10
		cobbly sandy loam	CB-SL	8
		clay loam	CL	0
		channery fine sandy loam	CN-FSL	8
		channery sandy loam	CN-SL	8
		fine sand	FS	9
		fine sandy loam	FSL	8
		gravelly loam	GR-L	8
		gravelly loamy sand	GR-LS	10
		gravelly sandy clay loam	GR-SCL	0
		gravelly sandy loam	GR-SL	8
		very gravelly sandy loam	GRV-SL	8
		loam	L	0
		loamy fine sand	LFS	10
		loamy sand	LS	10
		loamy very fine sand	LVFS	10
		loamy very fine sand, silt loam, very fine sandy loam	LVFS SIL VFSL	10
		mucky fine sand	MK-FS	0
		mucky loamy fine sand	MK-LFS	0
		mucky loamy sand	MK-LS	0
		mucky sand	MK-S	0
		mucky silty clay loam	MK-SICL	0
		mucky silt loam	MK-SIL	0
		mucky sandy loam	MK-SL	0
		muck	MUCK	0
		peat	PEAT	0
		sand	S	9
		sandy clay loam	SCL	0
		silty clay	SIC	0
		silty clay loam	SICL	0
		silt loam	SIL	0
		sandy loam	SL	8
		stony loam	ST-L	8
		variable	VAR	0
		very fine sandy loam	VFSL	8
Soil Moisture	50			
Drainage		excessively - well drained (DI 20 - 40)	E - W	10
		somewhat poorly drained (DI ≥ 60)	SP	0
Direct Competition	Constraint			
		reduce jack pine suitability values by spruce potential		

Table A.4. Aspen/Birch Overstory Habitat Model Criteria

Criteria	% Influence	Value Description	Value	Scaled Value
Soil Texture	50			
Textures		clay	C	0
		cobbly loam	CB-L	9
		cobbly loamy sand	CB-LS	8
		cobbly sandy loam	CB-SL	9
		clay loam	CL	10
		channery fine sandy loam	CN-FSL	9
		channery sandy loam	CN-SL	9
		fine sand	FS	7
		fine sandy loam	FSL	9
		gravelly loam	GR-L	9
		gravelly loamy sand	GR-LS	8
		gravelly sandy clay loam	GR-SCL	0
		gravelly sandy loam	GR-SL	9
		very gravelly sandy loam	GRV-SL	9
		loam	L	10
		loamy fine sand	LFS	8
		loamy sand	LS	8
		loamy very fine sand	LVFS	8
		loamy very fine sand, silt loam, very fine sandy loam	LVFS SIL VFSL	8
		mucky fine sand	MK-FS	0
		mucky loamy fine sand	MK-LFS	0
		mucky loamy sand	MK-LS	0
		mucky sand	MK-S	0
		mucky silty clay loam	MK-SICL	0
		mucky silt loam	MK-SIL	0
		mucky sandy loam	MK-SL	0
		muck	MUCK	0
		peat	PEAT	0
		sand	S	7
		sandy clay loam	SCL	9
		silty clay	SIC	10
		silty clay loam	SICL	10
		silt loam	SIL	10
		sandy loam	SL	9
		stony loam	ST-L	9
		variable	VAR	0
		very fine sandy loam	VFSL	9
Soil Moisture	50			
Drainage		excessively drained (DI ≤ 20)	E	0
		well – moderately well drained (DI 40 - 50)	MW - SP	10
		very poorly drained (DI 90)	VP	0
Direct Competition	Constraint			
Species		reduce aspen/birch suitability values by spruce potential		
		reduce aspen/birch suitability values by jack pine potential		

Table A.5. Alder/Willow Overstory Habitat Model Criteria

Criteria	% Influence	Value Description	Value	Scaled Value
Soil Texture	50			
Textures		clay	C	9
		cobbly loam	CB-L	0
		cobbly loamy sand	CB-LS	0
		cobbly sandy loam	CB-SL	0
		clay loam	CL	8
		channery fine sandy loam	CN-FSL	0
		channery sandy loam	CN-SL	0
		fine sand	FS	0
		fine sandy loam	FSL	7
		gravelly loam	GR-L	0
		gravelly loamy sand	GR-LS	0
		gravelly sandy clay loam	GR-SCL	8
		gravelly sandy loam	GR-SL	0
		very gravelly sandy loam	GRV-SL	0
		loam	L	7
		loamy fine sand	LFS	6
		loamy sand	LS	6
		loamy very fine sand	LVFS	6
		loamy very fine sand, silt loam, very fine sandy loam	LVFS SIL VFSL	6
		mucky fine sand	MK-FS	10
		mucky loamy fine sand	MK-LFS	10
		mucky loamy sand	MK-LS	10
		mucky sand	MK-S	10
		mucky silty clay loam	MK-SICL	10
		mucky silt loam	MK-SIL	10
		mucky sandy loam	MK-SL	10
		muck	MUCK	10
		peat	PEAT	8
		sand	S	0
		sandy clay loam	SCL	8
		silty clay	SIC	9
		silty clay loam	SICL	8
		silt loam	SIL	8
		sandy loam	SL	7
		stony loam	ST-L	0
		variable	VAR	0
		very fine sandy loam	VFSL	7
Soil Moisture	50			
Drainage		moderately well drained (DI ≤ 50)	MW	0
		poorly drained (DI ≥ 70)	SP	10
Direct Competition	Constraint			
Species		reduce alder/willow suitability values by spruce potential		
		reduce alder/willow suitability values by jack pine potential		
		reduce alder/willow suitability values by aspen/birch potential		

Table A.6. Balsam Fir Understory Tree/Large Shrub Habitat Model Criteria

Criteria	% Influence	Value Description	Value	Scaled Value
Soil Texture	33.33			
Textures		clay	C	9
		cobbly loam	CB-L	6
		cobbly loamy sand	CB-LS	5
		cobbly sandy loam	CB-SL	6
		clay loam	CL	8
		channery fine sandy loam	CN-FSL	6
		channery sandy loam	CN-SL	6
		fine sand	FS	0
		fine sandy loam	FSL	6
		gravelly loam	GR-L	6
		gravelly loamy sand	GR-LS	5
		gravelly sandy clay loam	GR-SCL	8
		gravelly sandy loam	GR-SL	6
		very gravelly sandy loam	GRV-SL	6
		loam	L	7
		loamy fine sand	LFS	5
		loamy sand	LS	5
		loamy very fine sand	LVFS	5
		loamy very fine sand, silt loam, very fine sandy loam	LVFS SIL VFSL	5
		mucky fine sand	MK-FS	10
		mucky loamy fine sand	MK-LFS	10
		mucky loamy sand	MK-LS	10
		mucky sand	MK-S	10
		mucky silty clay loam	MK-SICL	10
		mucky silt loam	MK-SIL	10
		mucky sandy loam	MK-SL	10
		muck	MUCK	9
		peat	PEAT	0
		sand	S	0
		sandy clay loam	SCL	8
		silty clay	SIC	9
		silty clay loam	SICL	8
		silt loam	SIL	8
		sandy loam	SL	6
		stony loam	ST-L	6
		variable	VAR	0
		very fine sandy loam	VFSL	6
Soil Moisture	33.33			
Drainage		well drained (DI ≤ 40)	E	0
		poorly drained (DI ≥ 70)	MW - SP	10
Partial Competition	33.33			
Species		spruce potential	Suit value	N/A
		jack pine potential	Suit value	N/A
		aspen/birch potential	Suit value	N/A

Table A.7. Chokecherry/Serviceberry Understory Tree/Large Shrub Habitat Model Criteria

Criteria	% Influence	Value Description	Value	Scaled Value
Soil Texture	33.33	clay	C	0
Texture		cobbly loam	CB-L	6
		cobbly loamy sand	CB-LS	8
		cobbly sandy loam	CB-SL	7
		clay loam	CL	0
		channery fine sandy loam	CN-FSL	7
		channery sandy loam	CN-SL	7
		fine sand	FS	9
		fine sandy loam	FSL	9
		gravelly loam	GR-L	6
		gravelly loamy sand	GR-LS	9
		gravelly sandy clay loam	GR-SCL	5
		gravelly sandy loam	GR-SL	8
		very gravelly sandy loam	GRV-SL	7
		loam	L	7
		loamy fine sand	LFS	10
		loamy sand	LS	10
		loamy very fine sand	LVFS	10
		loamy very fine sand, silt loam, very fine sandy loam	LVFS SIL VFSL	10
		mucky fine sand	MK-FS	0
		mucky loamy fine sand	MK-LFS	0
		mucky loamy sand	MK-LS	0
		mucky sand	MK-S	0
		mucky silty clay loam	MK-SICL	0
		mucky silt loam	MK-SIL	0
		mucky sandy loam	MK-SL	0
		muck	MUCK	0
		peat	PEAT	0
		sand	S	9
		sandy clay loam	SCL	5
		silty clay	SIC	6
		silty clay loam	SICL	6
		silt loam	SIL	8
		sandy loam	SL	9
		stony loam	ST-L	6
		variable	VAR	0
		very fine sandy loam	VFSL	9
Soil Moisture	33.33	excessively drained (DI ≤ 20)	E	0
Drainage		moderately well drained (DI 50)	MW	10
		very poorly drained (DI ≥ 90)	VP	0
Partial Competition	33.33			
Species		spruce potential	Suit value	N/A
Direct Competition	Constraint			
Species		reduce chokecherry/serviceberry suitability values by balsam fir potential		

