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**AN INDIVIDUAL-BASED COMPARATIVE ADVANTAGE MODEL:
DID ECONOMIC SPECIALIZATION MEDIATE THE FLUCTUATING
CLIMATE OF THE LATE PLEISTOCENE DURING THE TRANSITION
FROM NEANDERTHALS TO MODERN HUMANS?**

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Abstract of the Thesis

AN INDIVIDUAL-BASED COMPARATIVE ADVANTAGE MODEL: DID ECONOMIC SPECIALIZATION MEDIATE THE FLUCTUATING CLIMATE OF THE LATE PLEISTOCENE DURING THE TRANSITION FROM NEANDERTHALS TO MODERN HUMANS?

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Anthropologists continue to debate the grounds for the survival of anatomically modern humans and the demise of the Neanderthals. One important distinction between the two groups may be the level of economic cooperation. I present a model for quantifying the benefits of within-group economic cooperation by examining all facets of productive, economic activity critical to survival in the fluctuating climate of Europe at the time of the transition from Neanderthals to Early Modern humans. The model's decision making engine is based on David Ricardo's Law of Comparative Advantage. Data from the prehistoric archaeological and physical anthropological records define the main economic parameters of the model: group size, task repertoire, and individual skill variation. Settlement patterns for both groups are based on individual site data, climate, and periods of occupation. Climate records, derived from ice-cores, terrestrial cores, and paleoclimate reconstructions define the climatic input for the model.

The model presented here covers new ground in that it addresses within-group individual skills across all tasks critical to survival, and not just foraging. It addresses the impact on individual and group survival, and it illustrates the importance of diversity and cooperation in stressful, climatic situations.

The archaeological data suggests that early modern humans performed a wider range of activities and tasks, congregated in larger groups, and possibly had a more diverse range of skills than Neanderthals. The model shows that all members of the group benefit when each task is assigned to that individual most proficient in the performance of that task, and when the resulting outputs are equitably distributed among the group members: the benefits achieved through cooperation by the early moderns are in the range of 17-19%, and by Neanderthals in the range of 11-13%. Settlement patterns in Europe indicate that early moderns moved into higher latitudes and colder zones than Neanderthals, despite the fact that severe and abrupt climate swings occurred during this period. This implies that economic cooperative behavior might have been an important adaptive response to the deteriorating climate of the time, and that such behavior enabled the modern humans to out-survive the Neanderthals.

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Chapter One

Introduction

1.1 Modeling Economic Specialization in Europe in the Late Pleistocene

“It is likely that a diversity of talent is present in a band of hunter-gatherers such that the best maker of a certain type of tool is not often the best maker of a different sort or the best user of the tool. This contributes to the symmetry of relationships, since altruistic acts can be traded with special reference to the talents of the individuals involved.” (Trivers 1971: Page 45)

The question of the demise of the Neanderthals and the survival of anatomically modern humans has been of continued interest to anthropologists for the last 100 years or so. This issue has been approached and modeled in a number of ways. Some pinpoint competition based on the principle of exclusion between competitive, interacting species as the driving force (Flores 1998; Shea 2003), whereas others maintain that there was little contact between Neanderthals and modern humans as the latter spread across Europe (Bocquet-Appel and Demars 2000; Stewart 2004; Finlayson, Pacheco et al. 2006). Finlayson (2004) proposes that the extinction of Neanderthals and growth of modern populations were independent events driven by bio-geographical and climate events that favored a population that was adapted to exploitation of the bio-rich open plains. One model shows that a small demographic advantage, amounting to less than one percent difference in mortality, might lead to a rapid extinction of Neanderthals (Zubrow 1989).

An analysis of dental remains of early hominids, Neanderthals, and Early Upper Paleolithic Europeans shows a dramatic increase in adult survivorship in the Early Upper Paleolithic (Caspari and Lee 2004); an increase that is not observed in earlier modern humans in the Levant from Qafzeh and Skhul (Caspari, personal

communication). This suggests a late cultural adaptation (Caspari and Lee 2005) that, together with the selective advantage provided by grand-mothering (O'Connell 1999), may have provided the impetus for the survival of modern humans in Europe (Hawkes and O'Connell 2005; Minichello 2005). The increases in longevity and reduction in mortality have been associated with increasing diet breadth (Hockett and Haws 2003; Hockett and Haws 2005) and maintenance of critical dietary balance by the substitution of dietary fat for carbohydrates in low plant environments (Cachel 1997).

Stringer and colleagues (2003) argue that modern humans survived in Europe during the late Pleistocene because they were better able to deal with the dramatic climate oscillations of the period. Neanderthals were skeletally more robust (Trinkaus 1983; Trinkaus 1986) and deemed to be the cold-adapted species (Holliday 1997a), yet recent studies show that they might not have been able to exist in temperatures below -8° to -12°C (Aiello and Wheeler 2003; Davies, Valdes et al. 2003), and preferably settled in more temperate locations. Neanderthals retreated from the Central European Plains as conditions deteriorated, whereas later modern human populations were able to move into these empty spaces and settle there even up to the height of the last glaciation (Dolukhanov 1982; Gamble 1999; Dolukhanov 2001; Dolukhanov, Shukurov et al. 2002).

Cultural adaptations are the usual explanation for this achievement, yet comparisons of behavior between the two species are hampered by the scarcity of the archaeological record and the seeming similarity in many morphological and behavioral patterns observed from Neanderthal and modern human skeletal and archaeological remains. Kuhn and Stiner (2006) suggest that division of labor in foraging activities,

especially between the genders, emerged in the subtropics and provided benefits to modern humans over the Neanderthals in Europe. However, the first, early modern human occupants of the Levant appear to have utilized technologies and behavioral patterns similar to the Neanderthals (Shea 1989). Where direct comparisons of foraging behaviors have been made, little notable difference between late Neanderthals and early Upper Paleolithic behaviors have been identified (Hoffecker and Cleghorn 2000; Shea 2003; Bar-Yosef 2004). However, changes in hunting patterns after 50 ka in Italy (Stiner and Kuhn 1992; Stiner 1994) indicate that Neanderthals began to adapt to the changeable climate and were moving towards a “modern” pattern of behavior just before their demise. Similar changes are observed in Cantabria at this time (Straus 2005). Even when the record is available, transitional forms in both skeletal morphology and the introduction of transitional industries (Dobson and Geelhoed; Svoboda 1993; d'Errico, Zilhao et al. 1998; White 2001) suggest that any transition was a mosaic of physiological and cultural adaptations. Clearer differences appear only with the introduction of the late Upper Paleolithic. Comparisons are further complicated by the fact that in the case of lithic artifacts, one of the most durable evidences of behavior, the typologies used to describe Mousterian and Upper Paleolithic assemblages, are not consistent and do not adequately describe functional differences (Bisson 2000).

Micro-wear analysis of tools indicates that Neanderthals were devoted wood workers (Anderson-Gerfaud 1990). They probably lived in more closed, woodland habitats, rarely venturing into the steppe (Hoffecker 2002; Finlayson 2004). The contrasting foraging styles derived from ethnographic studies of modern hunter-

gatherers in sub-tropical and arctic conditions may offer some insights. The Neanderthals were probably closer to the high mobility forager model (Binford 1980), occupying a relatively fine-grained habitat that required high, less than seasonal, mobility frequency and essentially the same set of activities carried out at successive camps (Shott 1986; Shott 1989). It is suggested that Neanderthals rarely ventured on to the steppe-plateau for logistic collecting, but this appears to be the preferred behavior of modern hunter-gatherers in northern habitats and seems to be reflected in the patterns identified for their Upper Paleolithic predecessors (Stewart 2004). The logistic collecting model observed in modern hunter-gatherers (Binford 1980) involves fewer moves of base camps but, from these semi-permanent bases, more frequent long-distance forays are made by specialized task groups seeking to procure particular clumped resources in specific contexts (Shott 1986; Shott 1989). At any single time, collectors exhibit greater complexity and economic specialization, and a number of distinct strategies depending on context.

Many anthropologists have highlighted changes in the social behavior and structure as key factors in a gradual transition towards 'modernity' that may have begun with the late Mousterian culture, continued through transitional Early Upper Paleolithic cultures, and finally established itself in the late Upper Paleolithic. Some claim that the nuclear family, bi-parental provisioning of the young (Soffer 1994), sexual division of labor (Binford 1985), and cooperative hunting are modern behaviors (Horan, Bulte et al. 2005) that arose only during this period. Many have called for a unifying theory to bring together the biophysical and cultural changes observed throughout the transition (Wobst 1976; Harrold 1992; Gamble 1998). Wobst identified the mating networks as a

behavioral concept that allowed humans to organize and integrate socio-cultural processes (Wobst 1974), and Gamble (1982) focused on the appearance of art, the release of proximity (Gamble 1998), and changes in economic structure (Gamble 1983; Mellars 1985).

Whallon (1989) suggests that the migration of modern humans into the tundra of northern Europe and the deserts of Australia triggered the emergence of new socio-cultural structures as well as certain economic strategies that were not present in their predecessors. He also suggests that separation of labor demanded a higher level of cooperation and verbal communication within the group, helped assure group success and equitable access to the fruits of labor. A restructuring of social relations across the transition is evidenced by the introduction of distinct regional styles in representational ornaments and artifacts, and long distance social and trading networks that implies a new social dynamic where individual and group identity is important (White 1993b). Soffer (1985b) argues that there is increasing evidence for the specialization of production as well as for hierarchic behavior through time. However, this emphasis on social aspects minimizes the role of agency and the creativity of individuals (Gamble 1999).

My focus is on the potential for economic specialization and the individual benefits to be derived within Mousterian and Upper Paleolithic groups, and whether these benefits enabled these groups better to survive the oscillating and deteriorating climate of the late Pleistocene in Europe. Rather than using a top-down method, I adopt the bottom-up approach advocated by Hinde (1976). It is the decisions and actions of individual group members, each with their own special skills and aptitudes, who may

achieve additional survivorship benefits for each and all by working cooperatively together. Therefore, I propose an individual-based, decision-making model for quantifying the benefits derived from intra-group, economic activities in small egalitarian societies. This Individual-based Comparative Advantage (ICA) model is based on Ricardo's Law of Comparative Advantage (Sraffa 1951), a law that is still applied to current economic exchange relationships (Bhagwati 1998). I present this model as a new approach to throw some light on the part played by economic cooperation through specialization and exchange between individuals within Neanderthal and Upper Paleolithic human groups during the course of this transition.

1.2 The Research

In the course of my involvement with many individuals in various team-work environments I observed that humans derive enjoyment and reward from participating in team projects, particularly when they have the opportunity to perform those tasks for which they have the greatest proficiency, while letting others do those tasks which for which they themselves are not well suited. Teams, which extend beyond related castes, are observed in insect and vertebrate societies, where individual, specialist skills are invoked to accomplish specific, joint and concurrent tasks (Anderson and Franks 2001). This leads me to conclude that such cooperative behavior is deep-rooted. I question whether humans have an innate propensity for this type of economic behavior that may have evolved and provided a selective advantage to those groups and societies that practiced such specialization and exchange. Evidence of economic specialization and exchange is observed first in early agricultural societies. Could these traits be discerned in societies that existed prior to the advent of agriculture and settled societies in the

Neolithic period? This question prompted me to test if one could construct a model to quantify the benefits of such cooperative behavior in pre-agricultural societies; a model that relied on data extracted from the prehistoric record. And if so, could such a model be applied to the Neanderthal / modern transition in the late Pleistocene, and could such a model be used to determine if increased levels of economic cooperation provided Upper Paleolithic humans with the selective advantage better to survive the deteriorating climate of the late Pleistocene than their Neanderthal cousins?

My research differs from other analyses of cooperative practices. Optimal foraging and per-capita maximization models can tell us much about prey choice, task group composition, and resource sharing. However, they generally make the assumption that individuals are homogeneous and interchangeable in skills and abilities, even though the more skilled may have different opportunity costs and make different choices than the less skilled (Smith 1991). The ICA model addresses the issue of diversity and the maintenance of broad skill sets within a population resulting from the benefits of cooperation and specialization (Dunbar 1981). I intend to examine whether this wider range of skill sets provides valuable adaptive rewards in terms of individual survival within a cooperative group when ecological conditions change on a seasonal or longer-term basis. Finally, per capita maximization foraging does not account for the opportunity costs of other activities or risk avoidance strategies, which could result in lower but more predictable returns. It is argued that males and females have different subsistence strategies as a result of individual selection with women following a low-risk, high predictability strategy while men follow a high risk, high reward one (Jochim 1988). The ICA model attempts to address both of these issues. Our hunter-gatherer

ancestors faced most of the risks of nature alone or in small bands composed primarily of close relatives. But larger group size brings several benefits in terms of task sharing, specialization, the accumulation of knowledge, and risk sharing, even among those who are not related (Seabright 2004). Hunter-gatherer societies began to specialize once they had found ways to manage cooperative efforts between people who were not related. Even small bands of relatives divide up tasks to some degree, but as groups grow larger, specialization became more ambitious, rewarding, and less risky, as larger populations of producers and consumers are able to even out probabilities of success.

Although specialization and exchange is more often associated with complex societies and with the organization, trade, and distribution of resources controlled by political elites (Brumfiel and Earle 1987), I examine whether it is possible to discern emergent traces of specialization and exchange in less complex and more egalitarian societies of Neanderthals and early Upper Paleolithic humans by looking at all activities critical to survival in high latitudes. Processes of differentiation, specialization, and integration indicate a trend towards increased complexity (Mellars 1985), and this movement appears to have been driven by local ecological circumstances. Although some archaeologists tend to see a diachronic progression from simplicity to complexity in cultural organization, anthropologists view this variability in terms of local ecological and cultural adaptation (Rowley-Conwy 2001). Other archaeologists see a progression in population densities and resource usage strategies from a) a simple, mobile and diversified model through b) specialization, c) specialization and storage to d) husbandry and domestication (Zvelebil 1986). The evidence from the Upper Paleolithic indicates that neither Neanderthals nor modern humans had yet achieved husbandry or

domestication, although patterns of intensification are evident in the central Russian Plains (Soffer 1985a), suggesting that even at that time some societies had moved beyond the simple, small but mobile paradigm. By looking at the role of specialization and its adaptive benefits in modern hunter-gatherers in categories a) through c), I expect to be able to determine what might have been the impact of increased specialization in the late Upper Paleolithic.

I approach this research by looking at the consumption and production economies of four populations within a time period spanning either side of the Neanderthal-Modern transition: early Neanderthal (prior to 60 ka), late Neanderthal, early Upper Paleolithic (prior to 28 ka) and middle Upper Paleolithic (27 to 20 ka). The demand side addresses those tasks and activities that are necessary to support the critical consumption needs of the populations. The supply side addresses the quantity and quality of skills within the group that are available to perform the tasks necessary to produce consumption needs. The decision-making engine in the ICA model assigns production roles to those most suited to the task and computes the benefits that might be achieved through specialization and exchange. I examine climate records and climate reconstruction models and extract data on human settlement patterns by period, by latitude, and by climate zone. I attempt to match these to the economic benefits projected by the ICA model to determine what effect these benefits might have had on Neanderthal and Upper Paleolithic human behaviors, with particular reference to temporal and spatial climatic conditions.

Chapter 2 describes the ICA model and how Ricardo's theory of comparative advantage might be applied for quantifying benefits derived from cooperation between

individuals within small groups, by examining specific data on group size, task repertoires and individual skill level variation. A prototype model validates the proof-of-concept and identifies individual and group benefits that might be anticipated in Neanderthal and Upper Paleolithic populations. Preliminary results suggest that this model may be helpful in quantifying benefits from economic specialization and cooperation. Chapters 3-6 outline the data collection procedures undertaken in order to assemble meaningful model parameters for each population. Chapter 3 examines the ethnographic record to identify the task repertoires for current hunter-gatherers in different ecological settings, to determine the proportionate amount of time devoted to key activities, and to identify the specific tasks undertaken to accomplish consumption requirements, particularly in high latitude groups. Chapter 4 surveys the archaeological record of artifacts, features, and human skeletal and faunal remains to identify to what extent the detailed task repertoire of prehistoric populations differed from that of current hunter-gatherers and from each other. Chapter 5 looks at the quantitative aspects of productive labor by examining group size and composition and the number of productive resources (quantity) available. Chapter 6 looks at the qualitative aspect of productive labor by addressing individual-based variation in skills (quality) that might be applied within a specialized economy to accomplish the production of goods for consumption: individual skill variation operates within the context of division of labor by skill proficiency as well as division of labor by gender. Chapter 7 addresses the seasonal variations and oscillating climate of the late Pleistocene and how the benefits from cooperation might have provided a significant advantage for the early modern humans in mediating the deteriorating and fluctuating climate of the period. An

examination of settlement patterns illustrates the response of these human populations to climate fluctuations and stress. Chapter 8 describes the ICA Transition model as applied to the data for Neanderthal and Upper Paleolithic populations, and presents the results obtained by applying the parameters collected in chapters 3-7. Chapter 9 concludes by interpreting the results from the model and its applicability to the transition. It discusses how these findings relate to conclusions and interpretations from other avenues of research, and explores what might be the reasons for any differences. Finally, it addresses the potential for such a comprehensive, economic approach for the examination of all critical activities, and not just foraging, in an individual-based approach to analyzing late Pleistocene human societies.

Chapter Two

The ICA Model and Its Theoretical Basis

The work of a scientist starts with the selection of an interesting problem or issue, rather than the collection of data, and the use of models or situation analyses is particularly useful in framing such an issue in the realm of the biological and social sciences (Popper 1983; Popper 1994). A model is simplistic, focuses on specific aspects of an issue that capture the essential measures of the problem and excludes aspects that are not of immediate interest. Many believe that a model of a problem cannot be built until the issue is fully understood. The reverse may be true: we build models to help solve problems where our understanding of the system is incomplete (Grimm and Railsback 2005). This hypothetico-deductive method has its roots in the eighteenth and nineteenth centuries and is based on the uncertainty of all inductive reasoning and the probationary status of the hypothesis. This method separates the creative and evaluative steps in scientific research: the processes of discovery and those of verification. This approach is characterized by sequential iterations between creating the model and testing it against empirical evidence (Medawar 1982). In this approach, a hypothesis or theory is developed based on a general knowledge or experience with the relevant facts. A process of evaluation, adjustment, and re-evaluation follows the development of the hypothesis. As in other scientific methods, hypotheses are subject to repeated testing to increase the degree of confidence and, strictly, can only be soundly disproved. Evolutionary ecologists follow this method to build simple models to examine the consequences of the hypothesis (Winterhalder and Smith 1992). These models define the issue, identify key parameters, and organize thought. They assist in

The ICA model I have designed is an actor-based, methodologically individualistic approach (Cronk 1991) similar to those used in ecological modeling (Grimm and Railsback 2005). Ecological models are used to determine how populations thrive within a specific ecological setting. I have adopted this form of model since I am specifically concerned with intra-group individual variation in their somatic or maintenance efforts and ultimately their survival prospects in an increasingly harsh environment. I am interested in how individuals might cooperate with others within their group to achieve their critical survival needs, minimize individual effort, and maximize fitness, specifically to avoid extinction in a harsh and fluctuating climate such as that of the late Pleistocene in Europe. For the model, I follow the cycle of development as defined by Grimm and Railsbach (2005):

- 2.1 The question
- 2.2 The hypotheses and theoretical bases
- 2.3 Variables, parameters, and processes
- 2.4 The prototype model as proof of concept
- 2.5 Analysis of results and evaluation of the prototype
- 2.6 Review of the design and communication of the results

2.1 The Question

The question addressed here is whether it is possible to quantify what benefits, if any, accrued from economic specialization and cooperative activities in the prehistoric societies of the Mousterian and Upper Paleolithic. Since it is not possible directly to observe the practice of cooperative behaviors in prehistoric societies, I developed the ICA model that examines the quantity and quality of productive human resources available in small prehistoric groups and the products or outputs produced in order to project the potential for economic specialization and exchange. I developed an ICA-Prototype of such a model, as proof of concept, to test hypotheses about cooperation, specialization and exchange, based on my interpretation of Ricardo's Law of Comparative Advantage as it might apply among individuals in small groups. This prototype is a stochastic model and it suggests that, within the bounds of the parameters defined, the benefits of cooperation among individuals in small societies may be quantifiably measured. I plan to test whether such a model is applicable to societies in the late Pleistocene by executing the model using key parameters derived from data in the archaeological and physical anthropological record: through genetic and morphological analysis of skeletal remains, and through the examination of archaeological features and artifacts from the Mousterian and Upper Paleolithic.

2.2 The Hypotheses and Theoretical Basis

i. The Hypotheses

Hypothesis 1: A model can be developed, that uses findings from the archaeological and physical anthropological record, to quantify

levels of cooperation and the benefits received there from in late Pleistocene societies.

Hypothesis 2: The potential for fitness benefits to be achieved through economic specialization is greater the larger the group size, the greater the repertoire of tasks, and the wider the variation of skills. These benefits of specialization accrue individually and offer better survival prospects to each individual as well as the group as a whole.

Hypothesis 3: The benefits of cooperation result in the maintenance of skill diversity within the group, allowing individuals better to adapt to the changing task complexity resulting from unpredictable climate fluctuations, as observed in the late Pleistocene.

Hypothesis 4: Survivorship benefits, accrued from intra-group, economic specialization and exchange, provided an advantage to early modern humans in Europe.

ii. Theoretical Basis - The Law of Comparative Advantage

Although rational theory and optimum foraging theory have been applied to foraging activities there has been little attention to overall economic activities in early societies. Most studies of economic prehistory are focused on Neolithic societies or later. I plan to examine how individuals may have divided all of their necessary chores among skilled individuals within small groups in order to improve survival prospects in the deteriorating conditions of the late Pleistocene.

The theoretical basis for the economic aspects of the ICA model is derived from the work of Adam Smith and David Ricardo. My ICA model is based on David Ricardo's Law of Comparative Advantage of 1817 (Sraffa 1951). Although Ricardo's law originally addressed exchange transactions between groups and countries, I suggest that it may be applied to individuals acting within a smaller market economy. In this guise, the law postulates that each individual will benefit by executing those specific tasks for which he/she has a comparative advantage (or is most skilled) when compared to other individuals in the group, while letting others pursue their own comparative advantage. Ricardo's law, when applied to relationships between nations, paid attention to differences in skills and access to natural resources that created advantage in producing specific agricultural and industrial outputs that could be exchanged bi-laterally or multi-laterally between nation states, and has recently been applied to an examination of Indian high-tech and low-tech industries (Bhagwati 1998). In the context of specialization and exchange among individuals within small groups I have identified three key parameters:

- The size and composition of the group among which tasks and products are exchanged – group size, and
- The range of tasks performed – task repertoire,
- Variations in individual skill levels between populations – skill spread.

Each of these factors is critical to the application of economic specialization and exchange. As group size increases, the number of links or contacts between individual producers and consumers grows exponentially, and this offers significantly more opportunity for inter-personal exchange. If all tasks are necessarily or habitually

produced and consumed by the same individual (e.g. eating, sleeping, and solo foraging) there is no opportunity for cooperation, but if production and consumption can be separated economic specialization may occur. Variation in skills is a key ingredient, since if all individuals are able to perform all tasks at the same level of proficiency, there is no advantage to specialization and exchange. In this context, specialization and exchange is productive only when individuals vary in their skill levels, when the repertoire of tasks can be divided into production and consumption modes, and when the repertoire is sufficiently broad and varied and the group sufficiently large to provide supply and demand volume.

iii. Theoretical Basis - Natural Selection and the Individual-based Model

The key factor that makes this approach distinct is the emphasis on the individual's skills and how the individual acts in the context of the society. Natural variation in individuals was emphasized in the *Origin of Species* (Darwin 1859; Darwin 1979: page 102): "No one supposes that all individuals of the same species are cast in the same mold". And, although Darwin was addressing inherited, biological traits, these biological predispositions have the potential to create behavioral variance among individuals (Trivers 1971). Both exchange and rational choice theory and sociobiology approaches assume a rational actor seeking his or her interest; sociobiology simply takes rational choice a step further by grounding them in evolutionary principles (Sanderson 2001).