Table A.8. Thimbleberry Shrub Groundcover Habitat Model Criteria

Criteria	% Influence	Value Description	Value	Scaled Value
Soil Texture		clay	C	0
Textures	33.33	cobbly loam	CB-L	8
		cobbly loamy sand	CB-LS	7
		cobbly sandy loam	CB-SL	8
		clay loam	CL	10
		channery fine sandy loam	CN-FSL	8
		channery sandy loam	CN-SL	8
		fine sand	FS	5
		fine sandy loam	FSL	8
		gravelly loam	GR-L	8
		gravelly loamy sand	GR-LS	7
		gravelly sandy clay loam	GR-SCL	9
		gravelly sandy loam	GR-SL	8
		very gravelly sandy loam	GRV-SL	8
		loam	L	10
		loamy fine sand	LFS	7
		loamy sand	LS	7
		loamy very fine sand	LVFS	7
		loamy very fine sand, silt loam, very fine sandy loam	LVFS SIL VFSL	7
		mucky fine sand	MK-FS	0
		mucky loamy fine sand	MK-LFS	0
		mucky loamy sand	MK-LS	0
		mucky sand	MK-S	0
		mucky silty clay loam	MK-SICL	0
		mucky silt loam	MK-SIL	0
		mucky sandy loam	MK-SL	0
		muck	MUCK	0
		peat	PEAT	0
		sand	S	5
		sandy clay loam	SCL	9
		silty clay	SIC	0
		silty clay loam	SICL	0
		silt loam	SIL	0
		sandy loam	SL	8
		stony loam	ST-L	8
		variable	VAR	0
		very fine sandy loam	VFSL	8
Soil Moisture	33.33			
Drainage		excessively drained (DI 20)	E	0
		moderately well drained (DI 50)	MW	10
		very poorly drained (DI 90)	VP	0
Partial Competition	33.33			
Species		spruce potential	Suit value	N/A
		jack pine potential	Suit value	N/A
		aspen/birch potential	Suit value	N/A
		alder/willow potential	Suit value	N/A
		balsam fir potential	Suit value	N/A
		chokecherry/serviceberry	Suit value	N/A

Table A.9. Cranberry/Labrador Tea Shrub Groundcover Habitat Model Criteria

Criteria	% Influence	Value Description	Value	Scaled Value
Soil Texture	50			
Texture		clay	C	0
		cobbly loam	CB-L	0
		cobbly loamy sand	CB-LS	0
		cobbly sandy loam	CB-SL	0
		clay loam	CL	6
		channery fine sandy loam	CN-FSL	7
		channery sandy loam	CN-SL	7
		fine sand	FS	0
		fine sandy loam	FSL	7
		gravelly loam	GR-L	0
		gravelly loamy sand	GR-LS	0
		gravelly sandy clay loam	GR-SCL	0
		gravelly sandy loam	GR-SL	0
		very gravelly sandy loam	GRV-SL	0
		Loam	L	8
		loamy fine sand	LFS	5
		loamy sand	LS	5
		loamy very fine sand	LVFS	5
		loamy very fine sand, silt loam, very fine sandy loam	LVFS SIL VFSL	5
		mucky fine sand	MK-FS	9
		mucky loamy fine sand	MK-LFS	9
		mucky loamy sand	MK-LS	9
		mucky sand	MK-S	9
		mucky silty clay loam	MK-SICL	9
		mucky silt loam	MK-SIL	9
		mucky sandy loam	MK-SL	9
		Muck	MUCK	9
		Peat	PEAT	10
		Sand	S	0
		sandy clay loam	SCL	6
		silty clay	SIC	0
		silty clay loam	SICL	6
		silt loam	SIL	6
		sandy loam	SL	7
		stony loam	ST-L	7
		Variable	VAR	0
		very fine sandy loam	VFSL	7
Soil Moisture	50	well drained (DI $\leq$ 40)	W	0
Drainage		poorly drained (DI $\geq$ 70)	P	10
Direct Competition	Constraint			
Species		reduce cranberry/Labrador tea suitability values by thimbleberry potential		

Table A.10. Blueberry Shrub Groundcover Habitat Model Criteria

Criteria	% Influence	Value Description	Value	Scaled Value
Soil Texture	50			
Textures		clay	C	0
		cobbly loam	CB-L	0
		cobbly loamy sand	CB-LS	9
		cobbly sandy loam	CB-SL	7
		clay loam	CL	0
		channery fine sandy loam	CN-FSL	7
		channery sandy loam	CN-SL	7
		fine sand	FS	10
		fine sandy loam	FSL	7
		gravelly loam	GR-L	0
		gravelly loamy sand	GR-LS	9
		gravelly sandy clay loam	GR-SCL	0
		gravelly sandy loam	GR-SL	7
		very gravelly sandy loam	GRV-SL	7
		loam	L	0
		loamy fine sand	LFS	9
		loamy sand	LS	9
		loamy very fine sand	LVFS	9
		loamy very fine sand, silt loam, very fine sandy loam	LVFS SIL VFSL	9
		mucky fine sand	MK-FS	0
		mucky loamy fine sand	MK-LFS	0
		mucky loamy sand	MK-LS	0
		mucky sand	MK-S	0
		mucky silty clay loam	MK-SICL	0
		mucky silt loam	MK-SIL	0
		mucky sandy loam	MK-SL	0
		muck	MUCK	0
		peat	PEAT	0
		sand	S	10
		sandy clay loam	SCL	0
		silty clay	SIC	0
		silty clay loam	SICL	0
		silt loam	SIL	0
		sandy loam	SL	7
		stony loam	ST-L	0
		variable	VAR	0
		very fine sandy loam	VFSL	7
Soil Moisture	50			
Drainage		excessively - well drained (DI ≤ 20 - 40)	E - W	10
		moderately well drained (DI ≥ 50)	MW	0
Direct Competition	Constraint			
Species		reduce blueberry suitability values by thimbleberry/labrador tea potential		

Table A.11. Reindeer Lichen Groundcover Habitat Model Criteria

Criteria	% Influence	Value Description	Value	Scaled Value
Soil Texture	50			
Textures		clay	C	0
		cobbly loam	CB-L	5
		cobbly loamy sand	CB-LS	8
		cobbly sandy loam	CB-SL	6
		clay loam	CL	0
		channery fine sandy loam	CN-FSL	0
		channery sandy loam	CN-SL	0
		fine sand	FS	9
		fine sandy loam	FSL	0
		gravelly loam	GR-L	5
		gravelly loamy sand	GR-LS	8
		gravelly sandy clay loam	GR-SCL	0
		gravelly sandy loam	GR-SL	6
		very gravelly sandy loam	GRV-SL	6
		loam	L	0
		loamy fine sand	LFS	7
		loamy sand	LS	7
		loamy very fine sand	LVFS	7
		loamy very fine sand, silt loam, very fine sandy loam	LVFS SIL VFSL	0
		mucky fine sand	MK-FS	0
		mucky loamy fine sand	MK-LFS	0
		mucky loamy sand	MK-LS	0
		mucky sand	MK-S	0
		mucky silty clay loam	MK-SICL	0
		mucky silt loam	MK-SIL	0
		mucky sandy loam	MK-SL	0
		muck	MUCK	0
		peat	PEAT	0
		sand	S	10
		sandy clay loam	SCL	0
		silty clay	SIC	0
		silty clay loam	SICL	0
		silt loam	SIL	0
		sandy loam	SL	0
		stony loam	ST-L	5
		variable	VAR	0
		very fine sandy loam	VFSL	0
Soil Moisture	50			
Drainage		excessively - well drained (DI ≤ 20 - 40)	E – W	10
		moderately well drained (DI ≥ 50)	MW	0

Table A.12. Summer Moose Habitat Model Criteria

Criteria	% Influence	Value Description	Value	Scaled Value/Rank
Terrestrial Browse	45			
Overstory		Trembling Aspen (*Populus tremuloides*)/Paper Birch (*Betula papyrifera*)	suit. value*1.0	10
		Willow (*Salix* spp.)	suit. value*1.0	10
Understory Tree/Large Shrub		Cherry (*Prunus* spp.)	suit. value*1.0	10
Shrub Groundcover		Mountain Cranberry (*Vaccinium vitis-idaea*)	suit. value*0.7	7
		Thimbleberry (*Rubus* parviflorus)	suit. value*0.4	4
		Velvetleaf/Low-Bush Blueberry (*Viburnum* spp.)	suit. value*0.4	4
Adjacency	10			
Adjacency of a Region To Open Water/Aquatic Vegetation		Areas Adjacent to Water/Aquatic Vegetation	suit. value*1.0	10
		Areas ≥ 2 Kilometers from Water/Aquatic Vegetation	suit. value*0	0
Water/Aquatic-Vegetation	N/A			
		Streams	perennial stream	10
		Permanently Flooded Wetlands (Lakes/Ponds)	permanently flooded	10
		Intermittently Exposed/Permanent Wetlands	intermittently exposed/permanent	9
		Intermittently Exposed Wetlands	intermittently exposed	8
		Semipermanently Flooded Wetlands	semipermanently	7
		Seasonally Flooded Wetlands	seasonally flooded	4
		Saturated/Semipermanent/Seasonal Wetlands	saturated/semipermanent/ seasonal	4
		Seasonally Flooded/Saturated Wetlands	seasonally flooded/saturated	2
Diversity of Terrestrial Browse	45			
Species Diversity		Number of Species ≥ 5	number of species	10
		Number of Species = 4	number of species	9
		Number of Species = 3	number of species	8
		Number of Species = 2	number of species	4
		Number of Species = 1	number of species	0

Table A.13. Winter Moose Habitat Model Criteria

Criteria	% Influence	Value Description	Value	Scaled Value
Terrestrial Browse	45			
Overstory		Trembling Aspen (*Populus tremuloides*)/Paper Birch (*Betula papyrifera*)	suit. value*1.0	10
		Willow (*Salix* spp.)/Alder (*Alnus* spp.)	suit. value*1.0	10
Understory Tree/Large Shrub		Balsam Fir (*Abies balsamea*)	suit. value*0.6	6
		Choke Cherry (*Prunus* virginiana)	suit. value*1.0	10
Shrub Groundcover		Mountain Cranberry (*Vaccinium vitis-idaea*)	suit. value*1.0	10
Diversity of Terrestrial Browse	45			
Species Diversity		Number of Species ≥ 3	number of species	10
		Number of Species = 2	number of species	8
		Number of Species = 1	number of species	0
Thermal Cover	10			
Overstory		Areas Adjacent to Favorable White Spruce (*Picea glauca*) Habitat	suit. 7 - 10	10
		Areas ≥ 500 Meters From Favorable White Spruce (*Picea glauca*) Habitat	suit. 7 - 10	0
	AND OR			
Understory		Areas Adjacent to Favorable Balsam Fir (*Abies balsamea*) Habitat	suit. 7 - 10	10
		Areas ≥ 500 Meters From Favorable Balsam Fir (*Abies balsamea*) Habitat	suit. 7 - 10	0

Table A.14. Mastodon Habitat Model Criteria

Criteria	% Influence	Value Description	Value	Scaled Value/Rank
Terrestrial Browse	50			
Overstory Browse		Trembling Aspen (*Populus tremuloides*)/Paper Birch (*Betula papyrifera*)	suit. value*1.0	10
		Alder (*Alnus* spp.)/Willow (*Salix* spp.)	suit. value*1.0	10
Adjacency				
Adjacency of a Region To Open Water/Aquatic Vegetation	50	Areas Adjacent to Water/Aquatic Vegetation	suit. value*1.0	10
		Areas ≥ 2 Kilometer from Water/Aquatic Vegetation	suit. value*0	0
Water/Aquatic-Vegetation	N/A	Streams	perennial stream	10
		Permanently Flooded Wetlands (Lakes/Ponds)	permanently flooded	10
		Intermittently Exposed/Permanent Wetlands	intermittently exposed/permanent	9
		Intermittently Exposed Wetlands	intermittently exposed	8
		Semipermanently Flooded Wetlands	semipermanently	7
		Seasonally Flooded Wetlands	seasonally flooded	4
		Saturated/Semipermanent/Seasonal Wetlands	saturated/semipermanent/ seasonal	4
		Seasonally Flooded/Saturated Wetlands	seasonally flooded/saturated	2

Table A.15. Muskrat Habitat Model Criteria

Criteria	**% Influence**	**Value Description**	**Value**	**Scaled Value/Rank**
Emergent Browse	50			
Emergent Vegetation		Wetland Class Emergent	emergent	10
		Wetland Class Scrub-Shrub/Second Class Emergent	scrub-shrub	7
Water *OR* Adjacency To Water	50			
Water		Streams	perennial stream	10
		Permanently Flooded Wetlands (Lakes/Ponds)	permanently flooded	10
		Intermittently Exposed/Permanent Wetlands	intermittently exposed/permanent	9
		Intermittently Exposed Wetlands	intermittently exposed	8
		Semipermanently Flooded Wetlands	semipermanently	7
		Seasonally Flooded Wetlands	seasonally flooded	4
		Saturated/Semipermanent/Seasonal Wetlands	saturated/semipermanent/seasonal	4
		Seasonally Flooded/Saturated Wetlands	seasonally flooded/saturated	2
	OR			
Adjacency To Water	50	Wetlands Adjacent to Open Water	wetlands adjacent to open water	10

Table A.16. Beaver/Giant Beaver Habitat Model Criteria

Criteria	% Influence	Value Description	Value	Scaled Value/Rank
Terrestrial Browse	50			
Overstory Browse		Trembling Aspen (*Populus tremuloides*)/Paper Birch (*Betula papyrifera*)	suit. value*1.0	10
		Alder (*Alnus* spp.)/Willow (*Salix* spp.)	suit. value*0.8	8
Adjacency				
Adjacency of a Region To Open Water/Aquatic Vegetation	50	Areas Adjacent to Water/Aquatic Vegetation	suit. value*1.0	10
		Areas ≥ 200 meters from Water/Aquatic Vegetation	suit. value*0	0
Water/Aquatic-Vegetation	N/A	Streams	perennial stream	10
Open Water/Aquatic Vegetation		Permanently Flooded Wetlands (Lakes/Ponds)	permanently flooded	10
		Intermittently Exposed/Permanent Wetlands	intermittently exposed/permanent	9
		Intermittently Exposed Wetlands	intermittently exposed	8
		Semipermanently Flooded Wetlands	semipermanently	7
		Seasonally Flooded Wetlands	seasonally flooded	4
		Saturated/Semipermanent/Seasonal Wetlands	saturated/semipermanent/ seasonal	4
		Seasonally Flooded/Saturated Wetlands	seasonally flooded/saturated	2

Table A.17. Caribou Migration Model Criteria

Criteria	% Influence	Value Description	Value	Scaled Value/Rank
Hydrologic Friction	50			
Hydrologic Feature Types		Streams	perennial stream	10
		Permanently Flooded Wetlands (Lakes/Ponds)	permanently flooded	10
		Intermittently Exposed/Permanent Wetlands	intermittently exposed/permanent	10
		Intermittently Exposed Wetlands	intermittently exposed	10
		Semipermanently Flooded Wetlands	semipermanently	5
		Seasonally Flooded Wetlands	seasonally flooded	4
		Saturated/Semipermanent/Seasonal	saturated/semipermanent/seasonal	3
		Seasonally Flooded/Saturated Wetlands	seasonally flooded/saturated	3
		Intermittent Streams	intermittent stream	3
Topographic Friction	50			
Slopes		+12% Slope	12	10
		+9% Slope	9	5.8
		+5% Slope	5	2.9
		0% Slope	0 (flat areas)	1.4
		-5% Slope	-5	0
		-9% Slope	-9	1.4
		-12% Slope	-12	2.9
		-16% Slope	-16	5.8
		-20% Slope	-20	10

Table A.18. Caribou Winter Habitat Model Criteria

Criteria	% Influence	Value Description	Value	Scaled Value
Terrestrial Browse	N/A			
Overstory		Trembling Aspen (*Populus tremuloides*)/Paper Birch (*Betula papyrifera*)	suit. value*0.7	7
		Willow (*Salix* spp.)/Alder (*Alnus* spp.)	suit. value*0.7	7
Shrub Groundcover		Mountain Cranberry (*Vaccinium vitis-idaea*)/ Labrador Tea (*Ledum groenlandicum*)	suit. value*0.3	3
		Thimbleberry (*Rubus pariviflorus*)	suit. value*0.3	3
		Velvetleaf/Low-Bush Blueberry (*Viburnum* spp.)	suit. value*0.3	3
Ground Cover		Reindeer Lichen (*Cladonia* spp.)	suit. value*1.0	10
Grasses/Sedges		Open areas along the shores of lakes, rivers, and unforrested wetlands.	suit. value*1.0	10
Water	N/A			
Frozen Water Bodies		Lakes, Rivers, and Unforrested Wetlands	suit. value*1.0	10

Table A.19. Hare Habitat Model Criteria

Criteria	% Influence	Value Description	Value	Scaled Value/Rank
Terrestrial Browse	50			
Overstory		Trembling Aspen (*Populus Tremuloides*)/Paper Birch (*Betula papyrifera*)	suit value*1.0	10
		Willow (Salix spp.)/Alder (Alnus spp.)	suit value*1.0	10
Shrub Groundcover		Late Low Blueberry (*Vaaccinium angustifolium*)/Velvetleaf Blueberry (*Vaccinium myrtilloides*)	suit value*0.3	10
Thermal Cover				
Overstory	50	Black Spruce (*Picea mariana*)	suit value*1.0	10
		Balsam Fir (*Abies Balsamea*)	suit value*0.8	8
		Willow (*Salix* spp.)/Alder (*Alnus* spp.)	suit value*0.7	7

APPENDIX B:

Early Paleo-Indian Resource Use And Settlement Criteria

Table B.1. Residential Resource Use Objective Ratings For Model One

	Minimum Amount of Resources	Risk Minimization	Population Aggregation
Minimum Amount of Resources	1		
Risk Minimization	1	1	
Population Aggregation	1/5	1/5	1

Table B.2. Logistical Resource Use Objective Ratings For Model One

	Minimum Amount of Resources	Risk Minimization
Minimum Amount of Resources	1	
Risk Minimization	1	1

Table B.3. Residential Resource Use Criteria Ratings For The Attainment Of A Minimum Amount Of Food And Manufacturing Materials Within Model One

	Caribou	Mastodon	Moose	Beaver	Muskrat	Hare
Caribou	1					
Mastodon	1/3	1				
Moose	1/5	1/2	1			
Beaver	1/7	1/4	½	1		
Muskrat	1/9	1/6	¼	1/2	1	
Hare	1/9	1/6	¼	1/2	1	1

Table B.4. Residential Resource Use Criteria Ratings For Population Aggregation Within Model One

	Caribou	Mastodon	Moose	Beaver	Muskrat	Hare
Caribou	1					
Mastodon	1	1				
Moose	1/5	1/5	1			
Beaver	1/5	1/5	1	1		
Muskrat	1/7	1/7	½	1/2	1	
Hare	1/9	1/9	¼	1/4	1/2	1

Table B.5. Residential Resource Use Criteria Ratings For Risk Minimization Within Model One

	Caribou	Mastodon	Moose	Beaver	Muskrat	Hare
Caribou	1					
Mastodon	1/5	1				
Moose	1/5	1	1			
Beaver	1/7	1/2	1/2	1		
Muskrat	1/9	1/4	1/4	1/2	1	
Hare	1/9	1/4	1/4	1/2	1	1

Table B.6. Rank Percent Equivalents For Criteria Ratings

Percent Rank	Importance Ranking
100%	Most Important (1)
90%	(1/2)
80%	Moderately Less Important (1/3)
70%	(1/4)
60%	Strongly Less Important (1/5)
50%	(1/6)
40%	Very Strongly Less Important (1/7)
30%	(1/8)
20%	Extremely Less Important (1/9)
10%	(1/10)
0%	Not a Factor (0)

Table B.7. Logistical Resource Use Criteria Rankings For The Attainment Of A Minimum Amount Of Food And Manufacturing Materials Within Model One

	Importance Ranking
Caribou	100%
Mastodon	80%
Moose	60%
Beaver	40%
Muskrat	20%
Hare	20%