An individual has the option to operate in a solitary manner and rely on his or her own skill advantage or may choose to cooperate with others to achieve adaptive value. Since an individual's skills and decision-making capacities (or predispositions)

are ultimately of a biological nature, they evolve through natural selection and confer some adaptive value (Mithen 1990). I am suggesting an economic argument and not a group-selectionist one. I argue that individual, adaptive benefits accrue from cooperative behavior resulting from specialization based on discrete variations in individual skill proficiency over a wide range of tasks. Decision-making, based on unique individual talents is the driver of the ICA model.

This approach incorporates methodological individualism (Smith and Winterhalder 1992; Halperin 1994), and differs from other approaches in that it stresses inter-individual variability and individual decision-making within small groups and maintains that the properties of groups are a result of the actions and decisions of each member in the group. Most archaeologists and hunter-gatherer ethnographers focus on group behaviors and do not address individual skill variation and the benefits conferred. I address the individual's economic decision-making role and focus on the group member, his/her unique skills, and contribution to and interaction with the social structure – a bottom-up model of society, which emphasizes the individual rather than the group (Hinde 1976). My approach specifically addresses the benefits to the individual of participating in cooperative specialization and exchange behaviors in small societies, before the advent of more complex societies, especially in times of climatic stress. The model I propose concentrates on somatic behavior on the understanding that an individual's ultimate reproductive fitness is dependent initially on that individual's own rational choices and motivational priorities for survival. The ICA model estimates time saved from specialization and exchange activities in performing all life's daily and critical, somatic tasks. It is not just restricted to foraging activities as

are other optimum foraging models (Kaplan and Hill 1992), models of strategies for high and low ranking individuals (Ranta, Rita et al. 1993), and economic foraging models (Horan, Bulte et al. 2005). My analysis shows that other indirect tasks such as tool making, clothing manufacture, and camp maintenance are as critical as foraging activities in high latitude groups. Any time saved through cooperation compensates for limitations in clement, daylight hours in high latitude winter, provides additional seek and search time required for acquiring widely distributed and mobile resources, and permits additional efforts to be devoted to important indirect tasks: all in support of ultimate reproductive and childcare activities. The proposed ICA model also differs from other exchange models that are based on trade networks between locations and groups (Plog 1977) in emerging complex societies. The ICA model is based on intrinsic, individual differences in skill levels that can be applied to specialized activities to generate direct benefits to the individual that consequently support the well being of the group.

Others have called for a more individual based approach to the analysis of the archaeological record; however, ethnographic and archaeological studies have rarely sought out the individual as a principal actor in the society that they are examining. Too often, analysis on early societies has focused on group activities and ignored the imprint of the individual even though methods to identify the individual do exist (Roberts and Parfitt 1999). Kuhn (2004) stresses that there is a need for an increased focus on intra-group variation in technological strategies. However, he cautions that evolutionary or economic models, though useful in determining how people *might* react if they were behaving rationally within the parameters of the model, should not assume that people

always acted rationally or in their economic best interest. Henshilwood and d'Errico (2005) argue that there is a need for defining testable hypotheses which may focus on individual decision-making and actions and their effect on cultural evolution.

The paucity of the record should not impede us from trying to extract the imprint of the individual within the group. It is possible to distinguish individual actions from the record. At Boxgrove, the pattern of transport is interpreted as being controlled by social factors governing the use and transport of artifacts rather than functional constraints (Pope and Roberts 2005). Analysis of the Schöningen spears suggests that differences in dimensions are related to individual abilities of the respective hunters and highlight the efficiencies that characterized these activities (Thieme 2005). An examination of the distinct perforations and decorations on various teeth extracted from the same animal found at Aven des Iboussières indicate that one individual made them all (Henshilwood and d'Errico 2005). At Wallerheim, individual knappers' and toolmakers' activities can be traced and linked to patterns of butchery and making of fire (Adler and Conard 2005). However, these types of observation have yet to be placed into a complex organizational or economic structure. With unique and varied skills and talents, individuals must have played key roles within their social circle, through their day-to-day social interactions, technological inventions, and contribution to behavioral strategies, and we should attempt to understand how these everyday and seemingly mundane material activities affected group stability, integrity, and survival (Dobres 2005).

In summary, the theoretical basis for the ICA model rests on rational choice and natural selection, which both offer plausible explanations for the pursuit of self-interest

with rational choice implying the pre-existence of specific preferences. Natural selection shapes these preferences both through genetic and cultural selection. Co-evolutionary theory argues that genetic selection and cultural selection tend to interact in the evolution of traits that are adaptively advantageous to some or all of their bearers (Durham 1991), and behaviors that are linked to greater fitness in a particular natural and social environment and that are heritable (through culture or genes) should, therefore, tend to become more prevalent in a population (Kelly 1995). Selection integrates phenotypic variation, some of which is heritable, between individuals, which differ in their ability to survive and reproduce (Smith and Winterhalder 1992). For evolutionary biology, proximate mechanisms such as plasticity and flexibility are the causes upon which selection acts (West-Eberhard 2003). Since behavioral traits are generally not controlled by single genes, and not easily analyzed in exact genetic models, ecologists and anthropologists use the observable phenotypes as adaptations and claim that behavioral strategies and decision-rules have been shaped by selection – the phenotypic gambit (Grafen 1984). Thus, evolutionary ecology treats the phenotype, not the genotype, as the unit of study and identifies a proximate currency for fitness to replace the more difficult to measure fertility rates. Currencies used may include reproductive success, survival frequency, and energy costs. The currency that I have adopted for the ICA model is time expenditure and individual survival rates. Those individuals that are capable of accomplishing all their life critical tasks in the least time are deemed to be the fittest. Those that fail to do so within the time available perish.

2.3 Variables, Parameters, and Processes

Intrinsic and extrinsic parameters or constraints (Stephens and Krebs 1986) are programmed into the ICA model. The first and controlling intrinsic parameter is individual variability. Unique skill levels are randomly assigned to each individual for each task to be performed. Each individual is separately endowed with unique skill proficiencies that enable that individual to perform some tasks more efficiently than other tasks in comparison to other individuals in a group. Some of these traits are grounded in biophysical variation; others are enhanced by habitual activity (Trinkaas 1983; Churchill and Smith 2000; Churchill 2001; Niewoehner 2001). The ICA model permits each population to have a different skill spread, depending on biological or cultural factors to be determined (see Chapter 6). The skill spread is represented by the standard deviation of a population with a mean skill level of 100. For example, with a standard deviation of 16 the range of skills for 95% of the population ranges from the lowest skilled individual at 68 to the highest at 132 – a range of 64. A skill proficiency below 68 is insufficient for individual maintenance, and a skill proficiency of above 132 is beyond the capacity of that population – satiation (Lomnicki 1988). These individual skill proficiencies are used to calculate the amount of time required to perform each applicable task and to determine the capability of that individual for performing daily chores in either a solo or cooperative setting.

The second key parameter for the model is group size and composition. Network size is critical for mate selection (Wobst 1976). Group size is important for two other reasons. First, in the economic arena a larger group or network offers more scope for the exercise of specialized skills. Second, an extended group network will

include non-related individuals whose rationale for cooperating cannot be attributed to inclusive fitness alone (Hamilton 1964) and must be associated with direct exchange or delayed reciprocity (Trivers 1971). The breadth of exchange networks of both utilitarian and non-utilitarian or symbolic objects may be evidence of the nature of such networks (Gamble 1982). Group composition acknowledges the demographic composition of the group (adults, seniors, and children) in order to assess their relative contributions or demands on the economic unit (Soffer 1994).

The third key parameter is the number of activities and tasks performed by the group, or task repertoire. The Prototype model looks only at the total number of tasks performed but does not discriminate between tasks in terms of the relative time or effort required to execute that task, but the later Transition model, used to evaluate the Neanderthal to modern transition, attempts to discriminate between critical activities and their relative importance in terms of time allocated to each activity, based on ethnographic time allocation data collected in this research. Critical activities, including food acquisition, food preparation, childcare, tool making, clothing-manufacture, and camp maintenance. The total of all specific tasks within each of these activities represents the task repertoire. Once again, the larger the number of life-critical tasks the greater is the scope for the application of individual skills to each task for which the individual is best endowed (Lorandi, Rivera et al. 1984).

Extrinsic constraints are those that may limit or modify the basic decision-making process of the model: these include gender related restrictions or taboos for handling specific tasks that may restrict the way work is allocated, illness or incapacitation that may require additional work on the part of those that are fit, and

seasonal and longer-term climate factors that limit the amount of time available for pursuing daily tasks and affect survival rates. Gender roles, incapacitation, and seasonal variation are not included in the prototype but are addressed in the later Transition model, based on the data collected in this research.

2.4 The Prototype ICA Model as Proof of Concept

i. Selection of a Decision-making Engine

The first step is to select a decision-making engine for the ICA model for the allocation of specific tasks to individuals based on individual proficiencies.

The management and allocation of productive tasks within a team or group may be accomplished with two opposing approaches in mind. The first approach is to maximize the output produced within the same amount of time (output maximizing); output maximizers optimize because it allows them to produce more output at the highest rate. The second approach is to minimize the time required to produce the same quantity of output (time minimizing); time minimizers optimize because it permits them to complete production in the shortest time period and allows for alternative uses of scarce time. Arguments about output maximization and time minimization have generally focused on hunting activities and fail to take into account the opportunity costs of other necessary and critical tasks such as parental care, tool production, and social activities. Most hunter-gatherer groups are time minimizers (Smith 1987; Hames 1992), although there may be certain instances in which output maximization is preferred when alternate uses of time are less fitness-enhancing than foraging tasks (Hawkes, O'Connell et al. 1985). High mobility and lack of storage facilities means that there is little benefit in accumulating excess resources in hunter-gatherer groups.

Furthermore, late Paleolithic societies would have had to contend with a deteriorating climate, where available time would have been an especially critical resource, and the completion of production in the shortest period of time would become an imperative. Therefore, I have developed an algorithm based on a time minimization approach.

A second factor is incorporated into task allocation - the equitable distribution of work. The repeated assignment of tasks to one individual solely on the basis of that individual's initial proficiency means that the most proficient will perform the bulk of the work and the least proficient may be assigned no work at all. This method (method 1) produces all requisite outputs in the least time possible but at the expense of the most proficient individual, who is expected to work considerably more hours than would have been necessary in a non-cooperative scenario: a significant fitness drawback for the most proficient. Clearly, the most proficient would not endure this state of affairs over any extended time period and would leave the cooperative group to the detriment of the group as a whole. Even where the assignment of work is limited to the hours that an individual would have spent solo, the distribution of work still produces inequitable results, since the most proficient would continue to spend the same amount of hours as they would have done in the solo scenario and all the savings in time would accrue to the least proficient (method 2).

In order to achieve an equitable distribution of work consistent with Ricardo's Law of Comparative Advantage and with the considerations discussed above, it is necessary to consider the law of diminishing returns. Tasks are assigned, one at a time, based on a comparison of each individual's skill at a specific task and his/her willingness to continue performing that particular task. Willingness is a function of

time available and opportunity costs of other activities and is represented by an indifference curve. There is an upper limit to the amount of time an individual is willing to spend in cooperative efforts before that individual will resort to performing other, personally more critical, activities or acting solo. An individual is not prepared to spend more total time in the cooperative scenario than he/she would have in the solo scenario (total solo time). In order to distribute work efforts equitably in each period work is assigned to that individual, who, relative to all other members of the group, has the highest individual propensity to perform:

$$\frac{\text{Total solo time} - \text{time already spent this period}}{\text{Time necessary to perform the specific task}} = \text{propensity ratio}$$

Thus, as more and more tasks are assigned to the most proficient their propensity to perform additional tasks will decline relative to others that have not been assigned any work, even though the latter may be less efficient at performing the task in question. Dynamically, others that have not been assigned work will eventually rise to the level of highest propensity.

This solution (method 3) achieves lower, overall savings than methods 1 and 2, but attains a level of equity at the individual level that supports the continued cooperation and integrity of the group. This method is consistent with research on cooperation and interdependence (Roberts 2005). Interdependence represents an individual's stake in another and is defined as the dependence of the former's fitness on that of the latter regardless of any kin relationship or reciprocity. This is a critically important factor for an individual-based model where dynamic decision-making is the prime driver.

A fourth method was tested in which tasks were allocated based solely on greatest proficiency for the first 50% of the individual's solo time and, after that, assigned based on the formula above for the remainder of the time. This method assumes that the propensity to work remains constant for the first half of the day and then declines as time remaining becomes scarcer. However, this method seems rather arbitrary and yields results that are almost identical to Method 3.

The results below, from a simulation of 1,000 iterations of individual skill proficiencies for each of the four scenarios described above, show the mean benefit achieved by each individual in a group, calculated by dividing the solo time into the time allocated in the cooperative scenario.

Table 2-1 Comparison of Time Allocation Methods

	Group Size	Tasks	Skill Spread	Method 1		Method 2		Method 3		Method 4	
				Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Small Group	5	10	13	85.85	59.54	88.74	11.28	93.76	3.09	9.378	3.17
Medium Group	10	20	14	80.93	57.63	82.69	24.61	88.88	2.17	88.94	2.14
Large Group	20	40	16	75.21	53.42	76.36	29.46	82.41	2.14	82.42	2.14
Largest Group	40	60	17	71.11	50.58	71.88	31.53	77.48	2.15	77.47	2.14
					221.17		96.88		9.55		9.59

Smith (1987) argues that a time allocation model must consider both the marginal returns from an activity and the marginal changes in opportunity cost for alternate strategies forgone. Therefore, method 3 is the one I chose for my model.

ii. The Decision-making Engine

The decision-making engine involves the dynamic assignment of work to individuals within a group, based on individual skill level and propensity to perform,

and re-computes the time required to execute each individual task in the repertoire for that population. The results from the decision-making process, in which work is shared based on skill level, are compared to the time required when working solo, so that the net gain or loss in time expended can be calculated. The step by step process is defined below:-

- a. Defined input parameters for each population are a) group sizes for local (dispersed) and seasonal (aggregated) group compositions, b) a defined number of activities and tasks in its task repertoire to be achieved within a time range of 100 time-units, and c) a defined skill spread. In the Prototype these values are arbitrarily defined but are selected to bracket the values anticipated as a result of this research.
- b. For each task in the repertoire, each individual is assigned a unique skill-proficiency. A Gaussian distribution, using a program from *Recipes in C* (Press 1992), is generated about a mean of 100 and a standard deviation as defined by the spread for that population. These values are retained in the skills matrix: $P_{t,i}$ - tasks by individual.
- c. Each task within activity is given equal weight based on the time units assigned to that activity. This factor (w) is calculated by dividing the activity time by the number of tasks in the activity and is stored in the array: W_t – weights by task. In the Prototype, all tasks within that population's repertoire are assigned to one overall activity and are weighted equally.

- d. The proficiency (p) and task weight (w) are used to compute the amount of time that individual needs to spend to accomplish that specific task in that specific season.

$$\text{Required individual task time: } r_{t,i} = (w_t * 100) / p_{t,i}$$

- e. When working solo, without cooperation from any others in the group, the total time required for that individual to complete all the tasks in the repertoire is the sum of each of the required task times for that individual. This is the individual base-time in the non-cooperative scenario: $b_i = \sum r_{t,i}$.

Each individual produces one unit for each task in the repertoire. Therefore, the total number of units of each task produced by the group is the same as the size of the group.

- f. In the cooperative exchange scenario, the model assigns tasks based on comparative advantage: that individual most suited to perform a specific task (i.e. that individual who has the lowest task time amongst all individuals in the group for the task being assigned) is assigned that task. The most time-consuming tasks are assigned first and the assignment continues recursively until all tasks have been assigned and the total output for each task for the group equals one unit per member, as in the solo case. The assignment is based on each individual's propensity ratio: $b_i - e_i' / r_{t,i}$ where e_i' represents the total time already spent in previous recursive rounds.

The total cooperative-exchange time expended by each individual is the sum of all task times assigned to that individual.

$$e_i = \sum r_{t,i} \quad \text{if } (b_i - e_i') / r_{t,i} > |b_j - e_j'| / r_{t,j} \text{ for } j = 1-n, j \neq i$$

- g. The Ricardan benefits achieved from specialization and exchange are computed:

$$(b_i - e_i) / e_i$$

- h. Climate pressures are represented by a reduction (c) in the total time units available to accomplish all tasks. Thus, less proficient individuals would be less likely to accomplish their critical tasks and would die out where: $e_i < c$.

This indication of individual and consequently group survivability is the real measure of fitness in this cooperative context. Varying degrees of cooperation, dependent on group size, habitual skill spread, and task repertoire, accrue different levels of savings to the individual and are available to provide for additional foraging time and reproductive effort. The adoption of specialization and exchange behaviors permits humans to overcome the disadvantages and rigidities of biological specialization (Orquera 1984). These savings might become particularly critical in times of rapid climate fluctuation, unpredictability, and stress and can make the difference between survival and extinction.

In summary, the ICA model covers new ground in five respects:

- It addresses individual variation in the context of cooperative, group activities.
- The decision making engine incorporates indifference curves and opportunity costs based on individual variation when dynamically assigning tasks to individuals.
- It focuses on somatic needs and survival, and addresses all critical activities and not just foraging.

- It quantifies the benefits of cooperation between many individuals, even those outside of the kin-network, and de-emphasizes inclusive fitness effects that might conceal the economic benefits of cooperation.
- It addresses the impact on surviving diversity within a cooperating group, and it illustrates the importance of cooperation and delayed reciprocity in unpredictable, climatic situations.

iii. Constraints on the Distribution of Output

I have applied Ricardo's law to the production of required outputs. Other economic laws of value and pricing apply to the distribution of goods produced. I have chosen not to apply these laws in my simplified model since all indications from ethnographic studies of current hunter-gatherers indicate that goods are not distributed based on economic laws of value and pricing. Frequently, current hunter-gatherers follow rules about the primary distribution of meat portions from carcasses that are based on participation and not supply and demand. However, secondary distribution networks are often based on need: those who have more are expected to give to those who have less, especially in times of scarcity (Wiessner 1977; Peterson 1993). This may account for the time minimizing practices since having too many possessions means more pressure to give. The ethnographic analyses in Chapter 3 shows that demand sharing and group oversight of the distribution process are critical elements in the allocation of resources. With the Saqqaq Inuit, the sharing procedure is a collective activity overseen by all in the community and often involves heated discussion before consensus is reached (Dahl 2000). Demand sharing is a common practice, which also may be a way of testing behavior to assure the state of a relationship in social situations,

where relationships have to be constantly monitored and cannot be taken for granted (Peterson 1993). Computer simulations show that moralistic aggression through strategies of observing others and punishing those that cheat or even do not enforce the rules can create strong pressures to abide by the rules (Boyd and Richardson 1992). Hunter-gatherers are egalitarian because any individual who attempts to cheat others is likely to encounter the coordinated resistance of the rest of the group. Other members of the group effectively control selfish impulses, since no single individual is strong enough to overcome the coordinated resentment of the remaining members (Wilson 2002). Team studies in the animal, bacterial and business arenas indicate that team cooperation tends to deter cheaters (Anderson and Franks 2001; HOW-FAIR-Report 2003; Brockhurst, Hochberg et al. 2006).

Whenever task specialization occurs there is an element of delayed reciprocity. The specialized maker of the spearhead to be used by the expert hunter relies on the future delivery of an equitable portion of the game killed by the hunter. The pursuer relies on the cooperation of the killer of the prey. The spearhead maker, just as the maker of arctic clothing, is at greater risk of being suckered than the hunter, who can more easily seize the full payoff. Uncertainty on the equity of distribution will cause both players to defect and not achieve the benefits of cooperation. The scales are not balanced evenly. There is more to this process than is implied in the instantaneous prisoner's dilemma game (Axelrod and Hamilton 1981).

My model assumes that distribution occurs equitably; that is that each individual receives back from the cooperative efforts an equivalent to that produced by working solo.

iv. The Prototype ICA Model with Predetermined Data

I developed a prototype of the model as proof of concept based on randomly generated data to quantify the benefits from cooperation that might accrue with varying group sizes, task repertoires, and skill variances. My model compares individuals who operate solo and perform all tasks without reciprocating with others (the control group), with those that specialize in certain tasks and exchange their product with others in the group.

The prototype is executed using permutations of group sizes from five to forty productive adults, and from ten to eighty tasks. In the skill matrix each individual is assigned a unique skill proficiency level within the skill spread for that population. Skill spreads are varied by adjusting the standard deviation of the distribution from a deviation of 13 to one of 17. The combination of individual skill levels as applied to each task weight results in the time required for an individual to perform each specific task as illustrated in Table 2-2 below, which shows the proficiency of a group of ten persons with a skill spread of 14 when performing twenty life-critical tasks. Bold indicates the best performer for each task. The table lists the amount of time each individual requires to perform all tasks solo, without cooperation with others.

Table 2-2 Hours Required Performing Life Critical Tasks when Acting Solo

Small Group	Individuals					
	1	2	3	4	5	Mean
Tasks						
1	5.70	4.81	4.63	4.71	5.65	5.10
2	5.69	5.07	4.43	4.64	5.93	5.15
3	4.54	4.80	5.25	4.50	4.47	4.71
4	7.38	5.58	5.38	4.25	5.47	5.61
5	5.76	6.41	4.99	5.47	5.18	5.56
6	4.79	4.49	5.09	6.98	5.25	5.32
7	5.23	4.96	4.44	4.94	5.30	4.97
8	4.63	8.16	7.97	4.81	6.59	6.43
9	5.91	5.09	5.91	4.80	5.49	5.44
10	5.04	5.89	4.44	4.87	5.81	5.21
11	5.29	5.84	4.99	4.67	5.73	5.30
12	5.37	6.27	5.15	5.07	4.74	5.32
13	3.70	4.37	5.84	4.24	5.58	4.75
14	4.07	6.46	4.57	3.81	4.01	4.58
15	5.22	5.01	4.64	5.99	5.16	5.20
16	5.48	5.03	5.16	5.22	5.25	5.23
17	4.91	5.54	5.84	5.48	4.70	5.29
18	5.08	4.44	5.67	5.73	4.90	5.16
19	4.21	4.78	4.41	6.21	4.25	4.77
20	4.32	5.42	5.33	4.96	5.74	5.15
Total Required Hours	102.32	108.42	104.13	101.35	105.20	5.21

Table 2-3 shows the results, using the data above, after applying the decision-making engine, which assigns each task to that person most suited to the task. The total allocated hours show the time assigned to each person for performing those tasks to which he/she is most suited. The comparison of total required hours from Table 2-2 to total allocated hours from Table 2-3 indicates the individual's net benefit or Ricardan benefit. This model is a modification of the Guttman Scale model as used to compare individual skills within various tasks among the Machiguenga (Johnson 1998).