Table B.8. Logistical Resource Use Criteria Rankings For The Risk Minimization Within Model One

	Importance Ranking
Caribou	100%
Mastodon	60%
Moose	60%
Beaver	40%
Muskrat	20%
Hare	20%

Table B.9. Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying The Attainment Of A Minimum Amount Of Resources Within Model One

Criteria	Weight
Caribou	0.4944
Mastodon	0.2290
Moose	0.1300
Beaver	0.0685
Muskrat	0.0390
Hare	0.0390

Table B.10. Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying Population Aggregation Within Model One

Criteria	Weight
Caribou	0.3703
Mastodon	0.3703
Moose	0.0898
Beaver	0.0898
Muskrat	0.0501
Hare	0.0299

Table B.11. Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying Risk Minimization Within Model One

Criteria	Weight
Caribou	0.5443
Mastodon	0.1470
Moose	0.1470
Beaver	0.0773
Muskrat	0.0422
Hare	0.0422

Table B.12. Low Risk Order Weights For Resource Use Within Model One, Two, And Three

Weight
0.4
0.3
0.2
0.1
0.0
0.0

Table B.13. High Risk Order Weights For Resource Use Within Model One, Two, And Three

Weight
0.0
0.0
0.1
0.2
0.3
0.4

Table B.14. Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Objectives Satisfying Residential Resource Use Within Model One

Objective	Weight
Minimum Amount of Resources	0.4545
Risk Minimization	0.4545
Population Aggregation	0.0909

Table B.15. Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Objectives Satisfying Logistical Resource Use Within Model One

Objective	Weight
Minimum Amount of Resources	0.5
Risk Minimization	0.5

Table B.16. Residential Resource Use Objective Ratings For Model Two

	Minimum Amount of Resources	Risk Minimization	Population Aggregation	Prestige
Minimum Amount of Resources	1			
Risk Minimization	1/5	1		
Population Aggregation	1/5	1	1	
Prestige	1/7	1/2	1/2	1

Table B.17. Logistical Resource Use Objective Ratings For Model Two

	Minimum Amount of Resources	Risk Minimization	Prestige
Minimum Amount of Resources	1		
Risk Minimization	1/5	1	
Prestige	1/7	1/2	1

Table B.18. Residential Resource Use Criteria Ratings For The Attainment Of A Minimum Amount Of Food And Manufacturing Materials Within Model Two

	Mastodon	Moose	Beaver	Hare	Muskrat
Mastodon	1				
Moose	1/3	1			
Beaver	1/7	1/4	1		
Hare	1/7	1/4	1	1	
Muskrat	1/9	1/6	1/2	1/2	1

Table B.19. Residential Resource Use Criteria Ratings For Population Aggregation Within Model Two

	Mastodon	Moose	Beaver	Muskrat	Hare
Mastodon	1				
Moose	1/3	1			
Beaver	1/7	1/4	1		
Muskrat	1/9	1/6	1/2	1	
Hare	1/9	1/6	1/2	1	1

Table B.20. Residential Resource Use Criteria Ratings For Risk Minimization Within Model Two

	Mastodon	Moose	Beaver	Muskrat	Hare
Mastodon	1				
Moose	1	1			
Beaver	1/2	1/2	1		
Muskrat	1/4	1/4	1/2	1	
Hare	1/4	1/4	1/2	1	1

Table B.21. Residential Resource Use Criteria Ratings For Prestige Within Model Two

	Mastodon	Moose	Muskrat	Beaver	Hare
Mastodon	1				
Moose	1/3	1			
Muskrat	1/9	1/6	1		
Beaver	1/9	1/6	1	1	
Hare	1/9	1/6	1	1	1

Table B.22. Logistical Resource Use Criteria Rankings For The Attainment Of A Minimum Amount Of Food And Manufacturing Materials Within Model Two

	Importance Ranking
Mastodon	100%
Moose	80%
Beaver	40%
Hare	40%
Muskrat	20%

Table B.23. Logistical Resource Use Criteria Rankings For Risk Minimization Within Model Two

	Importance Ranking
Mastodon	100%
Moose	100%
Beaver	80%
Muskrat	60%
Hare	60%

Table B.24. Logistical Resource Use Criteria Rankings For Prestige Within Model Two

	Importance Ranking
Mastodon	100%
Moose	80%
Beaver	20%
Muskrat	20%
Hare	20%

Table B.25. Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying The Attainment Of A Minimum Amount Of Resources Within Model Two

Criteria	Weight
Mastodon	0.5473
Moose	0.2581
Beaver	0.0753
Hare	0.0753
Muskrat	0.0441

Table B.26. Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying Population Aggregation Within Model Two

Criteria	Weight
Mastodon	0.5526
Moose	0.2683
Beaver	0.0830
Muskrat	0.0480
Hare	0.0480

Table B.27. Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying Risk Minimization Within Model Two

Criteria	Weight
Mastodon	0.3643
Moose	0.3643
Beaver	0.1308
Muskrat	0.0703
Hare	0.0703

Table B.28. Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying Prestige Within Model Two

Criteria	Weight
Mastodon	0.5601
Moose	0.2810
Muskrat	0.0530
Beaver	0.0530
Hare	0.0530

Table B.29. Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Objectives Satisfying Residential Resource Use Within Model Two

Objective	Weight
Minimum Amount of Resources	0.6429
Risk Minimization	0.1401
Population Aggregation	0.1401
Prestige	0.0769

Table B.30. Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Objectives Satisfying Logistical Resource Use Within Model Two

Objective	Weight
Minimum Amount of Resources	0.7396
Risk Minimization	0.1666
Prestige	0.0938

Table B.31. Residential Resource Use Objective Ratings For Model Three

	Minimum Amount of Resources	Risk Minimization	Efficiency	Population Aggregation	Taste	Variety	Prestige
Minimum Amount of Resources	1						
Risk Minimization	1	1					
Efficiency	1	1	1				
Population Aggregation	1/3	1/3	1/3	1			
Taste	1/3	1/3	1/3	1	1		
Variety	1/3	1/3	1/3	1	1	1	
Prestige	1/3	1/3	1/3	1	1	1	1

Table B.32. Logistical Resource Use Objective Ratings For Model Three

	Minimum Amount of Resources	Risk Minimization	Efficiency	Taste	Prestige
Minimum Amount of Resources	1				
Risk Minimization	1	1			
Efficiency	1	1	1		
Taste	1/3	1/3	1/3	1	
Prestige	1/3	1/3	1/3	1	1

Table B.33. Growing Season Residential Resource Use Criteria Ratings For The Attainment Of A Minimum Amount Of Food And Manufacturing Materials Within Model Three

	Mastodon	**Moose**	**Cranberry**	**Blueberry**	**Chokecherry/Serviceberry**	**Thimbleberry**	**Beaver**	**Muskrat**	**Hare**
Mastodon	1								
Moose	1	1							
Cranberry	1/3	1/3	1						
Blueberry	1/3	1/3	1	1					
Chokecherry/Serviceberry	1/3	1/3	1	1	1				
Thimbleberry	1/3	1/3	1	1	1	1			
Beaver	1/5	1/5	1/2	1/2	1/2	1/2	1		
Muskrat	1/5	1/5	1/2	1/2	1/2	1/2	1	1	
Hare	1/5	1/5	1/2	1/2	1/2	1/2	1	1	1

Table B.34. Dormant Season Residential Resource Use Criteria Ratings For The Attainment Of A Minimum Amount Of Food And Manufacturing Materials Within Model Three

	Caribou	**Mastodon**	**Moose**	**Beaver**	**Muskrat**	**Hare**
Caribou	1					
Mastodon	1	1				
Moose	1	1	1			
Beaver	1/3	1/3	1/3	1		
Muskrat	1/3	1/3	1/3	1	1	
Hare	1/3	1/3	1/3	1	1	1

Table B.35. Growing Season Residential Resource Use Criteria Ratings For Risk Minimization Within Model Three

	Chokecherry/Serviceberry	Mastodon	Moose	Beaver	Cranberry	Blueberry	Thimbleberry	Muskrat	Hare
Chokecherry/Serviceberry	1								
Mastodon	1/5	1							
Moose	1/5	1	1						
Beaver	1/7	1/2	1/2	1					
Cranberry	1/7	1/2	1/2	1	1				
Blueberry	1/7	1/2	1/2	1	1	1			
Thimbleberry	1/7	1/2	1/2	1	1	1	1		
Muskrat	1/9	1/4	1/4	1/2	1/2	1/2	1/2	1	
Hare	1/9	1/4	1/4	1/2	1/2	1/2	1/2	1	1

Table B.36. Dormant Season Residential Resource Use Criteria Ratings For Risk Minimization Within Model Three

	Caribou	Mastodon	Moose	Beaver	Muskrat	Hare
Caribou	1					
Mastodon	1/5	1				
Moose	1/5	1	1			
Beaver	1/7	1/2	1/2	1		
Muskrat	1/9	1/4	1/4	1/2	1	
Hare	1/9	1/4	1/4	1/2	1	1

Table B.37. Growing Season Residential Resource Use Criteria Ratings For Efficiency Within Model Three

	Chokecherry/Serviceberry	Mastodon	Moose	Cranberry	Blueberry	Thimbleberry	Beaver	Muskrat	Hare
Chokecherry/Serviceberry	1								
Mastodon	1	1							
Moose	1	1	1						
Cranberry	1/3	1/3	1/3	1					
Blueberry	1/3	1/3	1/3	1	1				
Thimbleberry	1/3	1/3	1/3	1	1	1			
Beaver	1/7	1/7	1/7	1/4	1/4	1/4	1		
Muskrat	1/9	1/9	1/9	1/6	1/6	1/6	1/2	1	
Hare	1/9	1/9	1/9	1/6	1/6	1/6	1/2	1	1

Table B.38. Dormant Season Residential Resource Use Criteria Ratings For Efficiency Within Model Three