Table 2-3 Hours Allocated to Individual Best Suited to Perform Each Task

Small Group	Individuals					
	1	2	3	4	5	Mean
Tasks						
1		9.62	9.26	4.71		4.72
2		5.07	8.86	9.28		4.64
3	9.08				13.41	4.50
4		5.58		17.00		4.52
5	5.76		9.98		10.36	5.22
6	9.58	13.47				4.61
7		4.96	13.32		5.30	4.72
8	18.52			4.81		4.67
9		10.18		4.80	10.98	5.19
10	5.04		13.32	4.87		4.65
11	5.29			9.34	11.46	5.22
12		6.27	5.15		14.22	5.13
13	11.10	8.74				3.97
14			4.57	11.43	4.01	4.00
15	5.22	10.02	9.28			4.90
16	5.48	5.03	5.16	5.22	5.25	5.23
17	4.91	5.54		5.48	9.40	5.07
18	5.08	8.88	5.67	5.73		5.07
19	4.21		8.82		8.50	4.31
20	4.32	5.42		9.92	5.74	5.08
Total Allocated Hours	93.59	98.78	93.39	92.59	98.63	4.77
Total Hours Solo	102.32	108.42	104.13	101.35	105.20	5.21
Ricardan Benefit	8.53	8.89	10.31	8.64	6.25	0.43

2.5 Analysis and Communication of the Results of the Prototype

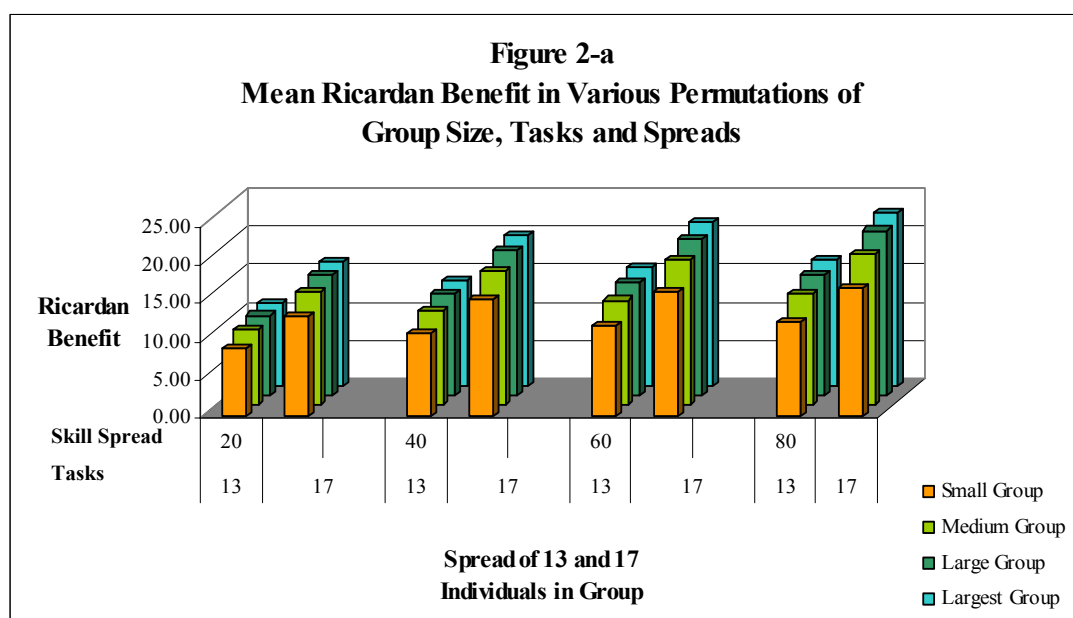
Since skills are randomly assigned based on a normal distribution, the model is subjected to a series of iterations in order to assure reasonable results. For each of the four populations, one thousand different sets of skills were generated and applied against the specified different task repertoire for that population. The average of the results for each individual are then compiled to generate individual averages as shown in the figures below. In these figures, 100 units represent the average effort required to perform all tasks solo. Thus, the data shown here represents the individual net benefit

or Ricardan benefit achieved from economic specialization and cooperation within the each population group.

i. **Results: Mean Ricardan Benefit for the Group**

The first test involves comparing results for groups of various sizes (5, 10, 20, and 40 individuals) with various task repertoires (20, 40, 60, and 80 tasks), and two skill spreads (first at a standard deviation of 13, and second, at a standard deviation of 17).

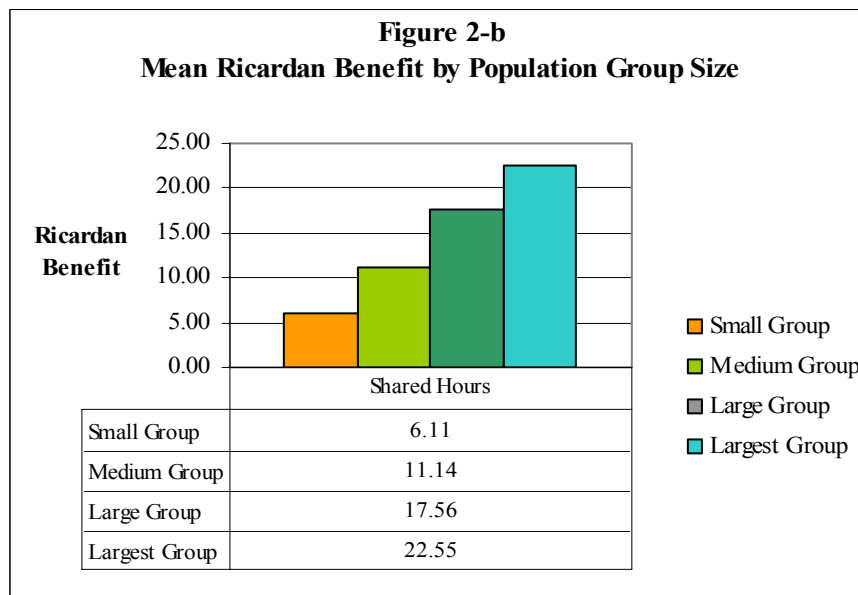
These are shown in Figure 2a below.



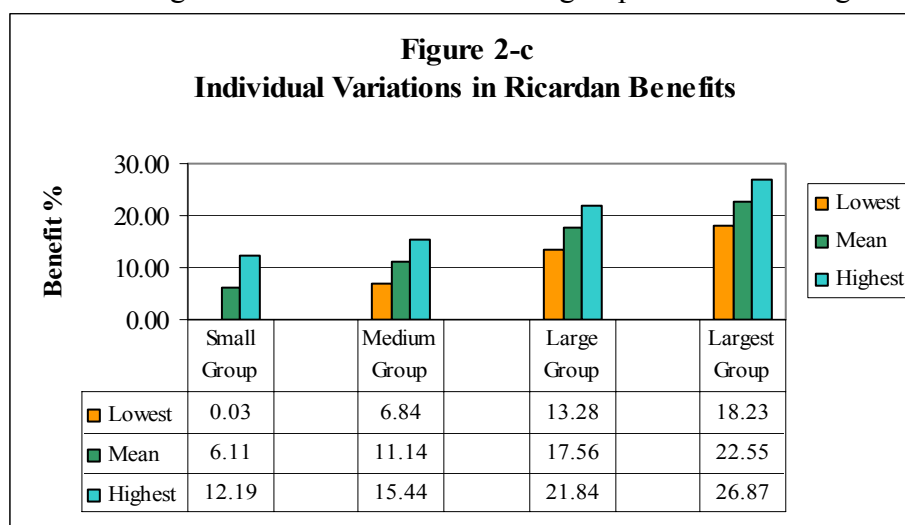
Results depicted above show that mean Ricardan benefits increase for all groups as group size, task repertoire, and skill spread increase. The smallest groups of five individuals with a skill spread of 13 achieves a net benefit of 8.68%, whereas the largest group of forty individuals with a skill spread of 18 and an eighty-task repertoire achieves 22.55%. The trend across all populations is that larger groups with more tasks and a greater skill spread achieve greater average benefits.

ii. Results: Individual Skill Diversity and Variation in Benefits

Averaged individual benefits hide significant variations between individuals. I selected four representative groups from the above data (those on the diagonal in Table 2-2), and computed the individual mean Ricardan benefits and standard deviations in one thousand iterations of skill sets in order to show this variation. Skill spreads are set at 13 for the Small Group, 14 for the Medium Group, 16 for the Large Group and 17 for the Largest Group. In each population the range of individual variation for any given selection of skill proficiencies is represented by twice the standard deviation. Thus, individuals in the group may achieve significantly different levels of benefit than the average. This average individual benefit for each of the four populations is shown in Figure 2b.



The range of variation for those same groups is shown in Figure 2c.



These data show the extent of range of individual rankings and benefits with various skill settings. Indeed, some individuals in the smallest group may achieve a no benefit from cooperation in some skill settings, whereas in the best season individuals in the smallest group may achieve a benefit of over 12%, where the average benefit is 6.11%. The largest group shows variances in individual benefit from a worst of 18.23% to a best of 26.87%. Note that in all these groups, the range of benefits overlaps with the adjacent group, even though on average the larger group, with more tasks and a wider skill spread, achieves a higher level of benefit than the smaller one. For example, in comparing the two middle groups, the worst performers in the large group are above the average performance of the medium one.

These results suggest that, within one group, lower ranked individuals may need to be supported by the more proficient. Ethnographic data suggests that roles change from season to season and that skills that are ranked less important in one season may become more critical in other seasons, in which case delayed reciprocity, from season to season, would justify this intra-group support behavior. Seasonally stochastic

individual variation and intra-group support is further addressed in chapter 8. At this point the data clearly suggests that individuals derive more benefit from cooperation in larger groups but that individual variations may significantly impact one individual's performance and ranking.

iii. Evaluation - Validation of the Model.

The comparative advantage law, as originally conceived, examined trade relations between nation states. Although some believe that the world is now “flat” in terms of equal access and opportunity (Friedman 2006), Bhagwati (1998), a strong proponent of this law, has examined the benefits achieved through comparative advantage in high and low tech industries in India and concludes that the law still valid.

I have chosen to apply this law to individuals in small groups and have selected key parameters (group size, task repertoire and individual skill variation) that are appropriate at this level. The individual-based comparative advantage model uses groups that do not cooperate as the control or baseline. This baseline is useful for calculating relative benefits among populations, even though groups that do not cooperate at all are unlikely to be found in real life – the Hadza seem to be the least cooperative of all hunter-gatherers. The application of the law of comparative advantage at the individual level is more difficult to validate in the context of the late Pleistocene, since it is hard to find a reasonable control group. The data gathered here suggests that it might be possible to compare early Upper Paleolithic groups from Iberia with those from the Russian Plains to determine if the different comparative advantage results

might be observed in these different regions, but the paucity of data might bias the study.

Ethnographic data shows that northern high latitude hunter-gatherers, such as the Inuit, are more interdependent and cooperate more actively than tropical groups such as the Hadza. The latter's social grouping is flexible and constantly changing. The Hadza are not dependent on others for access to basic requirements; they use a very limited tool kit, and have few long-term social commitments even with immediate kin (Woodburn 1988). Cape York groups also fall at the lower end in the social commitment scale (Chase and Sutton 1998). On the other hand, northern groups, such as the Inuit and Nganasan, maintain high levels of social commitment; they create extensive tool kits, invest considerable effort in clothing and shelter, and recognize individual skill and talents (Popov 1966; Golovnev 1999; Dahl 2000).

Analogous examples from nature of this cooperative effect from individual diversity within groups or teams are found in different fields. Anderson and Franks (2001) define a team as one with division of labor among team members, each performing different subtasks concurrently for successful completion. In their examination of vertebrate and invertebrate societies, they discovered that there are many more teams in animal societies than previously thought and suggest that such teams are an important part of a society's economy. They predict that insect teams are more likely to be found in complex, polymorphic rather than simple, monomorphic societies. The authors' definition of team attributes is clearly similar to the parameters of group size, tasks, and skill diversity, as used in this model.

In the microbial field, Brockhurst and colleagues (2006) studied diversity and the success of cooperation within the biofilm formed by the bacterium *Pseudomonas fluorescens*. In the context of social evolution, this work explores how division of labor may have evolved to increase efficiency by minimizing functional redundancy and reduce cheating. Diverse cooperators use different nutrients, reduce the competition for resources within the biofilm. The evolution of niche specialists in response to resource limitations provides a net benefit to the cooperating group. “Diverse groups are more likely to be more productive than clonal groups if a wide range of total resources is being used” (Brockhurst et al, 2006). Furthermore, by manipulating diversity within the biofilms, the researchers determined that fewer cheats evolved in diverse biofilms, which are able to maintain larger groups than non-diverse biofilms. Thus, diversity and division of labor within biofilms is beneficial, as it is in other ecological communities.

Other examples of this cooperative effect are found in teamwork studies in business, education and sports. Teams, that are able to bring together a variety of talents to accomplish a series of subtasks necessary to reach the target, are the winners, whether that target be the goal-line or the shortest design-to-production period. My personal (but non-scientific) experience in the business world has taught me that the completion of a series of tasks with minimal effort in the shortest period of time leads to a successful outcome, particularly in a highly competitive and dynamically changing environment. Others who have studied teams support this conclusion. “As organizations seek to become more flexible in the face of rapid environmental change and more responsive to the needs of customers, they are experimenting with new, team-based structures” (Jackson and Ruderman 1995). This

quotation might well apply to early modern humans in the late Pleistocene.

Furthermore, studies in business practices suggest that, within such diverse teams, cheaters are deterred by group consensus and social pressures. A 2003 study of opportunities in the workplace (HOW-FAIR-Report 2003) revealed that Americans, both employers and employees, think that 'being a team player' was the most important factor in getting ahead in the workplace. 'Being a team member' was ranked higher than all other factors, including 'merit and performance', 'leadership skills', 'intelligence', 'making money for the organization', and 'long hours'.

These analogous team studies demonstrate that the key drivers for productivity improvement are observed in teams comprising a diverse range of individual traits that enable the performance of a range of disparate, but concurrent tasks through division of labor. This corroborates the parameters that I have selected as variables for the model. The findings, that groups that possess these characteristics are more productive and generate more beneficial outcomes, uphold the conclusions of this research. In addition, they support my assumption that cheating is not a serious consideration within diverse cooperative teams..

iv. Evaluation - the Limitations of the ICA Model

This prototype ICA model design makes a number of assumptions that could falsify the results. Some of these I will correct as a result of this research.

First, it addresses prime-aged productive adults only, on the basis that these drive the economic engine of the nuclear family. The model does not address changes in adult productivity during the lifespan and does not address any learning process that takes place as a result of repeatedly performing similar tasks during adulthood. In

effect, it averages skill proficiencies over the entire adult lifespan. The model takes no account of the contributions of older adults even though evidence from skeletal remains indicates that the proportion of older to younger adults increased in Europe in the Upper Paleolithic (Caspari, personal communication). Similarly, no account is taken of the productive contributions or potential for cooperation of youths even though studies of skeletal remains suggest that youth mortality decreased during this period (Soffer 1994): an extended juvenile period would have provided even more opportunities for cooperation among modern humans (Dean, Leakey et al. 2001). I do not adjust for any non-adult contribution since the ethnographic data available on time allocations to tasks applies to adult members only. Adult time allocation data includes not only the time devoted to self-preservation but also that devoted to the care of infants, juveniles and the elderly: infants and youths are still dependent on their elders for the bulk of their support and this effort is included in the time allocation data available in the record and in any BMR calculations (Sorensen and Leonard 2001). Thus, although non-productive adults do make some contribution to the total effort, the adult time allocations account for all the supplementary time required fully to support the nuclear family unit. To extrapolate the data to include juveniles and the elderly would only add more uncertainty to a sparse database.

Second, this model assumes that individuals are time-minimizers (Hames 1992): ethnographic studies indicate that mobile hunter-gatherers act in this manner and do not maximize resource accumulation (Smith 1987). Even delayed-return, semi-nomadic groups in high latitude areas, under most conditions, tend to accumulate only what is required to see them through the winter. Large resource accumulation is not observed

in the archaeological record for this period. Mobility imposes severe restriction on the accumulation of resources. However, Hawkes and colleagues (1985) found the Ache to be resource-maximizers during their periodic forays into the jungle. They found that, individually, more productive hunters spent more time hunting. At the individual level this behavior is consistent with the application of the opportunity cost of other activities since in a short-term, foraging expedition other opportunity costs such as childcare and camp maintenance activities are less significant.

Third, the model assigns tasks strictly according to skill proficiency and availability as described in the formulae. It does not address the organizational process that takes place to ensure the proper allocation of tasks. Adam Smith talks about the “invisible hand” that directs economic activities. Here, it might be achieved by a community consensus to induce those most suited to perform specific tasks; alternatively it might be accomplished under the direction of an elder or respected leader or organizer. Brockhurst examines character displacement in bacterial biofilms which shows an “adaptive divergence into different niche specialists driven by resource competition” (Brockhurst, Hochberg et al. 2006). In either case, the model assumes that under the most stressful conditions the most able individuals will be called upon to perform for their own benefit and contribute to the well-being of the entire group, since their own survival depends on maintaining group integrity.

Fourth, only adult tasks that directly contribute to daily survival are counted in this analysis. Nearly all time allocation studies focus on the activities of adults in non-social activities (Hames 1992). Ethnographic time allocation studies indicate that hunter-gatherers spend only part of their day in these activities. All other activities are

treated as leisure. Some of these leisure activities are purely personal and as such cannot be shared with others (e.g. eating, personal hygiene, bodily functions etc). However, it is clear that some of these so-called leisure activities are social, networking tasks that are really necessary for the long-term survival of the group. Wiessner has estimated that the effort that goes into the production of goods for the *hxaro* network and travel to neighboring groups among the !Kung consumes a considerable amount of effort and, furthermore, that the bulk of all the goods that the !Kung possess are destined for or come from *hxaro* (Wiessner 1977). The omission of these tasks from the model, however, will tend to underestimate the benefits of cooperation since it limits the number of tasks that provide potential for specialization and exchange.

Fifth, the ICA model does not distinguish different modes of cooperation. In division of labor, by age, gender, or skill level, individuals carry out different tasks and share the fruits of their activities. In mutualism, several individuals of similar talent cooperate to achieve an end that one individual cannot achieve alone, either because of the number of 'hands' required or because of limited time availability. Group tasks of this nature add an extra layer of complexity that is not incorporated into this model. With separation of labor (Whallon 1989), individuals carry out the same tasks, but separately at different times and locations, in anticipation of increasing the probability of success when resources are scattered. In both cases, the products of the activities are made available to the group as a whole. In the ICA model I do not distinguish between these three. All tasks are fungible as regards the method of cooperation. The key condition is that the specialist or separate worker must be assured that efforts are rewarded equitably otherwise that individual is more secure in working solo. In a

specialist economy, the toolmakers and clothiers must be assured that they will receive food in return and, conversely, the hunters expect to be clothed and supplied with weapons. The separate hunter or gatherer must be assured of access to the food gathered by the entire group even if his own efforts are in vain.

Fifth, and most critical, the ICA model assumes that each contributes at his maximum skill level and the outputs from specialized production are distributed equitably among the participants – that is there is no significant cheating. This assumption is based on data on food sharing practices from the ethnographic record for egalitarian societies - in small groups social pressures to contribute one's full weight to the task at hand and share equitably with those that have not is very strong: cheaters are ostracized, and forced to live in the hostile environment outside of the camp where survival is threatened, by heat, cold, dehydration, or predation (Howell 2000). In addition, the team spirit and cultural rules on demand sharing and distribution of food apply considerable pressure to preempt cheating (Peterson 1993). Boyd and Richardson (1992) suggest that coercion through punishment has a role in enforcing cooperation if, for the punishing individual, the long-run benefits of cooperation are greater than the cost of coercing non-cooperating individuals. Nevertheless, some cheating appears to be tolerated (Blurton Jones 1984; Blurton Jones 1987). For the purposes of this research I have assumed that the pressures of the group mean that individuals work at the rate appropriate to the skill level assigned and there is minimal cheating in the equitable re-distribution of outputs.

2.6 Review of the Design and Communication of the Results

In summary, critical parameters that impact the level of cooperation and consequently the amount of benefit include:

- The number of productive individuals in the group that might participate in specialization activities,
- The number of tasks or subtasks that may be shared, which extends the scope for specialization, and
- The degree of variation in individual skill levels. If all individuals had identical skills and levels of expertise then there would be not benefit from cooperation.

The ICA model addresses the efforts of productive adults in non-leisure activities only; it assumes that every contributing, productive adult member in the group is nominally treated as kin. It assumes that individuals are time minimizers and that the societies are egalitarian, where produced resources are distributed relatively equitably and governed by rules of demand sharing rather than economic or predatory pricing.

These results suggest that the size of the group and task repertoire, and the range of skill spreads positively affect the amount of benefit achieved from economic specialization in populations that congregate in relatively small groups, but that variations in individual performance as a result of skill diversity may be quite significant, even to the extent of eliminating all benefit in very small groups.

The remainder of this research addresses three issues:

- Whether this ICA model may be applied to Neanderthal and Early Upper Paleolithic societies in Europe, by extracting data from the ethnographic, archaeological and physical anthropological record,

- What other factors may impact group and individual performance, such as time devoted to specific tasks, gender roles, and other circumstances that are important for small-group survival, such as support for temporarily incapacitated individuals, and
- If the ICA model is applicable, what are the implications for the survival or demise of these populations in the fluctuating climate of the late Pleistocene?
- **Application of the ICA Model to Societies in the Late Pleistocene**

I propose this ICA model as a framework for extracting and analyzing information contained in the archaeological and physical anthropological record that might indicate the potential for specialization and exchange in early societies.

Economic cooperation is observed in more complex societies than those of the late Pleistocene, and it is possible that this model is not applicable to the societies and behaviors that characterize this period. However, there are signs of incipient economic activity at this time, and my aim is to identify those opportunities for specialization and exchange to determine if and to what extent this model can be applied to the period of transition between Neanderthals and modern humans. Using this model, I intend to compare levels of cooperation in distinct populations at various points during the period of transition from early Neanderthals to later Neanderthals, early Upper Paleolithic (Aurignacians), and middle Upper Paleolithic (Gravettians), based on observations from the archaeological and physical anthropological record. These four populations bracket the period of transition, when late Neanderthals and early Upper Paleolithic humans were contemporaneous inhabitants in Europe.

I look at the tasks repertoire and techno unit analyses as applied to current hunter-gatherers, and match these to the archaeological record of tools, utensils, and features in the sites of the period. I examine the time allocated to basic activities by hunter-gatherer groups in various ecological settings, to determine the weighting of the various activities identified for the prehistoric groups. Tasks lists derived from high latitude, hunter-gatherer groups provide a useful guide to the range of tasks that might have been performed by late Pleistocene groups. I analyze ethnographic studies of modern hunter-gatherers to gain insights into group and network size and its seasonal variations and attempt to match this to archaeological data on settlement patterns. I review studies of skeletal remains that might shed light on demographics and group composition. I make use of skeletal morphology and genetic data together with evidence of habitual activities to assess skill spreads. Finally, I examine the record of climate conditions, both for seasonal and periodic fluctuations and settlement patterns during this period to consider the impact of climate stress on these life-critical activities. These subjects are addressed in the following chapters.

Chapter 3

The Identification of Major Activities and Tasks within Activity from the Ethnographic Record

Based on my application of Ricardo's law, one of the key controlling parameters is the task repertoire, or the range of significant tasks performed by individuals within a (potentially cooperating) group. The variation between each individual's skill and proficiency in performing every discrete task is the foundation for specialization between individuals, where each executes preferentially those tasks for which that individual is most suited, either because of an inherited propensity or a learned behavior. The size of the local group, and the critical tasks to be performed, set limits for the scope and extent of specialization and cooperation. The subject of this chapter is the identification of those critical tasks and subtasks, their ranking and relative weighting in terms of time required for completion.

My first objective is to identify how much time recent hunter-gatherers spend in key critical activities by examining the ethnographic record, since time allocation data for the specific daily routine is not retrievable from the archaeological record. At best the prehistoric archaeological record may be able to suggest how long a group spent at a particular site and what activities were performed at that site. On the other hand, the ethnographic record may give a weight and ranking in terms of the amount of time devoted by men and women to those key activities that might be pertinent for prehistoric groups. By analyzing seasonal activities of the !Kung, Tolowa, Great Basin Shoshoni and Eskimo, Halperin (1980) determined that the ratio of specific productive activities to one another, hunting to gathering, food processing to clothing, varies

seasonally, and argues that those studies that emphasize solely hunting and gathering activities, on the assumption that these accurately reflect prehistoric behavior, impede our understanding of economic processes. From my analysis I have identified six major activities executed by current hunter-gatherers: those that are directly involved in group survival and continuity, and those that indirectly support the former. Direct activities are food acquisition, food preparation, and childcare. Indirect activities are tool making, clothing manufacture, and camp maintenance. At a high level, these represent the basic activities that are critical for humans, both Neanderthal and modern, to survive and procreate in various ecological settings.

The second objective is to list, within these high-level key activities, those more detailed tasks or subtasks that are habitually performed in a particular environment. Clearly, tasks from the present will differ from those performed in the late Pleistocene, since current hunter-gatherers use technology that was not available in prehistoric times. However, I expect to be able to reconstruct, from the archaeological record, a comparable list of tasks that were executed by prehistoric peoples in the late Pleistocene. Artifacts and features of the archaeological record represent the end products of a series of tasks, similar to the ones to be identified herein from the ethnographic record. Skeletal remains may provide information on the habitual practices of these prehistoric peoples. It is these separate and distinct tasks and subtasks that could potentially have been shared and distributed amongst individuals within a prehistoric group – a possible contributor to specialization and exchange behaviors.

The ethnographic record shows that the amount of time devoted to each activity varies by latitude and by season, and, particularly for women, these changes are

significant enough to reorder task rankings and individual roles. For example, food preparation is the top ranked category in tropical zones, whereas clothing manufacture becomes the most critical female activity in high latitude areas. I intend to use this high-level data as a baseline from which time allocations may be derived (based on data from the prehistoric archaeological record) for the early and late Neanderthal, and the Early and Middle Upper Paleolithic. Neanderthal behavior is sufficiently close to that of the earliest modern humans in many of their sustenance and maintenance activities that the baseline, derived from current hunter-gatherers should be as applicable, subject to any adjustments based on findings from the archaeological record.

3.1 The Allocation of Time and Effort Devoted to Direct and Indirect Activities among Recent Hunter-Gatherers

Hunting and gathering was the main way of life, and a successful mode of existence for humans throughout most of the last two million years. Only in the last 10,000 years has agriculture become predominant, and only in the last few hundred years has the industrial way of life held sway. Recent hunter-gatherer communities are the closest proxies for our ancient Paleolithic lifestyle. Unfortunately there are few, if any, communities that live in a Pleistocene economy, with only wood, stone or bone tools (no metal), with no domesticated animals, and, of course, no contact with agricultural or industrial economies (Woodburn 1966b). Added to this, modern hunter-gatherers have been relegated to marginalized and circumscribed environments unlike those experienced by their Pleistocene forebears. Those having minimal contact with outsiders live in remote areas of the desert, dense forest, or arctic tundra where agriculturalists or pastoralists are hesitant to enter. The most likely candidates for comparison with Pleistocene societies are limited in number and in the total size of

population. Thus, there are significant concerns about using current hunter-gatherers as proxies for their late Pleistocene forebears:

- By the time anthropologists were able to perform more rigorous analysis of hunter-gatherers, the only surviving peoples were living in marginal environments and had already had some considerable contact with pastoral, agricultural or even industrial societies (Schrire 1984). The Kalahari debate revolves around the history and degree of isolation of the !Kung bushmen as described by Lee (Lee and DeVore 1966). It is suggested that, in earlier times, the !Kung were herdsmen with a lifestyle quite different from that depicted by Lee, and that these people are really not representative of late Pleistocene peoples. Here, my focus is to gain insight into the activities and tasks performed by groups from various latitudes that gain a substantial portion of their sustenance from foraging, whatever their historical lineage.
- The quality of the data gathered varies considerably. Earlier data gathered prior to the 1950-1960's was primarily qualitative but did represent a first hand view of current hunter-gatherers in their least adulterated form – an aboriginal, baseline ethnography best compiled shortly after a people's contact with post industrial societies (Oswalt 1973). Later research using quantitative methods from human behavioral ecology has been restricted to the interpretation of earlier data (Lee 2003) or applied to groups that may have changed dramatically over the recent years as a result of increased contact (Hill and Hawkes 1983).
- Most research is limited to, at worst, a single season but, at best, to several generations. Even though studies have been able to discriminate between seasonal

variations in behavior and activities (Halperin 1980), short term (4-7 year) climatic episodes and longer-term climatic variation are beyond their purview. The extinction of the Dorset peoples following northward expansion of the Thule culture and during the warming period around 900 AD, and the subsequent changes in foraging practices of the later Thule inhabitants during the Little Ice Age from 1550-1850 AD offers an historical perspective of what might happen to local populations and social organization when the climate changes dramatically (Cachel 2000; Cachel 2001) and traditional lifestyles remain unchanged. But, since we now exist in a relatively stable and benign stage in the Holocene climate, few studies of modern hunter-gatherers have been able to examine first-hand the type of dramatic climate swings experienced in the late Pleistocene during Dansgaard-Oeschger cycles. At that time, significant temperature and aridity fluctuations occurred within one to four generations and within longer and more extreme Bond cycles of five to seven thousand years (Taylor, Lamorey et al. 1993). Reconstructions of the climate of Europe during these times indicate that there were long warm interstadials, only slightly cooler than today, in which a rich flora and fauna flourished. These were interspersed with short but harsh periods of extreme arctic cold and aridity with winter temperatures about 10-20° C cooler than today mediated by relatively long cool summer days (Cortijo, Labeyrie et al. 2000; van Andel 2003c). Such late Pleistocene conditions are not mapped to any of the surviving hunter-gatherer groups studied, who generally live in tropical forests, tropical deserts or arctic conditions.

- Nevertheless, recent hunter-gatherers are able to define their own mode of life and be economically self sufficient through foraging. They maintain this lifestyle, even allowing for some level of contact and exchange with other, more sedentary societies, and represent more than cultural residue degraded by their contact with more powerful cultural systems (Layton 2001). For example: it has been suggested that, if farming did not spread into Arnhem Land, it was because hunting and gathering provided a more efficient and stable subsistence strategy (Yen 1989). For the Shoshone and !Kung foraging has continued as the basic subsistence mode down to the recent past because the regions' aridity and environmental variability make agriculture or pastoralism non-viable (Johnson and Earle 2000). In the case of the Mbuti, because of their mobility, they are better able to survive periodic, local droughts than their sedentary Lese neighbors - they even supply local Lese farmers with foraged wild meat, honey, and forest products, which are high preference foods, and in return have access to Bantu gardening produce. Both benefit from the improvement in diet (Turnbull 1983). Likewise, early modern humans defined a new mode of existence by adapting to the ecology of high-latitude Europe at a time of intense climate fluctuation and were able to move into marginal areas depopulated by the previous Neanderthal inhabitants, even though, later, they too were forced to move south during the pleniglaciation (Soffer 1994; Hoffecker 2002).
- Finally, analysis of human skeletal morphology of foragers from the Kalahari region suggests a continuity of behaviors going back at least 10,000 years. Continuity is seen in small body size, lean physique, habitual patterns of squatting postural

behavior, reliance on lower limb strength, and gender-based division of labor (Pfeiffer 2005). Current hunter-gatherers may yet have something to tell us about their prehistoric forebears.

3.2 Hunter-Gatherer Groups Examined

In order to compile a list of critical activities necessary for survival of modern humans in the climate of Europe in the late Pleistocene, I researched data on time allocation, division of labor, and seasonal variation in duties in current hunter-gatherers. These data may provide some indication of the minimal critical tasks that humans must execute in order to survive in the wild. The analysis also indicates that men and women in current hunter-gatherer societies divide these tasks differently based on ecological context. Most hunter-gatherer groups recognize separate roles for men and women; roles that change based on ecological context and become more strongly defined and interdependent in the higher latitudes (Giffen 1930). Finally, most groups, and once again most noticeably northern groups, recognize two distinct seasons with specific seasonal activities in each (Popov 1966; Mauss 1979).

I examined selected groups from low latitude areas in Africa, South America and Australia, and other high-latitude groups from North America, Greenland and Siberia, as listed in Table 3-1. A limited number of studies provided particularly valuable information and are the focus of my analysis. Unfortunately there are no detailed time allocation reports from high latitude groups; the most detailed time allocation data comes from studies from the Dobe Ju/'hoansi, Ache, Efe, and Machiguenga. These provide the starting point for my analysis and might provide insights that are somewhat applicable to the interstadial environment of the late

Pleistocene in Europe. The caribou and reindeer hunting groups - the Nganasan, Slave Lake Indians, and Nunamiut - might provide insight into the time devoted to particular aspects of daily survival-activities in high-latitude areas, which might be applicable to the seasonal patterns of the European Late Pleistocene.

Table 3-1 Hunter-Gatherer Groups Surveyed

Hunter-Gatherer group	Latitude	Habitat	Sources
Efe and Mbuti of Democratic Republic of Congo	Equatorial	Ituri rain forest	(Turnbull 1962; Turnbull 1983; Bailey and Peacock 1989; Bailey 1991)
Dobe Ju/'hoansi !Kung of Botswana	Tropical	Kalahari Desert	(Lee 1970; Lee 1972a; Wiessner 1977; Lee 1979; Biesele and Royal - /O/OO 1999; Howell 2000; Lee 2003)
Hadza of East Africa	Equatorial	Dry savanna	(Woodburn 1966a; Woodburn 1970; Woodburn 1972; Woodburn 1988; Kaplan, Hill et al. 2000)
Ache of Paraguay	Temperate	Broad leaf forest	(Hill and Hawkes 1983; Kaplan, Hill et al. 1984; Hill, Kaplan et al. 1985; Kaplan and Hill 1985a; Kaplan and Hill 1985b; Hill, Kaplan et al. 1987; Kaplan, Hill et al. 1990; Hawkes 1993a; Hawkes 1993b; Hill and Hurtado 1996).
Aborigines of Cape York and Arnhem Land, Australia	Temperate	Coastal	(Radcliffe-Brown 1930; Hiatt 1982; Rose 1987; Dingle 1988; Jones and Meehan 1989; Peterson 1993; Myers 1998) and (White 1971; Altman 1998; Chase and Sutton 1998; Martin 1999),
Pitjandara and Pintupi of Australia	Tropical	Western Desert	(Rose 1987; Myers 1998), and (Tindale 1966).
Machiguenga of Peruvian Amazon	Temperate	Highland rain forest	(Carneiro 1983; Johnson 1998; Johnson and Earle 2000; Sugiyama and Chacon 2000; Johnson 2003; Sugiyama 2004)
Shoshone of North American Plains	High latitude	Open prairie	(Steward 1938; Murphy and Murphy 1960; Thomas, Pendleton et al. 1986; Johnson and Earle 2000),
Nganasan of the Samyr Peninsula, Siberia	Arctic	Inland tundra (reindeer)	(Popov 1966; Golovnev 1999)
Slave Lake Indians of the Northwest Territories	Arctic	Inland tundra (caribou)	(Coon 1971; Ingstad 1992)
Nunamiut Caribou herders of Anaktuvuk Pass in Alaska	Arctic	Inland tundra (caribou)	(Ingstad 1954; Gubser 1965; Binford 1978a).
Saqqaq Inuit of West Greenland	Arctic	Coastal (sea mammals)	(Kleivan 1984; Wenzel 1993; Dahl 2000),
Netsilik, the Copper, and Iglulik Inuit of the Canadian central Arctic	Arctic	Coastal (sea mammals)	(Balikci 1966; Damas 1966; Damas 1972; Balikci 1984; Damas 1984).

These studies focus on adult, productive activities necessary to support the nuclear family including infants, juveniles and the elderly. They show that the primary tasks performed differ by gender, by latitude, and by season: the latter two changes driven by ecological richness and patchiness. Thus, foraging for wild plant food is the primary task for women in warm seasons and low latitudes, and there the manufacture of clothing has low priority, whereas in colder habitats the reverse applies. These studies also show that people in higher latitudes are more concerned with indirect activities other than those associated directly with food acquisition. Efe women spend little time in clothing manufacture, Machiguenga women, living in a seasonally cool temperate climate, spend 13.8% of their time in clothing manufacture (Johnson 2003), but Inuit and Nganasan women spend most of the fall and winter in working hides and preparing boots and clothing (Balikci 1966; Popov 1966; Balikci 1984). Other studies also show the changing task priorities of men and women under different ecological conditions (Giffen 1930; Mauss 1979). In the Arnhem Land, aborigines show a clear distinction in roles for men and women between the wet season when vegetal matter is unavailable and men provide almost all of the subsistence support, as opposed to the dry season when women are able to resume foraging for plant food (Jones and Meehan 1989; Altman 1998).

Extreme seasonal variation, such as was experienced in Europe during the late Pleistocene, would suggest that women might have been the primary subsistence providers during milder summers and men during the harsh winters. In times or seasons when plant resources are scarce, women emphasize indirect activities such as making clothes, housekeeping, processing and preserving food - activities that are compatible

with childcare (Jochim 1988). Since there is such a noticeable difference between the allocations among tropical/temperate groups and groups from higher latitudes, and since the best time allocation data comes from tropical and temperate groups, I have divided my analysis in two parts. First, I look at time allocation data from tropical/temperate groups, those living below latitudes 40° N or S. Then I examine the differences in task complexity and ranking in high-latitude groups (above 40° in latitude) in order to project time allocations for the latter groups.

3.3 Major Activity Rankings for Men and Women in Lower Latitudes

The best quantitative data on time allocation comes from studies of tropical and temperate groups. Ethnographies of the Dobe !Kung and Efe provide valuable information on specific allocations of time to daily tasks, and data from the other tropical groups provide qualitative data on division of labor, food gathering and processing tasks. Time allocation data from the Machiguenga provides additional and specific data on time management for a group in a more temperate zone and highlights the increased attention to clothing.

i. The Dobe Ju/'hoansi

The Dobe Ju/'hoansi live in an area of about 8,000 square kilometers in the north west Kalahari Desert on the borders of Botswana and Namibia (Lee 1970; Bieseke and Royal - /O/OO 1999; Lee 2003). The area comprises a cluster of ten waterholes north and south of the Aha hills. The Dobe Ju/'hoansi are spread over the region in areas of "land-rights" called *n!ores*. Each *n!ore* has enough food and water to sustain one band through its seasonal rounds in the average year, although resources are quite varied from *n!ore* to *n!ore*. At the center of the *n!ore* is a core of siblings - both brothers

and sisters – and their offspring of both sexes, who share a claim to the stewardship of the waterhole (Lee 1972a). These are the hosts to whom visitors come to request permission to settle and forage at the waterhole in times of need. The annual climate changes from hot summers with a four-month rainy season to moderate winters without rainfall.

Since the Dobe Ju/'hoansi have little personal property, mobility is not an issue. In the wetter season, the Dobe exploit first the nearby high quality resources until these are depleted, and then forage within a five-mile radius, even reverting to less desirable foods, before moving on to a new camp (Lee 1979). In the dryer seasons they may have to forage up to 15 km away, since they are confined to camps near to the permanent water resources. Climatic conditions are unpredictable and vary considerably from *n!ore* to *n!ore*, seasonal rains may bypass one but deluge another nearby, and groups will keep an eye out for the rain clouds in the distance to determine where the rains fell and where foraging opportunities will prevail. Local droughts are frequent and severe droughts occur one year in four. The seasonal rounds illustrate the adaptability of the Dobe Ju/'hoansi to this topography and climate.

Fifty resident mammal species provide a solid subsistence base of which the non-migratory ungulates: warthog, steenbok and duiker are the main game animals (Lee 1970). Honey is prized as a delicacy but is highly subject to seasonal fluctuation. The mongongo nut is the most important vegetable food and is available in all months of the year near all waterholes. Top preference foods are meat, mongongo, honey and fruits and they gather food in this priority order, whenever available (Lee 2003). Roots and bulbs are fall-back foods during the dry season. Meat provides about 31% of the annual

diet, mongongo nuts 28%, and the rest is from vegetable foods. The day's collection of foods is pooled so that all have a variety of fare at the end of the day (Lee 1970).

Although the Dobe Ju/'hoansi complain about sharing, they do it because it makes their way of life possible and enhances their chances of survival.

The division of labor among the sexes is such that the women go out in groups of three to five with the aim of collecting specific items. Their tools consist of the *kaross*, an antelope hide garment and carrying bag, a digging stick, and nut-cracking stones. The men hunt in smaller groups of two to four but often solo. Weapons include bow, arrow poison, spear, springhare probe, club, iron tipped arrows, quiver, hunting dogs, rope snares, *kaross* and carrying bag. Small and even medium sized animals may be run down until exhausted and then caught or killed by hand (Liebenberg 2006). Both sexes return to camp at the end of their day. Males manufacture and maintain tools such as the fire drill, flints, digging stick, carrying yoke, knotted net, traded iron knife and adze-axe, poison making cup, pestle and applicator, whetstones, wild cotton for polishing rope snares, sinew, twine, poisonous grubs, bone chips for arrow shafts, grass stems for arrows, wood for bows, spears and iron fencing wire. Females perform food preparation and housework duties using wooden mortar and pestle, wooden serving spoons, tortoise shell bowls, feather fans for the fire, shovels for the ashes, and traded pottery and metal pots (Lee 1979; Lee 1998; Bieseke and Royal - /O/OO 1999; Howell 2000). The need for clothing and shelter is minimal. Clothing consists of loin coverings and housing consists of man's most basic house type: the domed hut (Coon 1971).

Time allocation data for the Dobe !Kung indicates that men work longer hours in food acquisition activities (21½ hours per week versus 17 hours for women) but

provide 22% of the all gathered foods, and 100% of meat. 1,000 calories of meat foods cost ten man-hours while 1,000 calories of vegetable foods cost only four woman-hours – a ratio of 2.5:1 (Lee 1998). Of course, additional time is spent in food preparation, nut cracking, gathering fuel and water, cleaning the living space, and in manufacturing and maintaining some 28 different tools and devices used for gathering, hunting and housekeeping as well as construction of housing and manufacture of clothing. On average men spend 21.6 hours per week in subsistence activities, 7.5 hours in tool making and 15.4 hours in housework for a total of 44.5 hours. Women spend a total of 40.1 hours per week, 17.1 hours in subsistence activities, 6.3 hours in tool making and 22.4 hours in housework (Lee 2003).

ii. The Ache

The northern Ache live in the southwestern part of the eastern Brazilian Highlands, an area of gentle rolling hills of tropical broadleaf, evergreen forest interspersed with valleys of tall broad-blade grass (Hill and Hurtado 1996). Extreme unpredictability in rainfall from month to month and year to year is the dominant weather pattern. The months of March through September are relatively drier, but any month in the year could be the wettest or driest. Temperature fluctuations are more predictable and mark seasonality, ranging from 17° C in July to 27° C in January. The Ache denote the hot time and the cold time as the two major seasons (Hill and Hawkes 1983).

This is an area that is well-endowed with small-bodied game that is easily caught by human hunters (Hill and Hawkes 1983). The Ache used to be full-time hunter-gatherers until the mid-1970's, but now live in the Chupa Pou agricultural

settlement. They are not particularly competent agriculturalists and spend about one quarter of their time foraging in the nearby forest. During these extended foraging trips they take a wide variety of animals species, among which the most important are peccaries, pacas, coatis, armadillos, and capuchin monkeys (Hill, Kaplan et al. 1987). On these trips they also collect fruit and honey. The Ache behave like immediate-return foragers during these trips; those in the foraging party consume all resources gathered and none are brought back to the camp for sale or trade.

Time allocation has been collected for Ache men during their periodic, (one week per month) hunting trips in the jungle away from the settlement. During these trips they spend 75% of the time foraging: 71% of that time is spent in searching, 25% in pursuit of game, 2% in fishing, and less than 2% in gathering vegetables and honey (Hill and Hawkes 1983). Although this only provides a snapshot of part of the total time spent by Ache men when on hunting trips, it may provide some insight for those societies that depend entirely on hunting of wild game for their sustenance during at least part of the year. In particular, it demonstrates how much time is devoted to searching for relatively small game, in a group lacking the technology to lure and trap wild animals. The Ache are bow hunters, although the hunting tool kit is not particularly specialized; of the many species of vertebrates hunted, some are caught with bows and arrows, some with sticks, and some even by hand (Hawkes 1993b). The bow is made of palm wood and arrow shafts from reeds with a carved hardwood head with barbs along one side: little time is taken in preparing weapons, which are usually made just before commencing the hunt (Hill, Kaplan et al. 1985). Bows are notoriously inaccurate and the key to success is proximity and persistence in releasing many arrows

until the prey succumbs. The Ache do not hunt with dogs, use no poisons, and use no tended or untended facilities.

Among the Ache, as among the !Kung, more successful hunters spend more time hunting. Hawkes (1993b) suggests this means that they maximize resource returns. However, Hawkes does acknowledge that opportunity cost may have some impact on the time spent in foraging activities, which might indicate some preferential assignment of tasks to those most suited, since ultimately the rewards are shared by all in the group. All food is shared within the camp, whether hunted solo or cooperatively. Specialist skills are evident in the hunting practices of the Ache, and they appear to adjust their search strategies to increase the possibility of encountering those preferred animals (Hill, Kaplan et al. 1987). Individuals specialize in pursuit (which consumes 70% of foraging time), retrieving honey, and extracting armadillos from their burrows.

Sexual and age division of labor is practiced among the Ache, and, although there is little data available on how women specialize or divide their duties, Hill and associates (1987) conclude that men's and women's abilities and foraging patterns differ sufficiently that they should be treated separately in all optimal foraging theory analyses. Women's returns are highest in the wet season when important fruits are available. However, processing time affects women's overall return rates more than men's. A white-lipped peccary, that might have taken 7.5 man-hours in pursuit and kill, would require a mere 15 minutes for preparation and cooking, or 4 % of the total time, whereas for palm fiber about 30% of time is spent in processing. Since the Ache live in an agricultural settlement at the Chupa Pou Catholic Mission, the state of their clothing and housing is not particularly relevant for my analysis.

iii. The Efe

A more comprehensive time allocation study of the Efe, together with a similar study of the Machiguenga, provides the foundation for the estimation of time devoted to major critical activities. These two studies present quantitative data on the allocation of tasks by gender, as well as the time or weight applied to each major task.

The Efe inhabit the equatorial Ituri Forest in the Zaire River Basin of the Democratic Republic of Congo (formally Zaïre). This area is the richest in number and biomass of faunal species of any comparable area in Africa (Bailey and Peacock 1989). The Efe are a nomadic group, that survive by hunting and gathering in the forest, but who engage in some exchange activities with their Lese agricultural neighbors. The Efe live day-to-day and are immediate return foragers (Woodburn 1980) that insure against drought or crop failure in one part of the forest by migrating to other areas not impacted by the failure. By doing so they are better able to survive ecological adversity than their Lese neighbors, although they do rely on the latter by providing labor to work in the Lese fields and by providing forest meat in exchange for agricultural products. As with their neighbors, the Mbuti, and other tropical groups, the Hadza, !Kung and Ache, the Efe make use of very simple technology, and most of the tools that they do use, such as digging sticks, gathering baskets, nets, bows and arrows, are not complex and easily created from forest products. Complex tools, made of several subcomponents, do not appear to be a necessity in tropical areas. Indeed, the Hadza (Woodburn 1970) and Ache (Hawkes 1993a) capture 50% of their animal resources by their bare hands, and the Dobe !Kung (Lee 2003) gather 75% of their vegetable diet – fruits, nuts, melons and leafy greens – without any special gathering tools. Similarly, the Pintupi and Pitjandara

of Australia employ simple spears and digging sticks but often no technology is necessary – birds are often caught by hand (Tindale 1966; Rose 1987).