	Caribou	**Mastodon**	**Moose**	**Beaver**	**Muskrat**	**Hare**
Caribou	1					
Mastodon	1	1				
Moose	1	1	1			
Beaver	1/3	1/3	1/3	1		
Muskrat	1/5	1/5	1/5	1/2	1	
Hare	1/7	1/7	1/7	1/4	1/2	1

Table B.39. Growing Season Residential Resource Use Criteria Ratings For Population Aggregation Within Model Three

	Mastodon	Moose	Cranberry	Blueberry	Chokecherry/Serviceberry	Thimbleberry	Beaver	Muskrat	Hare
Mastodon	1								
Moose	1/3	1							
Cranberry	1/3	1	1						
Blueberry	1/3	1	1	1					
Chokecherry/Serviceberry	1/3	1	1	1	1				
Thimbleberry	1/3	1	1	1	1	1			
Beaver	1/7	1/4	1/4	1/4	1/4	1/4	1		
Muskrat	1/9	1/6	1/6	1/6	1/6	1/6	½	1	
Hare	1/9	1/6	1/6	1/6	1/6	1/6	½	1	1

Table B.40. Dormant Season Residential Resource Use Criteria Ratings For Population Aggregation Within Model Three

	Caribou	Mastodon	Moose	Beaver	Muskrat	Hare
Caribou	1					
Mastodon	1	1				
Moose	1/5	1/5	1			
Beaver	1/5	1/5	1	1		
Muskrat	1/7	1/7	1/2	1/2	1	
Hare	1/9	1/9	1/4	1/4	1/2	1

Table B.41. Growing Season Residential Resource Use Criteria Ratings For Taste Within Model Three

	Blueberry	Thimbleberry	Mastodon	Beaver	Moose	Cranberry	Hare	Muskrat	Chokecherry/Serviceberry
Blueberry	1								
Thimbleberry	1/3	1							
Mastodon	1/5	1/2	1						
Beaver	1/5	1/2	1	1					
Moose	1/7	1/4	1/2	1/2	1				
Cranberry	1/7	1/4	1/2	1/2	1	1			
Hare	1/9	1/6	1/4	1/4	1/2	1/2	1		
Muskrat	1/9	1/6	1/4	1/4	1/2	1/2	1	1	
Chokecherry/Serviceberry	1/9	1/6	1/4	1/4	1/2	1/2	1	1	1

Table B.42. Dormant Season Residential Resource Use Criteria Ratings For Taste Within Model Three

	Mastodon	Beaver	Moose	Caribou	Muskrat	Hare
Mastodon	1					
Beaver	1	1				
Moose	1/3	1/3	1			
Caribou	1/3	1/3	1	1		
Muskrat	1/5	1/5	1/2	1/2	1	
Hare	1/9	1/9	1/6	1/6	1/4	1

Table B.43. Growing Season Residential Resource Use Criteria Ratings For Dietary Variety Within Model Three

	Mastodon	Moose	Beaver	Muskrat	Hare	Cranberry	Blueberry	Thimbleberry	Chokecherry/Serviceberry
Mastodon	1								
Moose	1	1							
Beaver	1/3	1/3	1						
Muskrat	1/3	1/3	1	1					
Hare	1/3	1/3	1	1	1				
Cranberry	1/5	1/5	1/2	1/2	1	1			
Blueberry	1/5	1/5	1/2	1/2	1/2	1	1		
Thimbleberry	1/5	1/5	1/2	1/2	1/2	1	1	1	
Chokecherry/Serviceberry	1/5	1/5	1/2	1/2	1/2	1	1	1	1

Table B.44. Dormant Season Residential Resource Use Criteria Ratings For Dietary Variety Within Model Three

	Caribou	Mastodon	Moose	Beaver	Muskrat	Hare
Caribou	1					
Mastodon	1	1				
Moose	1	1	1			
Beaver	1/3	1/3	1/3	1		
Muskrat	1/3	1/3	1/3	1	1	
Hare	1/3	1/3	1/3	1	1	1

Table B.45. Growing Season Residential Resource Use Criteria Ratings For Prestige Within Model Three

	Mastodon	Moose	Beaver	Muskrat	Hare	Cranberry	Blueberry	Thimbleberry	Chokecherry/Serviceberry
Mastodon	1								
Moose	1/3	1							
Beaver	1/9	1/6	1						
Muskrat	1/9	1/6	1	1					
Hare	1/9	1/6	1	1	1				
Cranberry	1/9	1/6	1	1	1	1			
Blueberry	1/9	1/6	1	1	1	1	1		
Thimbleberry	1/9	1/6	1	1	1	1	1	1	
Chokecherry/Serviceberry	1/9	1/6	1	1	1	1	1	1	1

Table B.46. Dormant Season Residential Resource Use Criteria Ratings For Prestige Within Model Three

	Caribou	Mastodon	Moose	Beaver	Muskrat	Hare
Caribou	1					
Mastodon	1/3	1				
Moose	1/7	1/4	1			
Beaver	1/9	1/6	1/2	1		
Muskrat	1/9	1/6	1/2	1	1	
Hare	1/9	1/6	1/2	1	1	1

Table B.47. Growing Season Logistical Resource Use Criteria Rankings For The Attainment Of A Minimum Amount Of Food And Manufacturing Materials Within Model Three

	Importance Ranking
Mastodon	100%
Moose	100%
Cranberry	80%
Blueberry	80%
Chokecherry/Serviceberry	80%
Thimbleberry	80%
Beaver	60%
Muskrat	60%
Hare	60%

Table B.48. Dormant Season Logistical Resource Use Criteria Rankings For The Attainment Of A Minimum Amount Of Food And Manufacturing Materials Within Model Three

	Importance Ranking
Caribou	100%
Mastodon	100%
Moose	100%
Beaver	60%
Muskrat	60%
Hare	60%

Table B.49. Growing Season Logistical Resource Use Criteria Rankings For Risk Minimization Within Model Three

	Importance Ranking
Chokecherry/Serviceberry	100%
Mastodon	60%
Moose	60%
Beaver	40%
Cranberry	40%
Blueberry	40%
Thimbleberry	40%
Muskrat	20%
Hare	20%

Table B.50. Dormant Season Logistical Resource Use Criteria Rankings For Risk Minimization Within Model Three

	Importance Ranking
Caribou	100%
Mastodon	60%
Moose	60%
Beaver	40%
Muskrat	20%
Hare	20%

Table B.51. Growing Season Logistical Resource Use Criteria Rankings For Efficiency Within Model Three

	Importance Ranking
Chokecherry/Serviceberry	100%
Mastodon	100%
Moose	100%
Cranberry	80%
Blueberry	80%
Thimbleberry	80%
Beaver	40%
Muskrat	20%
Hare	20%

Table B.52. Dormant Season Logistical Resource Use Criteria Rankings For Efficiency Within Model Three

	Importance Ranking
Caribou	100%
Mastodon	100%
Moose	100%
Beaver	80%
Muskrat	60%
Hare	40%

Table B.53. Growing Season Logistical Resource Use Criteria Rankings For Taste Within Model Three

	Importance Ranking
Blueberry	100%
Thimbleberry	80%
Mastodon	60%
Beaver	60%
Moose	40%
Cranberry	40%
Hare	20%
Muskrat	20%
Chokecherry/Serviceberry	20%

Table B.54. Dormant Season Logistical Resource Use Criteria Rankings For Taste Within Model Three

	Importance Ranking
Caribou	100%
Mastodon	100%
Moose	100%
Beaver	80%
Muskrat	60%
Hare	40%

Table B.55. Growing Season Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying The Attainment Of A Minimum Amount Of Resources Within Model Three

Criteria	Weight
Mastodon	0.2520
Moose	0.2520
Cranberry	0.0892
Blueberry	0.0892
Chokecherry/Serviceberry	0.0892
Thimbleberry	0.0892
Beaver	0.0464
Muskrat	0.0464
Hare	0.0464

Table B.56. Dormant Season Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying The Attainment Of A Minimum Amount Of Resources Within Model Three

Criteria	Weight
Caribou	0.2500
Mastodon	0.2500
Moose	0.2500
Beaver	0.0833
Muskrat	0.0833
Hare	0.0833

Table B.57. Growing Season Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying Risk Minimization Within Model Three

Criteria	Weight
Chokecherry/Serviceberry	0.4414
Mastodon	0.1210
Moose	0.1210
Beaver	0.0626
Cranberry	0.0626
Blueberry	0.0626
Thimbleberry	0.0626
Muskrat	0.0332
Hare	0.0332

Table B.58. Dormant Season Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying Risk Minimization Within Model Three

Criteria	Weight
Caribou	0.5443
Mastodon	0.1470
Moose	0.1470
Beaver	0.0773
Muskrat	0.0422
Hare	0.0422

Table B.59. Growing Season Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying Efficiency Within Model Three

Criteria	Weight
Chokecherry/Serviceberry	0.2203
Mastodon	0.2203
Moose	0.2203
Cranberry	0.0909
Blueberry	0.0909
Thimbleberry	0.0909
Beaver	0.0291
Muskrat	0.0186
Hare	0.0186

Table B.60. Dormant Season Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying Efficiency Within Model Three

Criteria	Weight
Caribou	0.2696
Mastodon	0.2696
Moose	0.2696
Beaver	0.1022
Muskrat	0.0556
Hare	0.0335

Table B.61. Growing Season Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying Population Aggregation Within Model Three

Criteria	Weight
Mastodon	0.3066
Moose	0.1230
Cranberry	0.1230
Blueberry	0.1230
Chokecherry/Serviceberry	0.1230
Thimbleberry	0.1230
Beaver	0.0351
Muskrat	0.0217
Hare	0.0217

Table B.62. Dormant Season Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying Population Aggregation Within Model Three

Criteria	Weight
Caribou	0.3703
Mastodon	0.3703
Moose	0.0898
Beaver	0.0898
Muskrat	0.0501
Hare	0.0299

Table B.63. Growing Season Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying Taste Within Model Three