Whereas the Mbuti tend to divide tasks based on age and marital status, time allocation studies among the Efe show that specialization is evident in the varied amount of time men spend in manufacture and maintenance (Bailey and Peacock 1989). Although all men are able to perform any task required, a few are considered more skilled or conscientious; for example, some are called upon to make poison for arrows, some specialize as beaters, bow and arrow shooters, or dog handlers.

The Efe have no real need of clothing for insulation and protection against the cold; when it rains hard, which it does often in the rainy season, they shelter under the flying-buttress-like root flanges of giant trees (Coon 1971). They cover their bodies in boiled termite oil, for some protection against the cold, but also as an insect repellent. They coil their hair and smear their heads with pomade as a shield against the summer sun. They wear, at most, a loincloth or top made from a strip of the softest bark taken, at some considerable risk, from the top of a wild fig tree, which is then beaten to make it as soft as cloth (Coon 1971). The Efe have limited needs for fire, shelter or food storage. They make simple shelters as required against the heavy rains and do not know how to make fire, although they carry smoldering embers from camp to camp (Turnbull 1962): these are simply not critical items in the tropical environment.

Since the Efe are highly mobile, possessions are kept to a minimum and camp work is simplified. These groups are immediate-return foragers and make few, if any, provisions for storage of food for future needs. The Efe are more mobile than the more residential Machiguenga and move on average every three weeks. They spend three to

four hours walking to the new location. During these moves the women carry their limited possessions from one site to the next and pitch camp while the men are out hunting along the trail. The men may not return until late when the new camp is set up. Most of the work of moving camp is performed by the women; they collect, pack and carry most of the household belongings. The men carry their hunting weapons so as to be able to hunt along the way. Once the group arrives at the new location, the men will spend fifteen to twenty minutes clearing away the brush and then leave to go hunting. The women are left to gather construction and bedding materials and to build the new dome-huts. Usually working in pairs, they cut flexible saplings and stick them into the ground in a circle, binding them at the top with vines. They then collect large leaves and affix them to the frame to complete the waterproof covering. The result is a hut six to eight feet wide, enough to shelter the Efe family (Coon 1971). Women are also responsible for cleaning and on-going maintenance, though these duties are less onerous since they move camp before the area becomes despoiled.

The division of labor and time allocated to basic tasks are shown in Table 3-2 below.

Table 3-2 Time Allocations for Efe Men and Women (Bailey and Peacock 1989).

Category Name	Efe Activity	<<<< Men >>>>			<<<< Women >>>>		
		Mins	Mins	%	Mins	Mins	%
Food acquisition	Hunting	152			0		
Food acquisition	Food gathering	4			48		
Food acquisition	Honey gathering	80			0		
Food acquisition	Village work	40	276	73	0	48	12
Food Preparation	Food preparation	23	23	6	182	182	45
Food Preparation	Childcare	5	5	1	94	94	23
Tool making	Make and repair implements	51	51	13	6	6	1
Clothing Manufacture	Clothing	0	0	0	5	5	1
Camp maintenance	Collect wood and water	4			36		
Camp maintenance	Housing	12			26		
Camp maintenance	Move camp	11			11		
Camp maintenance	Care of animals		27	7	2	75	18
	<u>Sub-total without Leisure</u>		<u>382</u>	<u>100</u>		<u>410</u>	<u>100</u>
Leisure	Self care	7			14		
Leisure	Recreation and smoking	45			13		
Leisure	Other leisure (doing nothing)	272			285		
Leisure	Travel, funerals, social interaction	14			137		
	<u>Total</u>		<u>720</u>			<u>859</u>	

iv. The Machiguenga

The Machiguenga at Shimaa live in Paraguayan Amazonia along river valleys surrounded by forested mountains (Johnson 2003); the *selva baja* flood plain is rather open under a canopy about twenty-five meters high. It is hot during the day (25-30° C) but cool at night (16-19° C), however winter cold spells may bring frigid air masses from Antarctica, when temperatures drop to 14° C at night and barely rise above 22° C during the day. Rainfall is heavy during the summer months from October to February and light to moderate during May through August.

The Machiguenga are semi-residential, slash-and-burn horticulturalists. They are almost completely independent of outside help, even from other Machiguenga

groups, and are able to survive harsh times by over-planting manioc so that their harvest exceeds their normal needs and provides a buffer against any annual shortfall. In this regard, they operate a version of a delayed return strategy (Woodburn 1980) by leaving their crops “stored” in the ground. The tool kit of the Machiguenga is more complex than the tropical groups: men spend 24% of their tool making time making twine, 24% making wood products, 37% on household goods and 10% on bows and arrows. Four kinds of arrowhead are made, and the Machiguenga recognize the value of skill specialization in this task, as demonstrated by a Guttman scaling analysis of twenty-three manufacturing sub-tasks performed by the males (Johnson 1975).

The Machiguenga need protection against the cold, particularly in the winter when frigid air masses blow in from Antarctica, and nighttime temperatures drop. The Machiguenga women spent over 1½ hours per day spinning and weaving. Clothing, consisting of a cotton gown (*cushma*), necessary for the cold winter days and nights, is the primary women’s manufacturing task. Ten weeks of spinning and three weeks of weaving are required to make the *cushmas*. Since adults usually have three *cushmas*, one for everyday, one for heavy or dirty work, and one for special occasions, this requires a considerable amount of time (Johnson 2003).

As slash-and-burn horticulturalists, the Machiguengans move much less frequently than nomadic hunter-gatherers and, apart from summer forays, they remain resident by their gardens until the slash-and-burned soil is depleted of nutrients. They make a major move, maybe every three to four years. The Machiguenga spend a great deal of time in constructing sturdy, secure and dry frame houses with thatched roofs. The most time-consuming part is to collect the palm for thatching since thousands of

palm leaves are required for one roof. It usually takes about three months to build a new house but it is expected to last four years, the life of a slash-and-burn garden. Building houses is a cooperative venture that requires the support of friends and neighbors, and during this time gardens tend to be neglected. In the dry season when families move to the river, simpler A-frame houses are built. These take about two hours to erect since they do not need extensive rain-proofing (Johnson 2003).

Although Machiguenga families are independent, they do cooperate and exchange good; spinners exchange products with weavers, good gardeners exchange food with good foragers, and gardeners work in other's gardens when the owner is ill or injured. Studies among the Shiwiar, forager-horticulturalists of the Ecuadorian Amazon, indicate that extended provisioning of disabled individuals effectively lowers mortality in this small-scale society: 82% of the first descending generation were born to individuals who had survived an incident likely to have been fatal without healthcare provisioning (Sugiyama 2004). This finding adds another dimension to the benefits of cooperation that I intend to test in my model.

Strictly speaking, the Machiguenga are not hunter-gatherers but the time allocation data provide important insights into the ranking of tasks in this cooler temperate climate. Machiguenga activities are reflected in the time allocation data in Table 3-3 below.

Table 3-3 Time Allocations for Machiguenga Men and Women (Johnson 1975)

Category Name	Machiguenga Activity	<<<< Men >>>>			<<<< Women >>>>		
		Mins	Mins	%	Mins	Mins	%
Food acquisition	Weeding	54			1		
Food Acquisition	Hunting	43			0		
Food acquisition	Planting	29			0		
Food acquisition	Preparing gardens	10			0		
Food acquisition	Harvesting	61			42		
Food acquisition	Fishing	44			21		
Food acquisition	Collecting wild foods	26	267	65	20	84	19
Food preparation	Preparing food	18	18	4	141	141	32
Childcare	Caring for children	3	3	1	63	63	14
Tool making	Plaiting (mats baskets)	0			13		
Tool making	Making items from wood	40			4		
Tool making	Making items of twine and netting	32	72	17	1	18	4
Clothing manufacture	Manufacturing Cloth	1	1	0	108	108	25
Camp maintenance	Housecleaning	0			11		
Camp maintenance	Washing clothes, pots	0			8		
Camp maintenance	Constructing houses	47			1		
Camp maintenance	Caring for yard	5	52	13	6	26	6
	<u>Sub-total without Leisure</u>		<u>413</u>	<u>100</u>		<u>440</u>	<u>100</u>
Leisure	Resting	76			112		
Leisure	Eating	61			59		
Leisure	Visiting in community	65			53		
Leisure	Traveling outside community	33			29		
Leisure	Recreation	28			15		
Leisure	Being ill	23			18		
Leisure	Caring for self	15			9		
Leisure	Caring for others (not children)	10			8		
Leisure	Chatting	7			8		
Leisure	Sleeping	8			4		
Leisure	Making beads, ornaments	2			8		
Leisure	Other	39			17		
	<u>Total</u>	<u>780</u>			<u>780</u>		

v. Summary of Tropical and Temperate Time Allocation Data

The data collected in these two detailed surveys of the Efe and Machiguenga provide important information on the activities, tasks and distribution of duties. In both groups the men spend the bulk (65-70%) of their non-leisure time acquiring food and the women's primary task is food preparation (32-45%), despite the fact that the food acquisition strategies of the groups are quite different, the one being foragers and the other horticulturalists.

Food preparation time is a major task for women, where plant food constitutes a significant portion of the diet. For the Machiguenga women food processing is a significant task; wild plant foods generally require more processing time than animal meats. Manioc accounts for nearly two thirds of the calories produced, and maize accounts for the other third. Roasting maize, a domesticated plant, is a fairly simple food preparation task but the processing of manioc, which is full of deadly prussic acid, is very much more complex. Once out of the ground, the manioc roots spoil quickly and the processing must proceed speedily. First, the roots need to be scraped and washed. Then they are vigorously grated, strained, and rinsed, and the grated flour is kneaded and squeezed to eliminate the toxic liquid, which together with the fine flour accumulates in the container below the strainer. The coarse flour is molded into a loaf to dry. The poisonous liquid and fine flour is left to stand so that the flour settles and the liquid can be poured off. The fine flour is then left to dry out. The flour cakes are left in the sun for several days to help volatilize the remaining poison. Not until the flour cakes are cooked is all the poison eliminated. The liquid is boiled to eliminate the toxins and is used to make a beverage (Carneiro 1983). Perhaps the presence of simply

processed maize in the diet accounts for the 25% reduction in food preparation time among the Machiguenga.

Optimal foraging theory indicates that food-processing cost is a deciding factor in the selection of plant foods in the diet. For example, the Alyawara groups in Australia (O'Connell and Hawkes 1981) typically ignore many seeds that are nutritious, common, and easily accessible in favor of grubs, roots and fruit, that are easily prepared, even though they are less common and are gathered only by traveling over long distances. Although some groups recognize the seeds as a valuable food resource, the Alyawara avoid these food items since the processing costs are too high relative to other available food resources. O'Connell and Hawkes conclude that, if high-ranked resources are so abundant that returns never fall to a point where it becomes efficient to include lower-ranked items in the diet, there is no reason to define the latter as food. For the Pintupi, seeds are winnowed and ground into a paste and compacted into balls for storage. Women gather in groups of three or four for about 4 ½ hours per day and spend an additional 2 ½ hours each day parching, grinding and preparing staples (Rose 1987). Thus processing costs are a critical factor in food selection in many societies.

In both the Efe and Machiguenga, men predominate in tool manufacture and women in childcare. Between the groups there is a significant difference in the amount of time that the women dedicate to clothing manufacture and camp maintenance activities. The Efe's need for clothing is limited to a loincloth, whereas the Machiguenga need woven cotton clothing to combat the cold winds of winter; the manufacture of clothing becomes the second highest priority for Machiguenga women. Gender-roles for house building, housekeeping and moving camp also differ

considerably. In the highly mobile Efe group, the women bear the brunt of the workload in both moving camp, the construction of huts, and maintenance, whereas, in the more sedentary Machiguenga group, the men undertake the heavier house building tasks but the women still do the housework.

Leisure and other activities consume a large part of daily time. I have excluded these from my analysis for the main reason that most of these tasks are personal and cannot be shared or outsourced to others. Some of the activities are strictly personal (eating, resting, recreation, smoking, and being ill). Other tasks fall into the social realm yet are still personal and cannot be delegated (social interaction or grooming, and *hxaro*). I do not mean to demean these latter tasks in terms of their importance for social bonding. Indeed, Polly Wiessner concludes that for the !Kung *hxaro* is so important in maintaining relationships with support groups that *hxaro* activities including the manufacture of gifts and travel may well turn a 14 hour work week into a forty-hour one (Wiessner 1977). Typically about 70% of a person's possessions come from *hxaro* and the remainder is destined for the *hxaro* network. This amount of time would not be spent if the benefits were not significant. However, these personal activities may not be candidates for economic specialization and, therefore, are not addressed in the model.

Clearly, these data from tropical and temperate groups are not representative of the specific time allocations of work required to survive in the colder and fluctuating seasonal climate of Europe during the late Pleistocene. However, they do highlight the major activities necessary in a hunter-gatherer lifestyle: 1) food acquisition, 2) food preparation, 3) childcare, 4) tool manufacture, 5) clothing manufacture, 6) camp

maintenance, and 7) leisure. These data (Table 3-4) illustrate the changing priorities of women and men under different ecological conditions, from the tropical conditions of the Efe (Bailey and Peacock 1989; Bailey 1991) to the temperate conditions of the Machiguenga (Johnson 1975; Johnson 2003).

Table 3-4 Comparison of Weighting and Rankings of Activities between Tropical Efe and Temperate Machiguenga Societies

<u>Men's Allocation</u>		Efe		Machiguenga	
Category Name		(mins)	Rankings	(mins)	Rankings
Direct					
1. Food acquisition		276	1	267	1
2. Food preparation		23	4	18	4
3. Childcare		5	5	3	5
Indirect					
4. Tool making		51	2	72	2
5. Clothing manufacture		0	n/a	1	n/a
6. Camp maintenance		27	3	52	3
Total (Excluding Leisure)		382		413	

<u>Women's Allocation</u>		Efe		Machiguenga	
Category Name		(mins)	Rankings	(mins)	Rankings
Direct					
1. Food acquisition		48	4	84	3
2. Food preparation		182	1	141	1
3. Childcare		94	2	63	4
Indirect					
4. Tool making		6	5	18	6
5. Clothing manufacture		5	6	108	2
6. Camp maintenance		74	3	26	5
Total (Excluding Leisure)		410		440	

The allocation of time to the major direct and indirect tasks in the two groups (excluding leisure activities), together with the rankings of tasks for each gender, highlights the dissimilar weighting of tasks and their rankings in varied ecological conditions. In other geographic areas, where seasonal variations are more severe, gender roles also change by season. Women predominate in subsistence activities when plant foods are readily available and men become critical at times when seasonal plant

food is not available because of inundation, such as in Arnhem Land (Altman 1998) and Cape York (Chase and Sutton 1998) or, as will be shown, in the extreme winter conditions of the Arctic Inuit (Giffen 1930; Mauss 1979). Sexual division of labor and cooperation becomes a viable, if not obligatory, adaptive response in each of these cases.

3.4 Major Activity Rankings for Men and Women in Higher Latitudes

During the late Pleistocene, Europe experienced significantly colder winters than today (on average, 10-12° Celsius less than today in the Russian Plains and 5° less in central France) but summers were only marginally colder than today (Frenzel, Pecsli et al. 1992). Thus although winter conditions might be compared to a recent sub-Arctic or Arctic climate, summers in Europe were relatively warm and the lower latitude provided a longer growing season than Arctic zones (van Andel 2003c; Finlayson 2004).

In order to assess comparable winter behaviors in recent hunter-gatherers, I focused on three inland, wild caribou/reindeer-hunting groups: the Nganasan of the Samyr Peninsula in Russia (Popov 1966; Golovnev 1999), and the Nunamiut Inuit of the Anaktuvuk Pass in Alaska (Ingstad 1954; Binford 1978a), and the caribou-eating Indians of Slave Lake in the Northwest Territories of Canada (Coon 1971; Ingstad 1992). These groups subsist almost entirely on wild caribou or reindeer in the winter and may approximate the dietary and lifestyle patterns of the first modern humans in Europe. I also examine the coastal Inuit, who are more sedentary than the caribou hunters since they rely on hunting sea mammals, yet exhibit a similar interdependence between males and females and a comparable emphasis on clothing manufacture.

i. The Nganasan

The Nganasan occupy areas of the Tamyr Peninsula and are the northernmost of the indigenous peoples of Eurasia to have maintained the traits of the ancient Arctic reindeer culture (Golovnev 1999). The annual range is centered on the lowland tundra, which is bounded by fir, pine, larch, and birch forest to the south and by the ridges of the Byrranga and northeastern plateau to the north. The mean annual temperature is 16° C, the temperature falls below freezing 263 days per year. The first snowfall comes in the lowlands at the end of September, and spring comes late but suddenly. Trees are rare, shrubs, lichens, and sedges are the main vegetation (Johnson and Earle 2000). There are several rivers with rich sturgeon and salmon, and sea mammals are available from the northern seas. Terrestrial species include wild reindeer, polar fox, ermine, wolf, hare, white and brown bears, bighorn sheep, as well as ducks, geese, partridges, and owls. Wild reindeer, geese, ducks, and various species of fish are the major food resources; tubers and roots are a fallback in the spring if starvation threatens. Wild reindeer go about singly or in small herds during the year, except for the rutting season when large herds of does are corralled by the dominant bucks. Mass migrations of several thousand reindeer occur in the spring, going north and in the fall going south, often using the same well-trodden paths. Migration may take them over one thousand km in each direction.

The men are responsible for most food procurement. The main season for hunting the reindeer is from August to November when they are fattened-up for the winter. The Nganasan herd domesticated reindeer for transport and to act as decoys during the wild reindeer hunt. During the summer, the men set traps in duck, partridge,

and goose nests, gather eggs, and seine fish. Domestic work is the woman's domain including childcare, fire control, food preparation, butchery, hide-processing, weaving, rope making, as well as constructing, erecting, and dismantling the conical tents. Women dress the skins, sew winter clothing, and jerk and render the reindeer meat in the fall. They do needlework, make summer clothing, summer tent coverings, and repair footgear during the summer.

The tool kit of the Nganasan is much more comprehensive and specialized than that of equatorial and tropical groups. The Nganasan have a series of toolkits designed especially for each season's hunting activities. The tool kit for reindeer drives includes the net, twine, posts, and flags made of goose wings, and picks for making holes in the ground to secure the net posts and flags. There are traps for catching polar fox with anchors for holding the traps in the snow, a net cul-de-sac 4 x 4 meters set up at the end of two divergent lines of netting enclosures for trapping geese on land, separate long net set up with decoy to attract flying ducks and capture them as they come in to land. Fishing gear comprises bone needles for salmon trout, bodkins for weaving the nets, mammoth ivory measuring rods for the meshes of the fish net, and iron hooks for taking the fish from the nets. Dugout canoes are built for fishing, hunting reindeer and geese, and crossing rivers.

In the early spring, when food is scarce, the Nganasan hunt partridges by driving them into specially staked nets. At the beginning of the summer they set up other kinds of nets to entice flying ducks to fall into the trap, and traps are set for geese, which are hatching eggs. Later in July fattened, molting geese are driven into a net cul-de-sac. A thousand or more may be killed in one hunt. Finally, fishing with hooks in the spring

may take place when other foods are scarce, summer fishing is by tended nets set up along the banks, and in the fall ice untended nets are set up under the ice, which are inspected periodically (Popov 1966). The significant fact here is that each of these food acquisition activities is brief, lasting usually just a few weeks, and requires specialized technology to take advantage of the narrow window of opportunity. These summer foraging activities fall into the immediate return pattern. These are stopgap foods that are not generally stored as insurance against winter shortages.

An inventory of the Nganasan wardrobe demonstrates the dramatic difference from the loincloth of the Efe or the spun-cotton clothing of the Machiguenga. The Nganasan make almost all of their own clothing out of reindeer hides that are prepared and dressed by the women and stitched with thread made of reindeer sinew. They make women's overalls and men's shorts of chamois. Winter hides with long fur are used for winter outer-garments; summer hides with short fur and fawn's hides are used for summer everyday clothing. Reindeer leg skins are used for mittens and boots for both men and women. Men's boots come over the knee and are attached to the belt and worn over warm knee socks made of reindeer skin. Men wear short pants with fur outside for winter wear, or of chamois for underwear. The men's coat (*malitsa*) is made of one black or one white, summer-reindeer or reindeer fawn hide with trimmings of dog fur and is used for everyday wear at home. A winter overcoat (*sovik*) is worn over this for traveling. On the summer overcoat (*sovik*), which serves as a raincoat, the fur is trimmed to half-length. The women's under garment, an overall, is made of chamois hide. The outer garment (*lifarie*) is made of reindeer hide trimmed with dog fur and is worn over an inner fur coat with the fur turned inside out. A traveling overcoat (*lun*) is

worn over the *lifarie*. These are the everyday clothes but in addition, the Nganasan, make a complete set of festive garments that mirrors the clothing described above (Popov 1966). Layered outer clothing is designed for ventilation and to prevent excessive heat build-up during intensive activities. Garments are decorated with their favorite colors of white, black and red as well as metal ornaments and beads. This inventory of attire accounts for the amount of time devoted to clothing manufacture and the critical importance of clothing in the harsh climate of the sub-Arctic.

Men's tools are the ax, knife, bow drill, awl, and handsaw and men spend most of their spare time building sledges. Women's tools are various forms of bone and iron scrapers for dressing skins. The women make all the clothing and boots. The hides are cut with knives on special cutting boards.

The shelter consists of a conical portable tent with a central hearth and smoke-hole at the top-center; these usually house two to five families. Inner and outer layers of reindeer hide provide adequate insulation when supported at the base with stones or snow banks. The erection and dismantling of tents are the main responsibility of the women with some participation from the men, but the women are solely responsible for the maintenance of the lamp, the fire and general housecleaning (Popov 1966).

Division of labor for the Nganasan follows familiar lines, though they tend to go further and recognize individual skills. Almost everyone can perform the tasks in their appropriate sexual domain but it is possible to find persons who are superior in their skills of woodworking, or blacksmithing, sewing or dressmaking. The Nganasan believe that an inclination to an occupational role is developed from childhood and one

or two hunters may provide for the entire community while others are productively involved in woodwork, weaving net, and tending reindeer (Popov 1966).

ii. The Nunamiut and Slave Lake Indians

The Nunamiut are inland Inuit who live in Anaktuvuk Pass in the Central Brooks Range of Northern Alaska (Gubser 1965). They are primarily dependent on the caribou for their existence as shown in Table 3-5, and follow their migration from the mountains to the northern slope of Alaska. Natural plant food and store bought resources contribute less than 15% of the diet.

Table 3-5 Nunamiut Sources of Food (Binford 1978a)

	1950 ¹	1969 ²
Natural plant food	0.04%	0.04%
Imported and packaged food	0.89%	14.93%
Food from animal sources	99.07%	85.03%
Caribou	85.5%	88.1%
Sheep	7.4%	2.4%
Bear	6.1%	1.0%
Moose	0.68%	5.8%
Fish	0.27%	2.46%

Note 1: 1950 was an abnormal winter and caribou were present in the area all winter.

Note 2: 1969 was a normal winter. Caribou migrated south, resulting in a greater reliance on store-bought foods.

The Caribou-eater Indians of the Northwest Territories, as their name implies, also depend on the caribou during the greater part of the year (Ingstad 1992). They are nomadic hunters that cover large distances to the east and south east of the Slave Lake.

Both groups congregate to hunt during the fall and spring migrations and disperse during the summer. Winter is driven by a delayed return economy where the late fall sees a time of intense activity surrounding the southward migration of the caribou. For all the deer hunting groups, the main season for hunting wild caribou begins in August and ends in November. During this period the men participate in logistic hunting and large-scale ambush hunting of the fattened migrating herds in order

to replenish caches of deer meat that will last the entire winter until the spring northern migration. Casual hunting may occur in other months but does not have the same economic importance as the fall hunt. In the late fall, sporadic hunting of deer takes place, but the cold dark days of mid-December to mid-February see little activity.

During the winter, congregated groups generally stay together to share cached resources, but some may strikeout independently believing that they can do better on their own (Gubser 1965). The dead of winter is a time of aggregation and feasting. One of the major activities of a good winter is visiting; every person in the settlement will visit every single household. Men will make occasional forays to hunt for fresh meat from roaming caribou or sheep. The early spring is a time of deprivation should stores become exhausted. The late spring sees the beginning of the northward migration and another season of group hunting, communal eating, dancing and trading. (The Nganasan, on the other hand, prefer not to take these animals at this time since they are thin and do not provide the necessary fat to support a balanced diet (Popov 1966), tubers and roots are a fall-back for them in the spring if starvation threatens.)

Summer is a time of dispersal into isolated family groups, mapped across the landscape to the small, wandering groups of reindeer. This is a period of opportunistic hunting for the men, and, for women, digging tubers, collecting vegetal shoots, herbs, grasses, and sedges in the spring, and berries in the early fall. Summer food resources are limited; a household usually spends the summer in one location, relying on caribou killed that spring. By late summer many plants are ready to be gathered (Gubser 1965). The summer economy is closer to the immediate return pattern. No supplies are laid in for winter. For the Snake Lake Indians, for example, no attempt is made to lay-by

winter stores even though there is a plentiful supply of fish that could be smoked or dried and stored as insurance against the failure of the return of the caribou in the fall. The summer season is characterized by monthly, specialized food acquisition patterns. But caribou is the real food (Ingstad 1992). Indeed the deer represents more than a food resource, it provides skins for hides and clothing, antlers for preparation of tools and other artifacts, and sinew for cord.

The caribou Inuit live in cone-shaped dwellings framed with poles and covered with sewn caribou skins. Nuclear-family households are typical, and, when caribou are plentiful, small numbers of families gather together for cooperative hunting. Caribou are the most important food sources, followed by moose, mountain sheep, bear, ducks, hares, porcupines and ptarmigan, with fish being the least important. Wild plant foods are of minor significance. Hunting technology used by the caribou Inuit is the most complex of all hunter-gatherer-groups (Oswalt 1976). Oswalt categorizes caribou Inuit food acquisition technology in terms of *subsistants* or composite tools and techno units or subcomponents - a total overall of 34 *subsistants*, and 118 techno units illustrates the breadth and complexity of their tool kit. Weapons described include relatively simple caribou-killing daggers, fish-killing bodkins, ice-picks, missile stones for killing ptarmigan, two-pronged leisters with fishing lures, and caribou lances. Complex weapons include throwing board with bird dart, bird slings, and sinew-backed bows and arrows. Tended facilities documented include antler head-gear to lure caribou, dams and weirs for leister fishing, caribou guide poles with gull skins attached, caribou pitfalls, cairn lures, and fish-shaped lures. Untended facilities such as wolf and fox pitfalls,

traps, and bird and hare snares complete the list of *subsistants* or tools used for food acquisition.

iii. The Coastal Inuit

The coastal Inuit (Netsilik, Copper, Iglulik and Saqqaq) hunt sea mammals and are thus more residential than the migratory reindeer/caribou hunters, but they too maintain strong interdependence within the nuclear family. All are dependent on the adult men for provisioning and all members of the group work to support the hunting activities of the adult men. The coastal Inuit diet is largely, and in some seasons almost exclusively, of sea mammals gathered and cached by the men. The preparation of skins for the making of clothing, a laborious process consisting of many scrapings and rubbings, is largely the work of women. These tasks are performed when accompanying men on inland reindeer hunts or to the sealing grounds. Women use their teeth, which are commonly well worn, for chewing skins, softening boot soles, tearing sinew thread, extracting blubber for lamp oil, and masticating food for children and puppies. Berries, herbs, buds, roots, grasses and seaweed are in the domain of women as is the curing of fish, which involves sewing them together to dry. Collection of water is by women and maybe young boys (Giffen 1930).

Netsilik technology consists of four complexes, the snow-ice complex, the skin complex, the bone complex and the stone complex. Division of labor follows gender lines. Snow-ice complex is the male's domain. The skin complex falls into the women's domain. Men own the tools, weapons and kayaks and women own the household furnishings and tools for processing skins (Riches 1982). With the Inuit, tool

making and utensil-making duties are divided generally such that men work with the harder materials, and women with softer materials such as leather and basketry.

The time spent by women on other indirect maintenance activities changes dramatically in high-latitude groups. With the limited availability of wild plant foods, the major women's tasks are almost all in the indirect category. Ingstad (Ingstad 1954) lists the Nunamiut women's priorities as follows: "She has to dress and sew skins, fetch cut up and skin caribou, provide meals, get fuel and water, look after children and dogs, drive the sledge on long journeys, help pitch camp and much else" (Ibid: 51). In the fall the women are busy flaying, flensing, and dressing skins to make winter clothing so that all may survive in the frigid winter conditions. This is a task associated with the coming winter: "The women must not start to make winter clothing until the first snow lies on the ground: with skins from July/August for anoraks, August/mid-September for breeches and socks, and with bull skins from September/October for soles" (Ibid: 135). An entire range of custom-tailored attire is manufactured. This multi-layered clothing not only provides insulation against the cold, but also is sufficiently flexible to permit hunting and foraging activities to be pursued without minimal impedance. Adding and removing layers allow for the management of internal body heat and prevention of over-heating from high levels of activity, which becomes a serious health hazard should the damp clothes freeze. "Then Eskimos undergo a transformation when they put on their new winter clothes of thick-haired, shining skin, which falls so comfortably and easily about the body and are so splendidly trimmed with wolf and wolverine skins. They seem to be festive attire. Clothes like this enable them to overcome winter; the Eskimos look forward to it without the slightest fear of the cold" (Ibid: 138). In the

spring the cycle repeats itself for the manufacture of lighter and more waterproof summer clothing and boots (Gubser 1965). Clothing manufacture seems to occupy the women for most of the eight-month winter except for the dark period when there is insufficient light for fine needlework.

These Inuit groups may not be representative of late Pleistocene groups but they provide valuable insights into seasonal variations in roles and activities (Mauss 1979) as well as gender roles (Giffen 1930) in an extreme climate. I use Giffen's list of tasks by gender as a model for identifying critical tasks from the archaeological record.

3.5 Projection of Time Allocations for High Latitude Groups

Although there are no quantitative time allocation data on these groups similar to those assembled for the Efe and Machiguenga, qualitative narratives describe the key roles and task priorities of men and women. Based on comparisons between the descriptive and qualitative data for the low- and high-latitude groups I have projected time allocations for a typical high latitude group and have laid out my rationale for the projections in the text below.

Qualitative and anecdotal data from those groups living in more temperate and even sub-Arctic regions show changes in the variety and seasonal pattern of food resources acquired – many resources have limited availability and demand a variety of specialized hunting methods and associated technology (tools, weapons and facilities) to assure their capture. There is an increased dependency on indirect tasks such as a more extensive tool kit, more sophisticated clothing and more complex camp maintenance activities, particularly during the winter. In high latitude groups, since food acquisition becomes a strictly male activity, clothing and camp maintenance tasks

generally fall into the female domain. Strong interdependency between genders in the nuclear family is critical to survival, unlike the equatorial Hadza where individuals are able to survive alone. Arctic women and infants are entirely dependent on male hunting activities for their sustenance, and men are entirely dependent on women for the provision of the necessary clothing designed to permit rigorous outdoor activities in the harsh climate, and the maintenance of hearth and shelter. The Inuit and Nganasan family is tied to this interdependence.

Northern groups, farther than 60° north, conduct seasonal communal hunts for three reasons: to take advantage of the animal herds concentrated during migration, to gain access to animals when their fat content is highest, and to obtain high quality hides for clothing and shelter (Driver 1990). An Inuit hunter with a wife and three half-grown children would need about thirty skins in the fall for winter clothing alone. Solo hunters, armed with only a thrusting spear or bow and arrow are rarely able to get close enough to capture sufficient deer to satisfy the family's needs for food and skins in the fall. Deer have adopted behaviors to combat their primary prey, the wolf. The wolf hunts by stealth since it is not able to catch a deer on the run. When the deer signals that it has observed the wolf, it does not flee immediately but waits to see the reaction of the wolf. If the wolf remains in the vicinity, the herd groups together for protection. This behavior offers humans two options. The solo hunter, armed with a thrusting spear or bow and arrow, may approach the deer in full view and attempt a final rush before the animal flees, but he is rarely able to get close enough to hit the animal with his weapon. Or, with the help others, he may corral the herd into a lane drive or restricted space where he can release his weapons into the mass of the herd and be able to achieve

the thirty or so carcasses needed for clothing the family for the winter. A lone hunter could not achieve this, and groups that are dependent on the reindeer or caribou for both food and clothing must therefore be cooperative hunters (Blehr 1990).

These adaptations of groups living in highly seasonal environments are instructive for reconstructing the behaviors in Europe during the highly seasonal and fluctuating climate of the late Pleistocene. The annual life cycle of the high-latitude groups is characterized by a dichotomy between winter and summer activities. In the summer, when families are dispersed and isolated, roles are not as clear; all family members will undertake whatever tasks are needed for family survival. In extreme circumstances, roles may be driven by necessity rather than by gender: a family with only boys will designate one son to undertake female duties and conversely a family with only daughters will chose one to become a hunter (Ingstad 1992). In this environment complementary roles are fundamental and essential. In the summer and fall, tasks have to be accomplished that can be achieved within a narrow window of time only through division of labor and dedication to specialized tasks. The major constraint in the assignment of tasks appears to be the need for childcare and the corollary requirement for women to remain close to camp. This inhibits caregivers from performing tasks that require distance travel, such as hunting, gathering fuel and raw materials from distant locations. Other jobs, such as clothing manufacture, food preparation, and even moving camp, which can be multitasked with childcare, become the responsibility of the caregiver.

In order to estimate rankings and time allocations for high latitude groups, I have projected weightings for the six activities, based on comparisons between the

tropical, temperate and high latitude behaviors as described in the literature. I outline the differences between low- and high-latitude activities, direct and indirect, I show projected time devoted to each activity in minutes for high latitude groups. Once all high latitude weightings are projected, the percentage of time allocated by these groups to each activity and the activity rankings are computed. These are shown in Table 3-17 Time Allocations for Tropical, Temperate and High-latitude Groups, towards the end of this chapter.

i. Food Acquisition

Arctic hunting is heavy work and it is estimated that the Inuit hunters, weighing an average 65 kg, bear an average energy cost of 3,670 kcal/day with an extra 30% loading for elevated BMR due to the cold amounting to 4,110 kcal/day, and Inuit females, weighing an average 55 kg, an energy cost of 2,400 kcal/day or 2,700 kcal/day with elevated BMR. These estimates are based on actual measurements of energy costs of various activities undertaken by members of an Igloolik community in the Canadian Arctic. This compares to an equivalent 3,000 kcal/day for the Kalahari bushmen (Godin and Shephard 1974).

I have calculated foraging times using the methodology used by Sorensen and Leonard in their analysis of Neanderthal foraging efficiency (Sorensen and Leonard 2001). The authors examined data from eleven hunter-gatherers to calculate foraging efficiency and project equivalent Neanderthal efficiency. From their work, I have extracted data on weight and total energy expenditure for the three groups. I use the foraging times for the Efe (Bailey and Peacock 1989) and Machiguenga (Johnson 1975) as listed herein to calculate their foraging efficiency. I use the mid-sex average total

energy expenditure (TEE) of 3,670 for the Inuit (Sorensen and Leonard 2001) and calculate the Inuit energy return and foraging time using the return and efficiency rates of the Machiguenga. Comparative foraging times are listed in Table 3-6 below.

Table 3-6 Estimates of High Latitude Foraging Times based on BMR

Population	Weight (kg)	TEE (person)	Return Rate	Energy Return (kcal/person/day)	Foraging Efficiency (kcal/ min foraged)	Foraging Time (av mins/day)
Efe	41.95	2650	1.35	3588	22.1	162
males	43.3					276
females	40.6					48
Machiguenga	48.15	3200	1.4	4500	25.7	176
males	51.8					267
females	44.5					84
High latitude	60.0	3670	1.4	5138	25.7	200
males	65.0					367
females	55.0					33

The above estimates for males and female foraging times are estimated as follows. In order to compute the distribution of effort between males and females I look at gathering activities. Analysis of data from the Ethnographic Atlas (Murdock 1967) concludes that gathering provides less than half the calories in 77% of hunter-gatherer societies (Ember 1978), even though gathering may consume more hours in the day. The ethnographic record shows us that plant food gathering priorities change significantly during the winter in higher northern latitudes. As far as basic sustenance is concerned, gathering of wild plant foods becomes almost non-significant as indicated by the sustenance records of the Nunamiut. The data on diet from Table 3-5 reflects the fact that northern societies consume less than 15% in plant food resources, in contrast to the 70% collected by the Efe and other tropical groups. However, during the spring they may gather fresh shoots and tubers, but during the summer they may capture birds,

reindeer fawn, foxes, marmots and squirrels and may participate in fishing activities, when men are off on the hunt. Collecting berries is a favorite occupation in the fall. Some of these plant foods are especially beneficial to women for whom an all-meat diet may be toxic, but all of these foods make up but a small and insignificant part of the annual diet. I project that women in sub-Arctic and Arctic latitudes might spend approximately one-half the time as their tropical and temperate counterparts collecting plant foods and small animals since the gathering season lasts for a minimum of six months. Males are responsible for the balance of food acquisition activities.

Table 3-7 Estimates of High Latitude Food Acquisition Time

Time Allocations for Food Acquisition	Efe (mins)	Machiguenga (mins)	High latitude (mins)	Basis for adjustment time allocated
Men	276	267	367	Energetics
Women	48	84	33	Availability of plant foods limited to summertime

ii. Food Preparation

Food preparation time is reduced in high latitudes, since meat, and even berries, require significantly less time to prepare than most plant foods. The time-consuming tasks of leaching, parching of tuber, winnowing and grinding of seeds, and cracking nuts, so necessary in tropical zones, do not constitute a significant part of food preparation duties among these northern, meat-eating groups (O'Connell and Hawkes 1981). An analysis of food processing time for meat versus vegetal matter among the Ache shows that it takes about 3% of the pursuit and kill time to prepare a white lipped peccary for eating, while, for wild palm fiber, processing time consumes about 30% of the total time spent in acquisition and preparation (Hawkes 1993a; Hawkes 1993b). The Nomlaki women of California would spend three hours pounding acorns and another four hours leaching the meal in order to produce 2.6 kg of edible meal -

sufficient to feed the family for several days, whereas a hunter would skin and butcher a deer in a few minutes (Goldschmidt 1951). If these ratios were applied to northern groups that rely almost exclusively on meat in their diet, then one would predict that food-processing costs would be reduced significantly. However, most of the time meat consumed by northern groups is from caches and is frozen, and although frozen meat is eaten on some occasions, most of the time it is cooked and this should add to the preparation time. In Table 3-8 below, I have conservatively projected a reduction of one half of the average of the Efe and Machiguenga food preparation times. Gathering and food preparation are critical but lesser roles in terms of total time allocation.

Table 3-8 Estimates of High Latitude Food Preparation Time

Time Allocations for Food Preparation	Efe (mins)	Machiguenga (mins)	High latitude (mins)	Basis for adjustment time allocated
Men	23	18	9	½ Machiguenga time
Women	182	141	71	½ Machiguenga time

iii. Childcare

There is no indication that the genders behave any differently towards childcare between all the groups examined and thus time allocated for childcare is assumed to be the average of the Efe and Machiguenga, as shown in Table 3-9 below.

Table 3-9 Estimates of High Latitude Childcare Time

Time Allocations for Childcare	Efe (mins)	Machiguenga (mins)	High latitude (mins)	Basis for adjustment time allocated
Men	5	3	4	Average of Efe and Machiguenga
Women	94	63	79	Average of Efe and Machiguenga

iv. Tool Making

The variety of specialized tool kits required for critical and sporadic food acquisition tasks in the caribou Inuit and Nganasan groups have been discussed earlier. Direct foraging time is restricted by bad weather, limited daylight hours in the critical fall period, and total darkness for about six weeks in mid-winter. Technology is the key. But solutions are adapted to ecology and habit or tradition.

First, in most cases there may be many technical solutions to a particular problem; the Mbuti rely on cooperative net hunting and the Efe rely on solo hunting by bow and arrows, yet they both live in similar habitats and achieve acceptable returns. They are fully aware of each other's technology and are capable of hunting by either means but each retain their own separate approach (Turnbull 1966). Clearly there is some cultural impact or "drift" here; once a group adopts a technology it works within the bounds of that technology and develops a tradition. Second, tools that are powered by human muscle power alone have limited capacity for maximizing energy returns: the Ache and Hadza capture almost as much prey with their hands or with simple clubs as they do with bow and arrow (Hill and Hawkes 1983), and most tropical plant food is gathered by hand, the only tool being a bag or carrying container (Lee 2003). Third, it is in cases where environmental constraints and risks are highest that technological solutions become more refined and more critical to survival. Tools are most effective in coping with problems that must be solved in minutes or hours: the prevention of loss by capturing prey that may be accessible only for a short period. Failure costs and the level of risk are greater in the higher latitudes because of longer winters and less available subsistence-level floral resources. To cope with the demands of making and

maintaining a reliable tool-kit requires some standardization of parts and specialist technicians with great knowledge and skill. A primary quality of Nunamiut artifacts is lightness in weight: most items are made from a great many small parts that are easily repaired if broken (Gubser 1965). The breakdown into subassemblies offers even more opportunity for task specialization and exchange.

In this context, food acquisition tools have been further categorized into a) tools used in situation where the foraged item is relatively motionless and not able to harm people (digging sticks, clubs, and probes), b) weapons which apply energy to a moving prey such as spears, bows and arrows, harpoons and fish hooks, and c) facilities that control a prey's movements, such as tended blinds, game surrounds, or untended traps and snares (Oswalt 1976). Bows and arrows are notoriously inaccurate, and any method that brings the prey into closer range increases the chance of a kill. Untended facilities are particularly important where search time is high or arduous but play almost no role in low latitude technologies. Oswalt points out that technological advancement should not be attributed to higher intelligence but rather to necessity; some of the most complicated traditional technologies were developed by foraging groups for hunting and fishing.

Four types of behavior to reduce risk have been identified: prevention of loss, storage, transfer of loss, and pooling of resources (Binford 1980; Wiessner 1982). Many of the behaviors imply commitments to relatively long timescales from weeks to years. In harsh and highly seasonal environments, a collecting strategy becomes more critical. Collectors must obtain bulk staples for storage during periods of scarcity. This generally demands more sophisticated technology that is highly specialized in function

and often difficult to make. Once made, such gear is carefully saved or curated for use when the appropriate conditions exist. Thus, equipment needs to be more specialized and efficient in order to exploit large volumes of seasonally restricted resources.

Curation is the equivalent of collecting as applied to technology, where tools and raw materials are prepared and saved in anticipation of future use (Bamforth 1986; Bettinger 1991; Odell 1996). In the archaeological record, curated tools are found concentrated in workshops and stored in caches; both of which are considered signals of specialization, the former specialization in manufacture and the latter specialization in usage (Odell 1996).

I previously referred to Oswalt's analysis in describing caribou Inuit technology. Oswalt's approach to analyzing the complexity of tools used for obtaining food using the concept of subsistants and techno units is a useful guide for comparing technical complexity between tropical and high latitude communities. A subsistant is a simple or complex tool used in the procurement of food resources. A techno unit is an integrated, physically distinct, and unique structural configuration that contributes to the form of a finished artifact (Oswalt 1976). A stone used as a hammer-stone is a one-techno unit artifact. A hafted end-scraper is a three-techno unit artifact, (haft, adhesive, and end-scraper) by this definition. Subsistants include simple instruments, weapons, tended facilities (such as blinds and drives), and untended facilities (such as traps and snares). Oswalt classified the toolkits of 20 hunter-gatherer groups from tropical to arctic latitudes and noted a clear association between number of tool types and latitude: more extensive toolkits are associated with higher latitude societies.

The design of tools can also help understand the organization of mobile tool assembly and usage (Kuhn 1994). Reliable design is costly but prevents failure at the critical time, redundancy permits replacement in the event of failure, and constructing the tool as a series of subassemblies allows for substitution or repair in the event of wear and tear in that one part. Maintainability is the characteristic of low latitude hunters: the !Kung carry multiple arrows and spare parts that can be quickly finished as backup (Bleed 1986). On the other hand the Iglulik of western Alaska have some 410 different forms (Oswalt 1976); reliability and maintainability are the hallmark of Inuit technology (Torrence 1989). Techno units are defined as the subcomponents that each makes a unique structural contribution to the final artifact. Precise counts of techno units for different cultures are close to impossible, but Tiwi Australian Aborigines are estimated to have about 75 different units as opposed to the 410 types employed by the Iglulik (Oswalt 1976)

This avenue of research may help in the analysis of individual task specialization. An understanding the role of tools in societies can be profitably applied to explaining the variety and differing level of technologies of recent and past hunter-gatherers (Torrence 2001). I shall use this methodology to estimate the amount of time allocated to the various indirect tasks in northern latitude groups and so translate the qualitative data described in the literature into quantitative measures. Later, I shall use the same methodology to construct time allocation data for prehistoric groups to be used in my model (Chapter 4).

In northern latitudes many technological solutions are required to accomplish all the tasks necessary in the harsher environment, not only gathering tools, hunting

weapons, and traps and snares but also clothing, shelter and storage facilities, and the immediacy and criticality of the task at hand demands reliability, redundancy and maintainability which adds further complexity to the indirect tasks of tool making, clothing manufacture and camp maintenance.

Torrance has shown that the tool inventory, expressed in techno units (Oswalt 1976) expands with increases in latitude among recent hunter-gatherers (Torrence 1983). The comparison between the hunting tool kit and amount of leisure of the Efe or Hadza and the extensive specialized toolkit and the daily caloric expenditure of the Netsilik may be an indication of the impact of extreme climate and latitude on behavioral patterns. Using data assembled by Oswalt (1976) from hunter-gatherer groups in different latitudes, Torrence (2001) demonstrated that groups living above 40 degrees latitude utilize an average of 34 (between 30-50) tool types compared to the 15 (between 10-20) utilized by tropical and sub-tropical groups. This represents an increase of about 225% in the amount of effort dedicated to tool making among recent hunter-gatherers in high latitudes. This provides a measure of the required effort to be put into subsistant manufacture in high latitudes compared to that recorded for the Efe and Machiguenga.