Criteria	Weight
Blueberry	0.3968
Thimbleberry	0.1900
Mastodon	0.1064
Beaver	0.1064
Moose	0.0550
Cranberry	0.0550
Hare	0.0301
Muskrat	0.0301
Chokecherry/Serviceberry	0.0301

Table B.64. Dormant Season Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying Taste Within Model Three

Criteria	Weight
Mastodon	0.3264
Beaver	0.3264
Moose	0.1254
Caribou	0.1254
Muskrat	0.0705
Hare	0.0259

Table B.65. Growing Season Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying Dietary Variety Within Model Three

Criteria	Weight
Mastodon	0.3287
Moose	0.1212
Beaver	0.1212
Muskrat	0.1137
Hare	0.0681
Cranberry	0.0618
Blueberry	0.0618
Thimbleberry	0.0618
Chokecherry/Serviceberry	0.0618

Table B.66. Dormant Season Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying Dietary Variety Within Model Three

Criteria	Weight
Caribou	0.2500
Mastodon	0.2500
Moose	0.2500
Beaver	0.0833
Muskrat	0.0833
Hare	0.0833

Table B.67. Growing Season Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying Prestige Within Model Three

Criteria	Weight
Mastodon	0.4402
Moose	0.2496
Beaver	0.0443
Muskrat	0.0443
Hare	0.0443
Cranberry	0.0443
Blueberry	0.0443
Thimbleberry	0.0443
Chokecherry/Serviceberry	0.0443

Table B.68. Dormant Season Resource Use Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Criteria Satisfying Taste Within Model Three

Criteria	Weight
Mastodon	0.5157
Moose	0.2631
Caribou	0.0823
Beaver	0.0463
Muskrat	0.0463
Hare	0.0463

Table B.69. Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Objectives Satisfying Residential Resource Use Within Model Three

Objective	Weight
Minimum Amount of Resources	0.2308
Risk Minimization	0.2308
Efficiency	0.2308
Population Aggregation	0.0769
Taste	0.0769
Dietary Variety	0.0769
Prestige	0.0769

Table B.70. Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Objectives Satisfying Logistical Resource Use Within Model Three

Objective	Weight
Minimum Amount of Resources	0.2727
Risk Minimization	0.2727
Efficiency	0.2727
Taste	0.0909
Prestige	0.0909

Table B.71. Growing Season Residential Settlement Objective Ratings For Model Two And Three

	Proximity to Resources	Dryness of the Ground
Proximity to Resources	1	
Dryness of the Ground	1/3	1

Table B.72. Dormant Season Residential Settlement Objective Ratings For Models One And Three

	Proximity to Resources	Shelter	Dryness of the Ground
Proximity to Resources	1		
Shelter	1	1	
Dryness of the Ground	1/3	1/3	1

Table B.73. Growing Season Logistical Settlement Objective Ratings For Model Two And Three

	Proximity to Resources	Dryness of the Ground
Proximity to Resources	1	
Dryness of the Ground	1/5	1

Table B.74. Dormant Season Logistical Settlement Objective Ratings For Model One And Three

	Proximity to Resources	Dryness of the Ground	Shelter
Proximity to Resources	1		
Dryness of the Ground	1/5	1	
Shelter	1/5	1	1

Table B.75. Residential And Logistical Settlement Criteria Ratings For The Attainment Of Shelter Within Model One And Three

	Cover	Terrain Slope	Terrain Aspect
Cover	1		
Terrain Slope	1/5	1	
Terrain Aspect	1/5	1	1

Table B.76. Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Objectives Satisfying Residential Settlement During The Growing Season Within Model Two And Three

Objective	Weight
Proximity to Resources	0.7500
Dryness of the Ground	0.2500

Table B.77. Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Objectives Satisfying Residential Settlement During The Dormant Season Within Model One And Three

Objective	Weight
Proximity to Resources	0.4286
Shelter	0.4286
Dryness of the Ground	0.1429

Table B.78. Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Objectives Satisfying Logistical Settlement During The Growing Season Within Model Two And Three

Objective	Weight
Proximity to Resources	0.8333
Dryness of the Ground	0.1667

Table B.79. Weights Resulting From Calculation Of Principle Eigenvector Of The Pairwise Comparison Matrix For Objectives Satisfying Logistical Settlement During The Dormant Season Within Models One And Three

Objective	Weight
Proximity to Resources	0.7143
Shelter	0.1429
Dryness of the Ground	0.1429

Table B.80. Weights Resulting From Calculation Of The Pairwise Comparison Matrix For Criteria Satisfying The Attainment Of Shelter With Models One And Three

	Weight
Cover	0.7143
Terrain Slope	0.1429
Terrain Aspect	0.1429

APPENDIX C:

Chi-Square Results

Table C.1. Chi-Square Calculated For Model 1 Dormant Season Paleo-Indian Logistical Settlement Without Water As A Factor, Type 1, 2, And 3 Sites

Category	Observed	Expected
Type 1-2 (High)	1	2
Type 1-2 (Medium)	1	1
Type 1-2 (Unsuitable)	3	2
Type 3 (High)	4	6
Type 3 (Medium)	12	9
Type 3 (Unsuitable)	2	3

Chi-Square = 3.000
P = 0.700

Table C.2. Chi-Square Calculated For Model 1 Dormant Season Paleo-Indian Logistical Settlement Without Water As A Factor, Type 1 And 2 Sites

Suitability	Observed	Expected
High	1	2
Medium	1	1
Unsuitable	3	2

Chi-Square = 1.000
P = 0.6065

Table C.3. Chi-Square Calculated For Model 1 Dormant Season Paleo-Indian Logistical Settlement, Without Water As A Factor, Type 3 Sites

Suitability	Observed	Expected
High	4	6
Medium	12	9
Unsuitable	2	3

Chi-Square = 2.000
P = 0.3679

Table C.4. Chi-Square Calculated For Model 1 Dormant Season Paleo-Indian Residential Settlement Without Water As A Factor, Type 1 And 2 Sites

Suitability	Observed	Expected
High	1	2
Medium	3	1
Unsuitable	1	2

Chi-Square = 5.000
P = 0.0821

Table C.5. Chi-Square Calculated For Model 2 Growing Season Paleo-Indian Logistical Settlement Without Water As A Factor, Type 1, 2, And 3 Sites

Category	Observed	Expected
Type 1-2 (High)	0	1
Type 1-2 (Medium)	0	2
Type 1-2 (Unsuitable)	5	2
Type 3 (High)	1	3
Type 3 (Medium)	9	5
Type 3 (Unsuitable)	8	10

Chi-Square = 12.433
P = 0.0293

Table C.6. Chi-Square Calculated For Model 2 Growing Season Paleo-Indian Logistical Settlement Without Water As A Factor, Type 1 And 2 Sites

Suitability	Observed	Expected
High	0	1
Medium	0	2
Unsuitable	5	2

Chi-Square = 7.500
P = 0.0235

Table C.7. Chi-Square Calculated For Model 2 Growing Season Paleo-Indian Logistical Settlement Without Water As A Factor, Type 3 Sites

Suitability	Observed	Expected
High	1	3
Medium	9	5
Unsuitable	8	10

Chi-Square = 4.933
P = 0.0849

Table C.8. Chi-Square Calculated For Model 2 Growing Season Paleo-Indian Residential Settlement Without Water As A Factor, Type 1 And 2 Sites

Suitability	Observed	Expected
High	0	1
Medium	1	3
Unsuitable	4	1

Chi-Square = 11.333
P = 0.0035

Table C.9. Chi-Square Calculated For Model 3 Dormant Season Paleo-Indian Logistical Settlement Without Water As A Factor, Type 1, 2, And 3 Sites

Category	Observed	Expected
Type 1-2 (High)	1	3
Type 1-2 (Medium)	2	1
Type 1-2 (Unsuitable)	2	1
Type 3 (High)	5	9
Type 3 (Medium)	12	6
Type 3 (Unsuitable)	1	3

Chi-Square = 12.444
P = 0.0292

Table C.10. Chi-Square Calculated For Model 3 Dormant Season Paleo-Indian Logistical Settlement Without Water As A Factor, Type 1 And 2 Sites

Suitability	Observed	Expected
High	1	3
Medium	2	1
Unsuitable	2	1

Chi-Square = 3.331
P = 0.1889

Table C.11. Chi-Square Calculated For Model 3 Dormant Season Paleo-Indian Logistical Settlement Without Water As A Factor, Type 3 Sites

Suitability	Observed	Expected
High	5	9
Medium	12	6
Unsuitable	1	3

Chi-Square = 9.111
P = 0.0105

Table C.12. Chi-Square Calculated For Model 3 Dormant Season Paleo-Indian Residential Settlement Without Water As A Factor, Type 1 And 2 Sites

Suitability	Observed	Expected
High	1	1
Medium	3	1
Unsuitable	1	3

Chi-Square = 5.333
P = 0.0695

Table C.13. Chi-Square Calculated For Model 3 Growing Season Paleo-Indian Logistical Settlement Without Water As A Factor, Type 1, 2, And 3 Sites

Category	Observed	Expected
Type 1-2 (High)	0	2
Type 1-2 (Medium)	1	1
Type 1-2 (Unsuitable)	4	2
Type 3 (High)	4	4
Type 3 (Medium)	7	8
Type 3 (Unsuitable)	7	6

Chi-Square = 4.292
P = 0.5082

Table C.14. Chi-Square Calculated For Model 3 Growing Season Paleo-Indian Logistical Settlement Without Water As A Factor, Type 1 And 2 Sites

Suitability	Observed	Expected
High	0	2
Medium	1	1
Unsuitable	4	2

Chi-Square = 4
P = 0.1353

Table C.15. Chi-Square Calculated For Model 3 Growing Season Paleo-Indian Logistical Settlement Without Water As A Factor, Type 3 Sites

Suitability	Observed	Expected
High	4	4
Medium	7	8
Unsuitable	7	6

Chi-Square = 0.292
P = 0.8643

Table C.16. Chi-Square Calculated For Model 3 Growing Season Paleo-Indian Residential Settlement Without Water As A Factor, Type 1 And 2 Sites

Suitability	**Observed**	**Expected**
High	0	2
Medium	3	1
Unsuitable	2	2

Chi-Square = 6.000
P = 0.0498

APPENDIX D:

Sample AML And IML Programs

Sample AML Program: White Spruce Overstory Habitat Model

```
&sv countylist = countylist.txt
&if [null %countylist%] &then
&return &warning No file entered
&sv filunit = [open %countylist% openstatus -read]
&if %openstatus% <> 0 &then
&return &warning Error opening %countylist%
&sv county = [read %filunit% readstatus]
&if %readstatus% <> 0 &then
&return &warning Could not read file
&do &while %readstatus% = 0

&system mkdir %county%
exit

w %county%

polygrid ..\..\..\..\gis_data\soils\%county%\soils soil_text wh_spruce
30
y

w e:\gis_temp

w c:\idrisi
&system environ x 1 e:
environ x 2 \gis_temp
erdidris x 1 dryness.gis temp
scalar x temp temp2 4 100
fuzzy x 1 20 50 50 80 temp2 temp3
scalar x temp3 soil_dry 3 100
convert x soil_dry soil_dry 1 1 2
erdidris x 3 soil_dry soil_dry.gis
maint x 1 1 soil_dry
maint x 1 1 temp
maint x 1 1 temp2
maint x 1 1 temp3
exit

w e:\dissertation\models\plants\white_spruce\%county%
imagegrid e:\gis_temp\soil_dry.gis temp

grid
soil_dry = temp / 10.0
q

kill temp all

grid
tmp_bl_sp = ..\..\black_spruce\%county%\bl_spruce * 100
q
```

```
gridimage tmp_bl_sp # e:\gis_temp\bl_tmp.gis erdas none
kill tmp_bl_sp all

w c:\idrisi
&system environ x 1 e:
environ x 2 \gis_temp
erdidris x 1 bl_tmp.gis temp
scalar x temp temp2 4 100
fuzzy x 1 0 0 0 10 temp2 temp3
scalar x temp3 bl_spr 3 100
convert x bl_spr bl_spr 1 1 2
erdidris x 3 bl_spr bl_spr.gis
maint x 1 1 bl_spr
maint x 1 1 temp
maint x 1 1 temp2
maint x 1 1 temp3
exit

w e:\dissertation\models\plants\white_spruce\%county%
imagegrid e:\gis_temp\bl_spr.gis temp

grid
bl_spr = temp / 10.0
q

kill temp all

grid
text_tmp = soil_text * 0.5
dry_tmp = soil_dry * 0.5
wh_tmp = text_tmp + dry_tmp
bl_spr_r = bl_spr * 0.1
wh_tmp2 = wh_tmp * bl_spr_r
wh_tmp3 = wh_tmp2 * 10
wh_tmp4 = reclass(wh_tmp3, ../suit.rcl, data)
wh_spruce = wh_tmp4 / 10.0
q

kill text_tmp all
kill dry_tmp all
kill wh_tmp2 all
kill wh_tmp3 all
kill wh_tmp4 all
kill bl_spr_r all
kill bl_spr all
rename wh_tmp wh_spr_orig
&system mkdir e:\dissertation\models\plants\spruce\%county%
exit

grid
temp = wh_spruce * ..\..\..\..\gis_data\base\%county%\hydro_dist
e:\dissertation\models\plants\spruce\%county%\spruce = temp + ..\..\black_spruce\%county%\bl_spruce
q

kill temp all
```

```
w ..

&sv county = [read %filunit% readstatus]
&end
/*Close the county list file
&if [close %filunit% -all] <> 0 &then
&return &warning unable to close %fil%
&return
```

Sample AML Program: Summer Moose Habitat Model

```
&sv countylist = countylist.txt
&if [null %countylist%] &then
&return &warning No file entered
&sv filunit = [open %countylist% openstatus -read]
&if %openstatus% <> 0 &then
&return &warning Error opening %countylist%
&sv county = [read %filunit% readstatus]
&if %readstatus% <> 0 &then
&return &warning Could not read file
&do &while %readstatus% = 0
&system mkdir %county%
exit
w %county%

copy ..\..\..\plants\aspen_birch\%county%\a_birch
copy ..\..\..\plants\alder_willow\%county%\alder_wil
copy ..\..\..\plants\cherry_serviceberry\%county%\cherry_ser
copy ..\..\..\plants\cranberry_labrador_tea\%county%\cran_bl_lt
copy ..\..\..\plants\raspberry\%county%\raspberry
copy ..\..\..\plants\blueberry\%county%\blueber
copy ..\..\..\..\gis_data\wetlands\%county%\nwi_water
copy cherry_ser under

grid
cran_r = cran_bl_lt * 0.7
rasp_r = raspberry * 0.4
blueber_r = blueber * 0.4
overst = a_birch + alder_wil
shrub = cran_r + rasp_r + blueber_r
browse_tmp = overst + shrub + under
browse_tmp2 = browse_tmp * 10
browse_tmp3 = reclass(browse_tmp2, ../browse.rcl, data)
browse = browse_tmp3 / 10.0
q

kill cran_r all
kill rasp_r all
kill blueber_r all
kill browse_tmp all
kill browse_tmp2 all
kill browse_tmp3 all
grid
```

```
water_tmp = reclass(hydro_grd, ..\water.rcl, nodata)
water_tmp2 = setnull(water_tmp == 0, water_tmp)
water = merge(water_tmp2, nwi_water)
wet1 = reclass(water, ..\wet1.rcl, nodata)
wet2 = reclass(water, ..\wet2.rcl, nodata)
wet3 = reclass(water, ..\wet3.rcl, nodata)
wet4 = reclass(water, ..\wet4.rcl, nodata)
wet5 = reclass(water, ..\wet5.rcl, nodata)
kill water_tmp all
kill water_tmp2 all
kill nwi_water all
kill hydro_grd all
q

grid
wetdist1 = eucdistance(wet1)
wetdist2 = eucdistance(wet2)
wetdist3 = eucdistance(wet3)
wetdist4 = eucdistance(wet4)
wetdist5 = eucdistance(wet5)
q
gridimage wetdist1 # e:\gis_temp\wetdist1.gis erdas none
gridimage wetdist2 # e:\gis_temp\wetdist2.gis erdas none
gridimage wetdist3 # e:\gis_temp\wetdist3.gis erdas none
gridimage wetdist4 # e:\gis_temp\wetdist4.gis erdas none
gridimage wetdist5 # e:\gis_temp\wetdist5.gis erdas none
kill wetdist1 all
kill wetdist2 all
kill wetdist3 all
kill wetdist4 all
kill wetdist5 all

w c:\idrisi
&system environ x 1 e:
environ x 2 \gis_temp
erdidris x 1 wetdist1.gis temp1
erdidris x 1 wetdist2.gis temp2
erdidris x 1 wetdist3.gis temp3
erdidris x 1 wetdist4.gis temp4
erdidris x 1 wetdist5.gis temp5
fuzzy x 1 0 0 0 200 temp1 fuz1
fuzzy x 1 0 0 0 200 temp2 fuz2
fuzzy x 1 0 0 0 200 temp3 fuz3
fuzzy x 1 0 0 0 200 temp4 fuz4
fuzzy x 1 0 0 0 200 temp5 fuz5
scalar x fuz1 wet1 3 1.0
scalar x fuz2 wet2 3 0.8
scalar x fuz3 wet3 3 0.7
scalar x fuz4 wet4 3 0.4
scalar x fuz5 wet5 3 0.2
overlay x 9 wet1 wet2 over1
overlay x 9 over1 wet3 over2
overlay x 9 over2 wet4 over3
overlay x 9 over3 wet5 over4
scalar x over4 wat_dist 3 100
convert x wat_dist wat_dist 1 1 2
```

```
erdidris x 3 wat_dist wat_dst2.gis
exit
w e:\dissertation\models\animals\moose_summer\%county%
imagegrid e:\gis_temp\wat_dst2.gis temp
grid
wat_dist = temp / 10.0
water_tmp = setnull(water == 0, water)
adj_grd = merge(water_tmp, wat_dist)
q
kill temp all
kill water_tmp all
kill wet1 all
kill wet2 all
kill wet3 all
kill wet4 all
kill wet5 all

grid
species1 = reclass(cran_bl_lt, ..\diversity1.rcl, data)
species2 = reclass(cherry_ser, ..\diversity1.rcl, data)
species3 = reclass(a_birch, ..\diversity1.rcl, data)
species4 = reclass(alder_wil, ..\diversity1.rcl, data)
species5 = reclass(raspberry, ..\diversity1.rcl, data)
species6 = reclass(blueber, ..\diversity1.rcl, data)
div_tmp = species1 + species2 + species3 + species4 + species5 + species6
diversity = reclass(div_tmp, ..\diversity2.rcl, data)
q

kill cran_bl_lt all
kill cherry_ser all
kill a_birch all
kill alder_wil all
kill raspberry all
kill blueber all
kill species1 all
kill species2 all
kill species3 all
kill species4 all
kill species5 all
kill species6 all
kill div_tmp all

grid
brow_tmp = browse * 0.45
div_tmp = diversity * 0.45
adj_tmp = adj_grd * 0.1
moose_sum = brow_tmp + div_tmp + adj_tmp
q

kill brow_tmp all
kill div_tmp all
kill adj_tmp all

w ..

&sv county = [read %filunit% readstatus]
```

```
&end
&if [close %filunit% -all] <> 0 &then
&return &warning unable to close %fil%
&return
```