Both Efe and Machiguenga live below the 25th parallel. Since groups at this latitude typically manufacture on average 15 techno units, whereas groups residing above 60° in latitude use an average of 34 techno units, I have adjusted the average of the Efe and Machiguenga tool making times accordingly for the high latitude groups, as shown in Table 3-10.

Table 3-10 Estimates of High Latitude Tool Making Time

Time Allocations for Tool Making	Efe (mins)	Machiguenga (mins)	High latitude (mins)	Basis for adjustment time allocated
Men	51	72	139	34/15 times average of subtropical groups
Women	6	18	27	34/15 times average of subtropical groups

v. Clothing Manufacture

Compared to the Efe and Machiguenga the inventory of clothing requirements for life in sub-arctic winters is huge. Heavy winter outfits and lighter summer outfits need to be manufactured each year. Each outfit consists of multiple elements of attire ranging from boots to leggings, under and over garments, hats and blankets. This is an extremely time consuming task and would far exceed the allocation recorded for the Machiguenga, whose only garments are simple spun-cotton *cushmas*. The only high latitude groups that did not invest a considerable effort in clothing appear to be the Tierra del Fuego Indians. The Yaghan went fishing in icy cold waters naked or with a single pelt of seal or seal otter tied over their backs so as not to impede upper arm movement. They eschewed any clothing when fishing even though they knew how to sew and made large bedding robes. They employed other technologies to keep warm: in addition to smearing their bodies with protective oils, they kept a fire burning in a clay-hearth in each canoe to provide the necessary additional warmth (Coon 1971).

Each element of arctic clothing is made from specific caribou skins, acquired at different times of the year for their insulation properties and trimmed with furs from arctic foxes, wolves and wolverines, each having their own special properties. For example, caribou hair, examined under scanning electron microscopy, is shown to have an open cellular structure quite different from many other mammalian hairs, which are

solid. The hairs are resistant to collapse or crushing and retain air trapped inside the ‘bubble-wrap’ cell structures. These properties contribute to making caribou garments warm, relatively light in weight, weatherproof and hardwearing (Meeks and Cartwright 2005). In addition, the Inuit trim their clothing with wolverine and wolf fur ruffs for maximum insulation especially around the nose and mouth, since the breath does not freeze on the fur of these animals (Coon 1971). A comparison of the garment inventory for tropical and arctic groups is shown in Table 3-11.

Table 3-11 Comparison of Garments Produced

	Efe	Machiguenga	High Latitude
Clothing produced	Bark loin cloth	<u>Three sets of clothing</u> Cotton <i>Cushmas</i> and shorts	<u>Three sets of clothing</u> Underwear Outer garments Overcoat (<i>sovik</i>) Traveling coat (<i>lifarie</i>) Mittens
Garments Produced	1	6	15
Time spent in production	Hours only	13 weeks for spinning and weaving	7 winter months, excluding dark winter

Not only is the northern wardrobe more extensive but also the amount of effort that goes into the selection, dressing and fitting of clothing is far more onerous than the effort required for preparing loincloths or *cushmas*. Gubser explains that one of the most important tasks performed by the Nunamiut women in the fall is preparing hides and tailoring clothing. It is the woman’s responsibility to clothe the members of her family (Gubser 1965). The first task is to remove the inner membrane and any particles of fat with a scraper. In the old days, men chipped scrapers from flint and hafted them in handles carved from the gnarled crotch of the alder tree. Now and again women would sharpen the scraping edge by pressure-flaking it with a tool of caribou antler. Once the inner membrane is removed, the skin is allowed to dry for a day or two and

then soaked in a paste of boiled brains or liver and water. Once the skin has thoroughly absorbed the moistening agent, after two or three more days, the skin is ready for more scraping. It is usually scraped from two to five times; the more the skin is scraped the softer and more pliable it becomes. For a particularly high-quality finish fine sand was used as a friction agent in the last scraping. The skin is finally ready for use. These methods of clothing manufacture have been experimentally recreated using Mousterian and Upper Paleolithic tools to assess the *gestes* and clothing skills of the Neanderthals and modern humans (<http://www.pole-prehistoire.com/>).

The Igloodik have named sixteen distinct steps (paniqtuq, pannaijaqtuq, siirliqsiqtuq, siirlirijaqtuq, imaqtuq, imujug, pulaugsigtuq, tasiuktiqtuq, kingmaluuktuq, sakuktug, urrurittiqtuq, tasijuktuq, naliqqaktigsimajug, qitiliuqtuq, qitiliugsimajuq, imusimajuq) in the preparation of caribou skins prior to sewing. These include drying, smoothing, curing, and delicate fracturing, wetting, folding and allowing the skin to seep and dampen, stretching, chewing and scraping to remove hypodermis, re-dampening and final stretching, and finally aligning the sides, marking the middle and folding the skin to prevent cracking (Aksaakjuq Otak 2005). In addition to working with tools, women chew skins, using their teeth to soften hides and boot soles and for tearing sinew (as well as for extraction of blubber for oil lamps and mastication of food for children and puppies) (Ingstad 1954). These different processes are summarized in Table 3-12.

Table 3-12 Clothing Manufacturing Processes

Major Task	Sub-tasks	Efe	Machiguenga	High latitude
Prepare raw hide	Flaying			√
	Flensing			√
	Remove hairs			√
	Wash			√
	Stretch and dry			√
Prepare untailored clothing	Cut fine bark	√		
	Make attachment	√		
Dress fine hide	Fine scraping			√
	Tanning			√
	Stretch and dry			√
	Burnish			√
Spin and weave textiles	Spin cotton/yarn		√	
	Weave cloth		√	
Prepare body wear	Cut to measure		√	√
	Sewing		√	√
Insulate and decorate	Animal furs			√
	Decoration		√	√
Construct foot wear		√	√	√
Total subtasks		3	6	15

Clothing manufacture is not in the male domain. Counting the number of garments made by each group and the number of manufacturing steps identified suggests that the high-latitude women should spend about 2½ times (15/6) the effort spent on clothing manufacture by the Machiguenga (Table 3-13).

Table 3-13 Estimates of High Latitude Clothing Manufacturing Time

Time Allocations for Clothing Manufacture	Efe (mins)	Machiguenga (mins)	High latitude (mins)	Basis for adjustment of time allocated
Time allocated by men	0	0	0	
Time allocated by women	5	108	270	15/6 times Machiguenga effort, based on number of garments and processing steps

vi. Camp Maintenance

In addition to the manufacture of clothing, the building of shelter and hearths to protect against the cold, and the construction and provisioning of storage pits for winter fuel and food, all necessitate the dedication of significant amounts of time that is not required in warmer climates. All of this is in stark contrast to the tropical groups'

activities, where requirements for clothing, fire and shelter are minimal, and most food is consumed immediately on capture and therefore storage is rarely used.

Northern groups are generally characterized by the dichotomy of winter and summer residences. These are semi-permanent and must be built to withstand the rigors of the harsh climate, wind, ice and snow and frigid temperatures. However these groups cannot afford the three months that the Machiguenga take to erect their houses. For the winter dwellings women build dwellings of willow frames covered in moss dug from the tundra (Gubser 1965), often with excavated subterranean floors and submerged entrances or erect heavily constructed tent-like structures covered with caribou/reindeer hides (Popov 1966). The willow-frame dwellings may be revisited from year to year but nevertheless they have to be refurbished each fall. More mobile groups use lightweight tent dwellings that can be packed and transported. The most expensive feature of these is the caribou-hide tarpaulins that are used to cover the dwelling. Hides provide bedding and insulation on the inside. Inside and outside layers are needed to provide protection needed against winter storms. These hides, together with the support poles are prepared in advance so that they may be rapidly assembled once the seasonal site is selected. Summer dwellings are lighter weight tents (Popov 1966). Whereas mobile, tropical groups need to construct huts quite frequently, high latitude groups build more permanent, but more complex dwellings, as shown in Table 3-14.

Table 3-14 Comparison of Camp Maintenance Tasks and Frequency

Efe	Machiguenga	High Latitude
1. Build temporary shelter, every three weeks on average	1. Build semi-permanent frame and thatched houses 2. Erect temporary summer shelter	1. Manufacture tarpaulins and tent supports 2. Erect winter and summer shelters 3. Build constructed hearth 4. Build storage facility

A necessity for human survival in the high latitudes is continuous heat. The ubiquitous hearth provides heat for melting ice for water and drying clothing to avoid freezing (Gubser 1965). Collecting wood is a daily chore and in some areas where wood is scarce or inaccessible, long trips are necessary to acquire fuel, or supplies are gathered in the fall and stored before the harsh winter sets in. Oil lamps provide light in the dark winter days and the woman's job is to render animal fats as fuel for the lamps.

Storage increases the time and space over which resources can be utilized. Therefore, one would expect the level of investment in storage facilities to reflect the degree of risk, Saqqaq and Central Arctic Inuit lay aside enough supplies to get them through the critical mid-November to mid-January lean period (Damas 1972; Dahl 2000). The deer-hunting groups aim to set aside enough meat in the fall to last through the spring migration, supplemented occasionally with fresh meat from wandering caribou or mountain sheep that are hunted opportunistically. The Shimaa villagers of the Machiguenga focus on overproduction, to the extent of leaving resources unharvested, and maintain their individual autonomy without resort to networking (Baksh and Johnson 1990). On the other hand the Efe, Dobe !Kung and Australian Aborigines store little food and have not developed the technology to do so (Gould 1969; Lee 2003). They are immediate-return foragers who rely on mobility, *hxaro*-like exchange or, moiety and section networks as insurance against infrequent droughts. The range of maintenance tasks is listed in Table 3-15.

Table 3-15 Comparison of Daily Camp Maintenance Tasks

Daily Tasks	Efe	Machiguenga	High Latitude
Maintain embers/ make fire	√	√	√
Collect water	√	√	√
Organize space		√	√
Fuel transport - local	√	√	√
Fuel transport - distant			√
Manage fuel storage			√
Maintain oil lamp			√
Clean camp		√	√
Manage food storage			√
Total Daily Tasks	3	5	8

The high latitude groups fall between the Efe and Machiguenga in the efforts put into camp maintenance (Table 3-14). Their moves are less frequent than the Efe and therefore spend less time in total per annum in pitching their tents, although the preparation of hides is an onerous task, comparable to that of collecting palms for thatching. The men spend about the same time as men in the temperate and tropical groups, providing help in building the rugged shelters necessary to withstand winter storms. The women, however, have to devote considerably more effort into the daily provision of heat, light, insulation, and maintaining food and fuel storage facilities than either the Efe or Machiguenga (Table 3-15). Once again the women take a key role in preparing hides for tarpaulins and bedding, erecting the tents and earthen dwellings and performing other housekeeping duties. Overall these daily tasks are more numerous and onerous and cost about twice the average effort dedicated by Efe and Machiguenga women, as shown in Table 3-16.

Table 3-16 Estimates of High Latitude Camp Maintenance Time

Time Allocations for camp maintenance	Efe (mins)	Machiguenga (mins)	High latitude (mins)	Basis for adjustment time allocated
Time allocated by men	27	52	40	Average of Efe and Machiguenga
Time allocated by women	74	26	100	Twice the average of Efe and Machiguenga

3.6 Summary of Rankings and Time Allocations by Group

Using the time allocation data and task descriptions from the Efe and Machiguenga as a guide, I estimated the rankings and approximate time that would be allocated to each of these six activities for high-latitude groups based on the ethnographic data from Nganasan and Inuit groups. These time allocations are summarized below in Table 3-17.

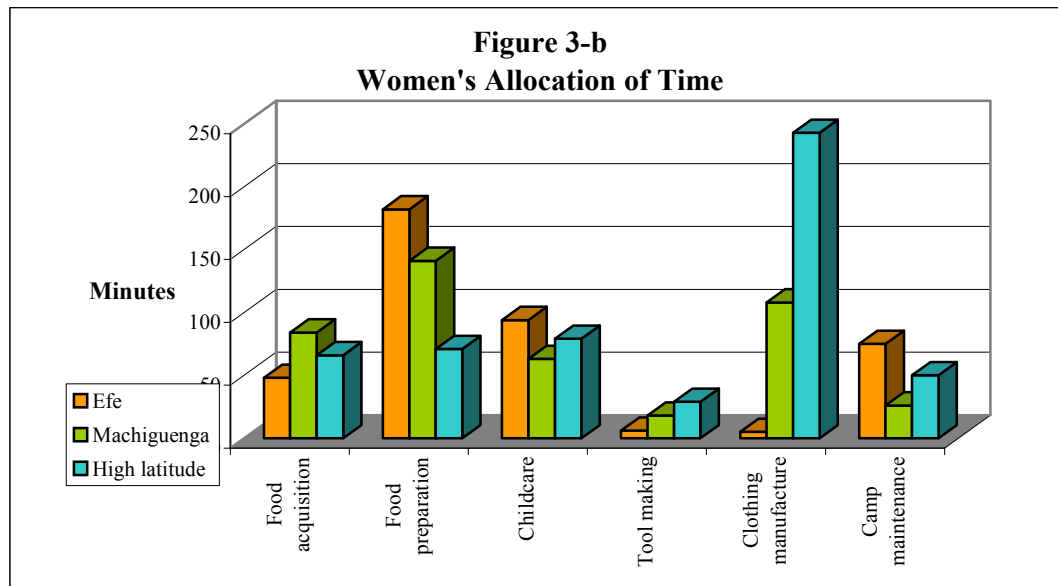
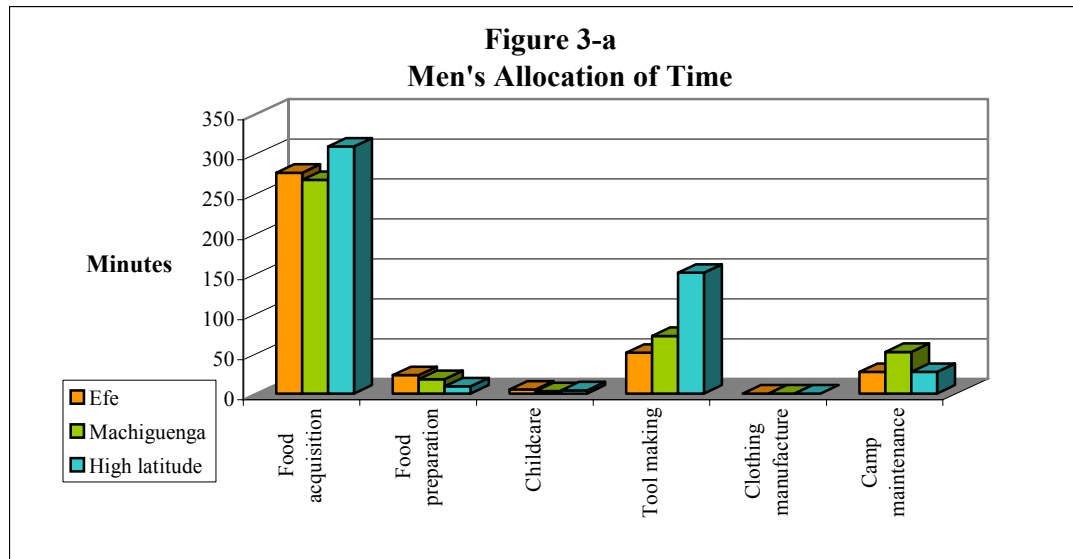
Table 3-17 Time Allocations for Tropical, Temperate and High-latitude Groups.

<u>Men's Allocation</u>	Efe		Machiguenga		High latitude	
Category Name	Mins	Ranking	Mins	Ranking	Mins	Ranking
Direct						
Food acquisition	276	1	267	1	367	1
Food preparation	23	4	18	4	9	4
Childcare	5	5	3	5	4	5
Indirect						
Tool making	51	2	72	2	139	2
Clothing manufacture	0	n/a	0	n/a	0	n/a
Camp maintenance	27	3	52	3	40	3
Total (Excluding Leisure)	382		409		559	

<u>Women's Allocation</u>	Efe		Machiguenga		High latitude	
Category Name	Mins	Ranking	Mins	Ranking	Mins	Ranking
Direct						
Food acquisition	48	4	84	3	33	5
Food preparation	182	1	141	1	71	3
Childcare	94	2	63	4	79	2
Indirect						
Tool making	6	5	18	6	27	6
Clothing manufacture	5	6	108	2	270	1
Camp maintenance	75	3	26	5	100	4
Total (Excluding Leisure)	410		440		580	

On inspection, these results seem reasonably to represent the activity rankings as noted in the literature, the relative importance of the key activities is supported by the qualitative data provided by the ethnographic studies examined. The changing ranking,

especially for women, between tropical and temperate groups and high-latitude groups is clearly illustrated in Figures 3a and 3b below.



The figures show time allocation for the Efe, Machiguenga as well as projected allocations for men and women based on the above predictions for high-latitude hunter-gatherer groups, based on Table 3-17. Male rankings changes with a greater emphasis on tool making offset by efficiencies in food acquisition but female responsibilities change significantly. Clothing manufacture becomes the most important with camp

maintenance, food preparation and childcare, all coming in a distant second. This finding is supported by anecdotal data from recent data from rural Greece where it is noted that as much time is spent on clothing manufacture as is spent on food acquisition and preparation (Brown 1970). These activity rankings will be used as a baseline for computing the time allocation of prehistoric groups and adjusted based on artifacts and features discovered in the archaeological record.

3.7 Identification of Tasks and Sub-Tasks

The activities identified above comprise tasks and subtasks, some of which might be separately performed by individuals uniquely skilled in the task. Little is written about specialization at this subtask level although some optimal foraging models do distinguish search, pursuit and capture in hunting activities (Kaplan and Hill 1992). Others have made similar distinctions in analyzing hunting patterns and efficiency (Hill, Kaplan et al. 1985). It is necessary to rely on descriptive narratives to identify those subtasks within each major activity. Giffen has compiled an excellent list of tasks and subtasks by gender for the coastal Inuit (Giffen 1930). Although this list applies to coastal seal and walrus hunting communities, the level of detail presented here is a template and provides an excellent guide for identifying critical tasks in the late Pleistocene from the archaeological record. The list below (Table 3-18) is a modification of Giffen's list and is intended to help in the interpretation of the archaeological record and the identification of behavior patterns from the artifacts, features and fossils recovered.

Table 3-18 Identification of Sub-tasks by Category and Task Rankings in High Latitude Groups for Men and Women by Season
(Data derived from (Giffen 1930))

Category	Men		Women		Major Task	Subtasks or Processes	Potential Source
	W	S	W	S			
1. Food acquisition	1	1	-	-	1.1 Hunt big game	Scavenging/Opportunistic hunting <ul style="list-style-type: none"> • Search (Scavenging only) • Pursue • Kill 	Faunal analysis
						Logistic hunting <ul style="list-style-type: none"> • Plan • Build drive/blinds • Ambush • Mass killing 	Faunal analysis Landscape Features
						Retrieval <ul style="list-style-type: none"> • Butcher at kill site • Transport • Build cache • Replenish cache 	Faunal analysis
	1	1	6	3	1.2 Collect small game	Active Collect - by hand - by digging stick	Faunal analysis
						Unattended Snares/nets/pits <ul style="list-style-type: none"> • Create/Set trap • Monitor • Retrieve and reset 	Faunal analysis
	1	1	6	3	1.3 Fish	Opportunistic fishing <ul style="list-style-type: none"> • Line • Net Logistic fishing – weir Shell fishing - collecting	Faunal analysis Features Faunal analysis
	-	-	-	3	1.4 Gather plant food	Cutting/uprooting	Micro wear analysis
						Scything grasses and sedges	Micro wear analysis
						Digging roots	Palynology
						Collecting fruit and nuts	Palynology
2. Food Preparation	4	4	3	2	2.1 Processing plant materials	Threshing Detoxification Mastication Grinding Cooking	Palynology Tools
					2.2 Processing meat	Cooked Uncooked	Hearth analysis
3. Childcare	5	5	4	3	3.1 Childcare	Childcare	
4. Tool making	2	2	5	6	4.1 Hard materials	Utensils Weapons Untended facilities	Tools Micro wear analysis
					4.2 Soft materials	Containers Carrying bags Bedding	Analysis of representation Site analysis
5. Manufacture clothing	-	-	1	2	5.1 Prepare skins and hides	Flaying Flensing Remove hairs Wash Stretch and dry	Experimental
	-	-	1	2	5.2 Dress skins	Fine scraping Tanning	Experimental
	-	-	1	2	5.3 Prepare string from tendons		Analysis of representation
	-	-	1	2	5.4 Prepare woven textiles	Spin cotton or other yarn Weave cloth	Analysis of representation
	-	-	1	2	5.5 Create clothing	Untailored cloak/poncho	Micro wear analysis
6. Camp maintenance						Tailored body wear Foot wear	Needles Morphology
	3	3	2	5	6.1 Moving camp	Transport Build/erect shelter	Site analysis Artificial structures
	-	-	2	5	6.2 Maintaining camp	Organize space/clean space	Spatial distribution of artifacts
						Build hearth	Artificial structure
						Make fire	Ash lens analysis
						Maintain oil lamp	Artifacts
	3	3	2	5	6.3 Storage	Build storage facility Manage storage	Features
	-	-	2	5	6.4 Fuel and water	Local /distant transport	Landscape analysis

I have listed task rankings, 1 is highest (columns 2-5). I have added the right hand column of Table 3-18 as a suggestion as to where the signature of these tasks might appear in the archaeological and physical anthropological records.

Using Giffen's list together with information on logistic versus opportunistic hunting (Binford 1980; Wiessner 1982), on hunting subtasks (Smith and Winterhalder 1992) and the literature examined for caribou/reindeer hunting groups (Ingstad 1954; Gubser 1965; Popov 1966; Binford 1978a; Ingstad 1992), I compiled the above list of male and female subtasks arranged by the six activities that might be applicable for a group of early modern humans in Europe. I intend to use this as a template when analyzing the prehistoric record

Examination of recent historical sites and the taphonomic processes at work, middle range archaeology and experimental studies to reconstruct past behavior, provide some of the tools for interpreting the signatures left behind by prehistoric peoples. It is through these methods that it might be possible to determine how behaviors and lifestyles of Neanderthals and early modern humans differed from each other as well as from the behavioral patterns observed in current hunter-gatherers. The above list will be the basis for identifying task complexity among the four groups addressed by this research (Early Neanderthal, late Neanderthals, Early Upper Paleolithic, and Middle Paleolithic).

3.8 Review of Activities from the Ethnographic Record

The rankings and time allocations for major activities for men and women in current hunter-gatherer groups might provide a guide to how one would expect modern humans to have behaved in the late Pleistocene. More extreme seasonal variation was

experienced in Europe in the late Pleistocene: summers appear to have been more similar to temperate climate zones and winters more similar to Arctic zones (Frenzel, Pecsí et al. 1992; van Andel 2002; van Andel 2003c). This would suggest that women might have played a greater role in gathering plant foods during milder summers but that they were entirely dependent on the men hunting for animal foods during the harsher winters. In tropical and temperate areas women provide 70-80% of the basic calories for the family. In northern latitudes where plant resources are scarce tasks are subdivided so that women may emphasize such activities as making clothes, housekeeping and food processing activities that are compatible with their childcare responsibilities (Jochim 1988). The data do also suggest that late Pleistocene women in northern groups would spend significantly less time in food preparation and significantly more time in clothing manufacture and camp maintenance in the form of heat and shelter, during the winters and during periods when plant foods were not available. Projecting from the Oswalt's analysis one would expect that early modern humans, living in Northern Europe at latitudes between 40-50 degrees north would have utilized 40 to 50 tools types.