Sample IML Program: Model 1 Dormant Season Resource Use

```
erdidris x 1*%1\beaver.gis*%1\beaver
erdidris x 1*%1\caribou.gis*%1\caribou
erdidris x 1*%1\hare.gis*%1\hare
erdidris x 1*%1\mastodon.gis*%1\mastodon
erdidris x 1*%1\moose.gis*%1\moose
erdidris x 1*%1\muskrat.gis*%1\muskrat
scalar x %1\beaver*%1\beaver2*4*10
scalar x %1\caribou*%1\caribou2*4*10
scalar x %1\hare*%1\hare2*4*10
scalar x %1\mastodon*%1\mastodon2*4*10
scalar x %1\moose*%1\moose2*4*10
scalar x %1\muskrat*%1\muskrat2*4*10
convert x %1\beaver2*%1\beaver2*i*3*2*2
convert x %1\caribou2*%1\caribou2*i*3*2*2
convert x %1\hare2*%1\hare2*i*3*2*2
convert x %1\mastodon2*%1\mastodon2*i*3*2*2
convert x %1\moose2*%1\moose2*i*3*2*2
convert x %1\muskrat2*%1\muskrat2*i*3*2*2
mce x
%1\residential_obj1l*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\Model1\Weight_Files_No_
Water\Residential\low_risk_residential_obj1.dsf
mce x
%1\residential_obj2l*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\Model1\Weight_Files_No_
Water\Residential\low_risk_residential_obj2.dsf
mce x
%1\residential_obj3l*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\Model1\Weight_Files_No_
Water\Residential\low_risk_residential_obj3.dsf
mce x
%1\res_use1dl*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\Model1\Weight_Files_No_Water\
Residential\low_risk_residential_objectives.dsf
erdidris x 3*%1\res_use1dl*%1\res_use1dl.gis
mce x
%1\residential_obj1*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\Model1\Weight_Files_No_W
ater\Residential\residential_obj1.dsf
mce x
%1\residential_obj2*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\Model1\Weight_Files_No_W
ater\Residential\residential_obj2.dsf
mce x
%1\residential_obj3*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\Model1\Weight_Files_No_W
ater\Residential\residential_obj3.dsf
mce x
%1\res_use1d*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\Model1\Weight_Files_No_Water\R
esidential\residential_objectives.dsf
erdidris x 3*%1\res_use1d*%1\res_use1d.gis
```

```
mce x
%1\residential_obj1r*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\Model1\Weight_Files_No_Water\Residential\high_risk_residential_obj1.dsf
mce x
%1\residential_obj2r*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\Model1\Weight_Files_No_Water\Residential\high_risk_residential_obj2.dsf
mce x
%1\residential_obj3r*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\Model1\Weight_Files_No_Water\Residential\high_risk_residential_obj3.dsf
mce x
%1\res_use1dr*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\Model1\Weight_Files_No_Water\Residential\high_risk_residential_objectives.dsf
erdidris x 3*%1\res_use1dr*%1\res_use1dr.gis
scalar x %1\caribou2*%1\caribou_obj1d*3*1
scalar x %1\mastodon2*%1\mastodon_obj1d*3*0.8
scalar x %1\moose2*%1\moose_obj1d*3*0.6
scalar x %1\beaver2*%1\beaver_obj1d*3*0.4
scalar x %1\muskrat2*%1\muskrat_obj1d*3*0.2
scalar x %1\hare2*%1\hare_obj1d*3*0.2
convert x %1\mastodon_obj1d*%1\mastodon_obj1d*i*3*2*2
convert x %1\moose_obj1d*%1\moose_obj1d*i*3*2*2
convert x %1\caribou_obj1d*%1\caribou_obj1d*i*3*2*2
convert x %1\beaver_obj1d*%1\beaver_obj1d*i*3*2*2
convert x %1\muskrat_obj1d*%1\muskrat_obj1d*i*3*2*2
convert x %1\hare_obj1d*%1\hare_obj1d*i*3*2*2
scalar x %1\caribou2*%1\caribou_obj2d*3*1
scalar x %1\mastodon2*%1\mastodon_obj2d*3*0.6
scalar x %1\moose2*%1\moose_obj2d*3*0.6
scalar x %1\beaver2*%1\beaver_obj2d*3*0.4
scalar x %1\muskrat2*%1\muskrat_obj2d*3*0.2
scalar x %1\hare2*%1\hare_obj2d*3*0.2
convert x %1\caribou_obj2d*%1\caribou_obj2d*i*3*2*2
convert x %1\mastodon_obj2d*%1\mastodon_obj2d*i*3*2*2
convert x %1\moose_obj2d*%1\moose_obj2d*i*3*2*2
convert x %1\beaver_obj2d*%1\beaver_obj2d*i*3*2*2
convert x %1\muskrat_obj2d*%1\muskrat_obj2d*i*3*2*2
convert x %1\hare_obj2d*%1\hare_obj2d*i*3*2*2
mce x
%1\caribou_log_1d*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\model1\Weight_Files_No_Water\Logistical\caribou_log_obj_dormant.dsf
mce x
%1\mastodon_log_1d*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\model1\Weight_Files_No_Water\Logistical\mastodon_log_obj_dormant.dsf
mce x
%1\moose_log_1d*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\model1\Weight_Files_No_Water\Logistical\moose_log_obj_dormant.dsf
mce x
%1\beaver_log_1d*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\model1\Weight_Files_No_Water\Logistical\beaver_log_obj_dormant.dsf
mce x
%1\muskrat_log_1d*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\model1\Weight_Files_No_Water\Logistical\muskrat_log_obj_dormant.dsf
mce x
%1\hare_log_1d*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\model1\Weight_Files_No_Water\Logistical\hare_log_obj_dormant.dsf
```

```
mdchoice x
#*%1\log_1d*3*1*10*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\model1\Weight_Files_No_
Water\Logistical\logistical_choice_dormant.dsf
mdchoice x
#*%1\log_1d_low*1*1*10*E:\Dissertation\Models\Hunter_Gatherer\Resource_Use\model1\Weight_Files
_No_Water\Logistical\logistical_choice_low_dormant.dsf
erdidris x 3*%1\log_1d1*%1\log_1d1.gis
erdidris x 3*%1\log_1d2*%1\log_1d2.gis
erdidris x 3*%1\log_1d3*%1\log_1d3.gis
erdidris x 3*%1\log_1d_low*%1\log_1d_low.gis
erdidris x 3*%1\mastodon_log_1d*%1\mastodon_log_1d.gis
erdidris x 3*%1\moose_log_1d*%1\moose_log_1d.gis
erdidris x 3*%1\beaver_log_1d*%1\beaver_log_1d.gis
erdidris x 3*%1\muskrat_log_1d*%1\muskrat_log_1d.gis
erdidris x 3*%1\hare_log_1d*%1\hare_log_1d.gis
erdidris x 3*%1\caribou_log_1d*%1\caribou_log_1d.gis
delete x %1\mastodon_obj1d.rst
delete x %1\mastodon_obj1d.rdc
delete x %1\mastodon_obj2d.rst
delete x %1\mastodon_obj2d.rdc
delete x %1\moose_obj1d.rst
delete x %1\moose_obj1d.rdc
delete x %1\moose_obj2d.rst
delete x %1\moose_obj2d.rdc
delete x %1\beaver_obj1d.rst
delete x %1\beaver_obj1d.rdc
delete x %1\beaver_obj2d.rst
delete x %1\beaver_obj2d.rdc
delete x %1\muskrat_obj1d.rst
delete x %1\muskrat_obj1d.rdc
delete x %1\muskrat_obj2d.rst
delete x %1\muskrat_obj2d.rdc
delete x %1\hare_obj1d.rst
delete x %1\hare_obj1d.rdc
delete x %1\hare_obj2d.rst
delete x %1\hare_obj2d.rdc
delete x %1\caribou_obj1d.rst
delete x %1\caribou_obj1d.rdc
delete x %1\caribou_obj2d.rst
delete x %1\caribou_obj2d.rdc
delete x %1\log_1d1.rst
delete x %1\log_1d1.rdc
delete x %1\log_1d2.rst
delete x %1\log_1d2.rdc
delete x %1\log_1d3.rst
delete x %1\log_1d3.rdc
delete x %1\log_1d_low.rst
delete x %1\log_1d_low.rdc
delete x %1\mastodon_log_1d.rst
delete x %1\mastodon_log_1d.rdc
delete x %1\moose_log_1d.rst
delete x %1\moose_log_1d.rdc
delete x %1\beaver_log_1d.rst
delete x %1\beaver_log_1d.rdc
delete x %1\muskrat_log_1d.rst
delete x %1\muskrat_log_1d.rdc
```

```
delete x %1\hare_log_1d.rst
delete x %1\hare_log_1d.rdc
delete x %1\caribou_log_1d.rst
delete x %1\caribou_log_1d.rdc
delete x %1\beaver.rst
delete x %1\beaver.rdc
delete x %1\beaver2.rst
delete x %1\beaver2.rdc
delete x %1\caribou.rst
delete x %1\caribou.rdc
delete x %1\caribou2.rst
delete x %1\caribou2.rdc
delete x %1\hare.rst
delete x %1\hare.rdc
delete x %1\hare2.rst
delete x %1\hare2.rdc
delete x %1\mastodon.rst
delete x %1\mastodon.rdc
delete x %1\mastodon2.rst
delete x %1\mastodon2.rdc
delete x %1\moose.rst
delete x %1\moose.rdc
delete x %1\moose2.rst
delete x %1\moose2.rdc
delete x %1\muskrat.rst
delete x %1\muskrat.rdc
delete x %1\muskrat2.rst
delete x %1\muskrat2.rdc
delete x %1\residential_obj1l.rst
delete x %1\residential_obj1l.rdc
delete x %1\residential_obj2l.rst
delete x %1\residential_obj2l.rdc
delete x %1\residential_obj3l.rst
delete x %1\residential_obj3l.rdc
delete x %1\residential_obj1.rst
delete x %1\residential_obj1.rdc
delete x %1\residential_obj2.rst
delete x %1\residential_obj2.rdc
delete x %1\residential_obj3.rst
delete x %1\residential_obj3.rdc
delete x %1\residential_obj1r.rst
delete x %1\residential_obj1r.rdc
delete x %1\residential_obj2r.rst
delete x %1\residential_obj2r.rdc
delete x %1\residential_obj3r.rst
delete x %1\residential_obj3r.rdc
```

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