The range of life critical tasks varies depending on local ecology. Tasks complexity depends on the ease of acquisition of food resources, the need for shelter, clothing and defense. The summer rankings, closer to that of the Efe and Machiguenga and the winter one, closer to the high-latitude groups, both reflect the extreme climate variation experienced during this period of the late Pleistocene, where winter temperatures and humidity were significantly less than those of today, and summer temperatures and humidity were only slightly lower than today's readings.

The ethnographic data has provided insight into the relative significance in terms of time allocated for the six activities. It is now necessary to examine the archaeological and physical anthropological record to identify which subtasks within these activities were employed by the four groups that are the subject of this research. The six activities represent those high-level functions that are prerequisites for survival and should apply to Neanderthal as well as modern human lifestyles. However, I anticipate that each group will employ its own adaptations to local environmental conditions and will exhibit different patterns of behavior in terms of sub-tasks performed which might be able to be inferred from the archaeological record. It is these differences that will distinguish the behaviors of each group, their task repertoire and potential for specialization and cooperation within the group. This analysis provides the basis for one of the key parameters for my model: the task repertoire. The number of tasks and sub-tasks that were employed by each of the four groups are important, since my hypothesis is that there is greater opportunity for specialization and exchange as the number of discrete tasks that can be shared among members of the group increases. My model quantifies whether a larger repertoire of tasks and subtasks that can be shared among the members of a group will lead to better opportunities for survival in the fluctuating climate of the late Pleistocene. Since we have no ethnographic data from this period of prehistory, archaeology and physical anthropology may help identify these task repertoires for prehistoric humans.

Chapter 4

The Identification of Major Activities and Tasks within Activity from the Archaeological and Physical Anthropological Record

In the previous chapter, I examined how task priorities vary amongst hunter-gatherer groups in different ecological settings and discovered that indirect activities become more significant in high-latitude environments. Here, I plan to examine the archaeological and physical anthropological record for Neanderthals and early Upper Paleolithic humans in Europe to determine how they spent their time. Just as Gamble took the archaeological record to reconstruct and understand the society of the Paleolithic (Gamble 1986), so I plan to look at the prehistoric record to construct and understand economic life during the late Pleistocene. The range and scope of artifacts and features created by prehistoric humans, as well as morphological and isotopic analysis of skeletal remains, may provide sufficient information to approximate allocations of time to the critical activities and tasks for the four groups under study. This time allocation information is to be used for the task repertoire parameters in the ICA Transition model I have developed. I approach this research by looking at the six direct (food acquisition, food preparation, childcare) and indirect (tool making, clothing manufacture and camp maintenance) activities identified from the record of current hunter-gatherers. I have divided the time period into four segments or populations:

- Early Neanderthal, before 60 ka,
- Late Neanderthal, from 60 ka until 28 ka,
- Early Upper Paleolithic, before 28 ka (Aurignacian), and

- Middle Upper Paleolithic from 27 to 20 ka, (Gravettian).

Archaeological sites, artifacts and features are categorized into these four grouping based on dating procedures, where appropriate dating materials are available, and identification of skeletal remains or lithic typologies. Significant issues arise because of this method of categorization.

First, the most definitive sign of Neanderthal or Upper Paleolithic presence at a site is the discovery of skeletal remains. Unfortunately, few of the sites contain human skeletal remains, especially during the Aurignacian period, and, in some cases even where human skeletal remains are found, there is not a consensus as to their specific attribution (Frayser 1997). Archaeologists resort to defining non-skeletal bearing sites according to their lithic typologies, namely Mousterian or Upper Paleolithic. Since Neanderthal skeletal remains have been found in association with Mousterian tools and anatomically modern human remains have been found in association with Aurignacian and Gravettian Upper Paleolithic tools, there is some rationale for classifying Mousterian tool bearing sites as Neanderthal sites (Klein 1999: page 486), and this is the position taken here. However, there is no definite proof that Upper Paleolithic peoples did not prepare and utilize Mousterian tools or vice-versa and this assumption may only be supported or discounted by future discoveries. Indeed, there are sites, such as Steletskaya in Russia where the tool inventory is predominantly Mousterian but with atypical end scrapers and triangular bifacial points (Hoffecker 1999; Hoffecker 2002), that are generally classified as belonging to the Upper Paleolithic. If these sites are reclassified as Neanderthal this would suggest that the Upper Paleolithic peoples were not so advanced in their tool technologies as currently presumed.

Second, dates are generally based on radiocarbon dating procedures which until recently were unreliable in the date ranges covered by this analysis. Recent improvements in dating methods at the University of Oxford allow for the elimination of contamination by more recent carbon through ultra-filtration of gelatin samples. This approach generates dates that are from two to seven thousand years older than previously thought (Mellars 2006). In addition, recent research into the fluctuating patterns of the carbon content of the earth's atmosphere in this period suggests that dates should be recalibrated and the new adjustments indicate that radiocarbon dates of 40 ka BP should be recalibrated to 43 ka BP and dates of 35 ka BP recalibrated to 40.5 ka BP. Clearly as new dates are established for existing sites this could move some sites from the middle Upper Paleolithic band to the early Upper Paleolithic category and thus expand the early Upper Paleolithic task repertoires accordingly.

In this analysis of economic tasks and activities, I classify sites with Mousterian technologies as Neanderthal, except where noted, and sites with Aurignacian and Gravettian tool assemblages as early Upper Paleolithic and middle Upper Paleolithic, respectively. Dating of sites is based on the dates currently available in the literature.

4.1 Food Acquisition

i. Food Acquisition Activities

Food intake requirements are a function of body mass and energy expenditures. Therefore, in order to determine total time devoted to food acquisition activities I first look to energetics studies that address differences between Neanderthal and early Upper Paleolithic human activities. In order to determine the types of tasks undertaken in the food quest, I examine isotopic analyses of the faunal remains as well as the distribution

of species found in archaeological assemblages to determine what species were targeted, and I look to evidence from hunting technology to determine how food acquisition methods may have differed between Neanderthal and Upper Paleolithic peoples.

Darwinian fitness encompasses survival and reproduction, and basal energy expenditures and activity costs are associated with maintenance and survival (Leonard and Ulijaszek 2002), which is the focus of my analysis. Sorensen and Leonard (2001) use basic metabolic rate (BMR) predictions to calculate and compare total energy expenditures and energy returns for current hunter-gatherers and prehistoric groups. They predict body weights for prehistoric humans using estimates derived from humeral, femoral, and tibial length, mid-shaft circumference, and mediolateral diameter of the femoral mid-shaft. They compute total energy expenditures of 2,700 kcal/day for males and 2,000 kcal/day for females, based on body weight and BMR predictions as derived from recommended dietary allowances from the National Academy of Sciences, and energy and protein requirements from WHO 1973 (Little and Morren 1976)

BMR for males and females are compiled using the formulae as follows:

- BMR for males: $(\text{kcal/day}) = 15.3 (\text{wt}) + 679$,
- BMR for females: $(\text{kcal/day}) = 14.7 (\text{wt}) + 496$.

The energy cost of bodily maintenance includes all functions that preserve bodily integrity, including thermoregulation (Lasker 1995). Measurements from 160 populations indicate that BMR varies inversely with mean annual temperature, from 1,800 kcal/day at -10°C to 1,400 kcal/day at 25°C (Little and Morren 1976). Genetic

thyroid function as well as acclimatization, both of which might apply to Neanderthals, seem to be factors in BMR elevation in circumpolar populations (Leonard, Sorensen et al. 2002). Sorensen and Leonard (2001) therefore elevated BMR for Neanderthals, in contrast to current hunter-gatherers, by a conservative 10% (from within a range of 8% to 40% elevation as determined from studies of polar subjects) to account for increases in metabolic costs resulting from living in cold environments with limited cold buffering technology, such as clothing and shelter (Holliday 1997a; Holliday 1997b). Sorensen and Leonard calculated the mid-sex average total energy expenditure (TEE) associated with heavy to very heavy physical activity levels, which resulted in an average TEE of 4,094 kcal per person per day for Neanderthals. This is in line with other estimates, using the Tierra del Fuego Indians as the comparative ethnographic model, that predict that Neanderthals required a comparable range of 3,360-4,480 kcal/day to support strenuous winter foraging and cold resistance costs (Steegman, Cerny et al. 2002). Sorensen and Leonard calculate energy returns using a low ratio of 1.35 times TEE, the returns achieved by the Efe, and the return factor I use in my calculations. In their findings, the authors conclude that Neanderthals must have been efficient foragers and must have foraged for more hours per day than any known hunter-gatherer group (Sorensen and Leonard 2001). I have therefore used the Machiguenga foraging rate, an average efficiency rate, to compute Neanderthal foraging times as shown in Table 4-1.

Table 4-1 Projected Neanderthal Foraging Time Based on Energy Expenditures

Population	Weight (kg)	TEE (person)	Return Rates	Energy Return (kcal/ person/ day)	Foraging Efficiency (kcal/ min foraged)	Foraging Time (av mins/ day)
Efe	41.95	2650	1.35	3588	22.1	162
Males	43.3					276
females	40.6					48
Machiguenga	48.15	3200	1.4	4500	25.7	175
Males	51.8					267
females	44.5					84
High latitude	60.0	3670	1.4	5138	25.7	200
Males	65.0					367
females	55.0					33
Neanderthal	60.0	4094	1.35	5527	25.7	215
Males	65.0					395
females	55.0					35

All energy expenditure, return, efficiency and foraging times are averages for both males and females. Foraging times for the Efe, Machiguenga and Inuit are taken from the time allocation data in Chapter 3, Table 3-17. Neanderthal data is based on energy expenditures of 4094 calories, energy returns of 1.35 from the Efe and the foraging efficiency rate of 25.7 from the Machiguenga.

These BMR findings (Table 4-1) are reinforced by examination of Neanderthal physical robusticity. Robusticity is pervasive in Neanderthals of all geographic regions and is exhibited in most bones including, ribs, upper and lower limb bones, the spine and cranium (Trinkaus 1983). The Neanderthal and early anatomically modern human residents of Western Eurasia represent a reversal in the long-term trend of declining robusticity from early hominids to modern humans (Ruff, Trinkaus et al. 1993).

In a widely dispersed species or subspecies of homeothermic animals, those in colder regions will tend to have greater body mass (Bergmann) and shorter extremities (Allen) than do their conspecifics in warmer regions. Analysis of six Neanderthal specimens, all presumed to be from glacial times: La Chappelle 1, La Ferrassie 1 and 2, Neanderthal 1, Regourdou 1, and Spy 2, illustrate Bergmann's and Allen's rules

(Holliday 1997a; Holliday 1997b). Cluster analysis of standard osteometric measurements (femoral anterior-posterior head diameter, skeletal trunk height, femoral bicondylar length, humeral maximum length, tibial maximum length and radial maximum length) indicate that the Neanderthals (although at the end of a long dendrogram branch) come closest to modern Koniag Eskimos in body shape and, it is suggested, are hyperpolar. Holliday concludes that this body shape likely results from two factors: first, the extremely cold temperatures of glacial Europe and second, less effective cultural buffering against cold stress such as layered clothing, complex shelters and constructed hearths.

Other typical Neanderthal features such as large noses and large paranasal sinuses, big brains, and robust, muscular bodies with barrel chests, and foreshortened limbs may also have been thermal adaptations to harsh glacial conditions, especially in hominids that perhaps lacked the technological sophistication to shield themselves from the cold (Churchill 1998). This may all have been the result of genetic drift (Howell 1952) and accretion (Hublin 1998) in small populations of foragers isolated from the rest of the world by the ice sheets of Alpine and Northern Europe.

However, recent analyses of climatic conditions at sites associated with Neanderthals indicate that they were not able to survive in sub-arctic conditions, and they preferred to settle in warmer areas with less snow cover than the Aurignacians and Gravettians (Davies and Gollup 2003). With their low level of clothing and shelter technology, they would not have been able to settle in colder areas without a significantly elevated BMR (Aiello and Wheeler 2003). This suggests that, if the Neanderthals were to survive in sub-arctic conditions, they would have had to support

energy expenditures considerably in excess of the conservative 10% included in Sorensen and Leonard's calculated TEE of 4,094. They would need to consume large amounts of animal fat to permit higher rates of non-shivering thermogenesis (Gisolfi and Mora 2000) with a consequent increase in foraging time and activity levels. Nevertheless, Neanderthals survived through conditions that were colder and more unstable than those experienced by *Homo heidelbergensis*, and occupied areas further north than *Homo antecessor*, whose range was restricted to southern Europe (Finlayson 2004). Thus, it appears that Neanderthals may have been more cold-adapted than their predecessors in Europe, but they were not adapted to hyperpolar conditions.

Further insight into the postcranial morphological changes that occurred from Neanderthals, through early modern humans from the early Upper Paleolithic (EUP) and late Upper Paleolithic (LUP), and recent humans comes from Pearson (2000b). Body proportions, robusticity and long bone shaft shapes were measured and patterns of morphological distance were constructed in order to determine the origins of modern humans. Pearson confirmed that the EUP postcranial skeletons (before 20-18 ka) were significantly different than those of recent humans. Early modern humans, which included Qafzeh/Skhul, Aurignacian and Gravettian specimens, differ dramatically from Neanderthals in many aspects of skeletal anatomy that reflect climatic adaptations; early modern humans have elongated distal limb segments, long limbs relative to trunk height and body mass, a linear physique, a narrow pelvis, and a low estimated body mass relative to stature and they do not exhibit most of the features that distinguish Neanderthals from more recent modern humans. Pearson concluded that these early

modern humans resemble recent humans from hot, dry climates (Nilotic Africans and Australian Aborigines).

Churchill (1998) concedes that cold adaptation alone could not account for all the features that distinguish Neanderthals from modern humans. The robusticity of the bones and joints, as well as the mechanical leverage provided by their large musculature, may be unrelated to aspects of cold adapted body shape. Churchill suggests that the behavioral loads on the Neanderthal skeleton reflect foraging activity associated with patchy and seasonal resources, high-mobility over uneven terrain, and close-contact hunting with short-range weapons. Comparison between earlier skeletons from Le Regourdou and Krapina and late skeletons from Vindija and Saint Césaire indicate that Neanderthal postcranial morphology changed little during the last glacial climate fluctuations, which implies that behaviors changed little, and climate deterioration did not further influence Neanderthal robusticity during the latter part of the Pleistocene (Trinkaus 1983). Trinkaus further suggests that the diaphyseal hypertrophy of the femur and humerus, in particular, is a result of long duration expeditions across rough terrain that required an exaggerated level of endurance. Pronounced muscle attachments in the post cranial elements reflect heavy mechanical loading caused by intense physical activity (Ruff, Trinkaus et al. 1993; Trinkaus 1997). Such a hypertrophied body would have required expensive development and maintenance costs in a population frequently close to the limits of their energy reserves, and must have been a necessary condition for their survival (Trinkaus 1983). These findings support the idea of increased level of physical activity and the associated,

elevated BMR proposed by Sorensen and Leonard (2001) and assigned to Neanderthals in my calculations.

Table 4-2 gives estimates of foraging times based on Sorensen and Leonard's methodology. I used the weight of the sub-Saharan and Nilotic type Hadza (male 53.6 kg, female 47.7 kg) as a proxy for Upper Paleolithic humans, Aurignacians and Gravettians (Sorensen and Leonard 2001). I used the same formulae for calculating BMR for Upper Paleolithic humans as outlined earlier. I also elevated BMR by 10% similar to Neanderthals, since the modern humans lived in slightly colder environments but had more effective insulation. Activity levels for modern humans were estimated at 2.25 times BMR, versus an average of 2.5 for Neanderthals, based on lower activity levels interpreted from the modern human's more gracile morphology. These are both conservatively within the range of 2 to 3 times used by Sorensen and Leonard for daily activity for foraging hominids exploiting glacial ecosystems with Paleolithic tools.

- Male TEE = $((53.6 \times 15.3) + 679) \times 1.1 \times 2.25 = 3710$
- Female TEE = $((47.7 \times 14.7) + 496) \times 1.1 \times 2.25 = 2963$
- Average TEE = $(3710 + 2963) / 2 = 3337$

I use the same return rates and foraging efficiency rates as applied to the Neanderthals (Adler, Bar-Oz et al. 2006). This means that, at this point, I make no allowance for efficiencies derived from technological differences between Neanderthals and Upper Paleolithic humans. I have made adjustments for this at the end of this section, based on my findings on effort spent in indirect activities by the four Paleolithic groups. The estimates below indicate that Aurignacians and Gravettians would have had to spend approximately the same time in food acquisition as the Machiguengans but less

time than the Artic and Neanderthal groups. However, the division of work by gender differs considerably from the Machiguenga distribution. This is based on the ratio calculated previously for the high latitude groups as shown below in Table 4-2.

Table 4-2 Projection of Upper Paleolithic Foraging Time Based on Energy Expenditures

Population	Male weight (kg)	Total Energy Expenditure (person)	Return Rate	Energy Return (kcal/person/day)	Foraging Efficiency (kcal/ min foraged)	Foraging Time (av mins/day)
Neanderthal	60.0	4094	1.35	5527	25.7	215
Male	65.0					395
female	55.0					35
Early Upper Paleolithic	50.65	3337	1.35	4504	25.7	175
Male	53.6					321
female	47.7					29
Middle Upper Paleolithic	50.65	3337	1.35	4504	25.7	175
Male	53.6					321
female	47.7					29

Neanderthal data are taken from Table 4.2. Upper Paleolithic data is based on the calculations described above.

ii. Food Acquisition Tasks

To understand what specific tasks were performed within the food acquisition activity I consider four perspectives: what is the evidence from isotopic analyses and faunal assemblages for what was eaten, what foraging methods were used, and what technology was employed in the food quest. From these data, I develop a picture of foraging patterns and processes in order to identify specific foraging tasks for each group.

- Diet Composition - Isotopic Analysis of what was Eaten**

Stable isotope analysis enables us to infer diets of past humans (Ambrose 1998a; Ambrose and Krigbaum 2003). In the context of food acquisition, mammal bone collagen $\delta^{15}\text{N}$ values may be used to indicate the trophic level of the food consumed.

The heavier ^{15}N isotope becomes concentrated as it moves up the food chain.

Terrestrial systems have relatively short food chains; aquatic systems are longer and the $\delta^{15}\text{N}$ in aquatic species, including waterfowl, have much higher values than terrestrial ones. Thus, humans, who eat aquatic foods in significant amounts, will achieve higher $\delta^{15}\text{N}$ values than those feeding solely on terrestrial plants and herbivores (Richards, Pettitt et al. 2001; Richards, Jacobi et al. 2005). Collagen $\delta^{13}\text{C}$ values are typically used to show the amounts of dietary protein derived from C_3 versus C_4 plant sources, the latter usually found in arid and tropical environments. But since C_4 plants are unknown from prehistoric Europe, it is unlikely that $\delta^{13}\text{C}$ values reflect different plant food sources but rather may reflect the contribution of freshwater organisms to the diet. Marine organisms are typically more enriched in ^{13}C and have more positive $\delta^{13}\text{C}$ values. Freshwater organisms, including waterfowl, may have $\delta^{13}\text{C}$ values that are more negative than those in terrestrial or marine systems because carbon may be derived from geological sources as well as from the atmosphere. A large freshwater component of the diet would then indicate high $\delta^{15}\text{N}$ values and/or more negative $\delta^{13}\text{C}$ values (Richards, Pettitt et al. 2001). Thus, the ^{13}C and ^{15}N isotope values taken from the skeletal remains of fauna and humans, is indicative of whether that individual consumed an herbivorous and carnivorous or omnivorous diet, and whether the protein was derived from terrestrial or marine sources.

An analysis of carbon and nitrogen isotopic compositions from early Neanderthal remains from Scladina Cave in Sclayn, Belgium (120 ka) and from late Neanderthal remains from Marillac in France (45 ka) suggest that, despite significant differences in climate, most dietary proteins were supplied by herbivore prey from open

environments (Bocherens, Billiou et al. 1999). The individual from Marillac obtained dietary proteins mainly from herbivore meat, in a cold steppic environment. And, although one might expect that humans living in a warmer climate would have had a more vegetarian diet, the Sclayn analysis indicates otherwise. The Sclayn inhabitants, from the last interglacial, lived in a forested habitat yet their diet indicated a similar pattern to that of the later Neanderthals from Marillac. Collagen isotopic analysis of skeletal remains of two very late Neanderthal specimens (at 28-29 ka) from Vindija Cave supports the above findings and suggests that Neanderthals were top predators (Richards, Pettitt et al. 2000). These Neanderthal collagen values reflect a protein source isotopically similar to that consumed by Paleolithic carnivores - mainly of meat from herbivores living in a rather open environment. Richards and colleagues suggest that, if Neanderthals were obtaining their protein from scavenging, they would have had to obtain most of their food from plants as a reliable food source, but the collagen results do not support a vegetal diet. Isotopic compositions of remains from Spy and Engis in Wallonia, Belgium, seem to reflect the consumption of dietary proteins from large herbivores, especially those with rather positive ^{13}C and ^{15}N , such as reindeer and suckling herbivores, or even omnivorous mammals such as bears. The Scladina-1B specimen is more ^{13}C -depleted and more ^{15}N -enriched than the Spy specimen, which may also reflect a diet based on large herbivore meat, but with more mammoth meat and possibly more freshwater fish in the diet of the former specimen (Bocherens 1997; Bocherens, Drucker et al. 2005). Mammoth meat may be a more likely protein source, since no evidence for fishing or fish remains have been found in Neanderthal sites in Belgium, not even in Scladina cave, where the sediment was systematically sieved

during the excavation (Bocherens, Billiou et al. 2001). These findings indicate that Neanderthals were meat eaters and that their dietary habits changed little over the period or across Europe.

Meat contains high-quality protein and the nine essential amino acids that the human body cannot synthesize. Meat also provides some essential minerals such as iron and zinc, vitamins such as B12, and some glucose – all in an easily digested form. However, safe protein intake for humans is about 20% of total caloric intake (Kelly 1995). The Inuit and Chukchi, who exceed this proportion of protein (23 - 26%), supplement their diet by high proportions of fat (32 – 40%) (Leonard, Galloway et al. 2002b). The faunal evidence suggests that Middle Paleolithic peoples similarly balanced such a high protein diet with energy-rich nutrients (Speth and Spielman 1983). In order to offset the lack of plant foods, they sought mainly fat-rich species, such as bovids, while avoiding animals with seasonally lean meat, such as males after the rut period and females after giving birth to calves. In lean times, Neanderthals sought fat-rich marrow, as shown by fractured bone (Patou-Mathis 2000), just as current hunter-gatherers butcher their prey solely for the fat-rich parts, such as brains, kidney, marrow and grease from the limb extremities (Speth and Spielman 1983).

Humans acquire energy from animal products but also need micronutrients, which are concentrated in vegetables and fruits. Thus, a varied diet of the available foods, including terrestrial herbivores, fowl, fish, shellfish and plant foods leads to a healthier human population (Hockett and Haws 2005). Isotope analysis reveals that diet breadth broadened between the Middle and Upper Paleolithic and that the benefits of a varied and more enriched diet may have contributed to the fertility of modern humans

above that of the Neanderthals: the Neanderthal diet was carnivorous, whereas the diet of modern humans was omnivorous. Whether the increase in diet breadth was driven by selection for nutritional richness or by a need to resort to fallback food resources in times of increasing climate stress, the net result is to augment the number and variety of food acquisition tasks required.

Analysis of three modern human skeletons from Sunghir' indicates that the diets and levels of dietary stress varied considerably between individuals. The adult male consumed mostly terrestrial vertebrate meat, whereas the adolescent boy and girl showed signs of protein deficiency and stress; the latter consumed a low proportion of meat, a large proportion of plants, and a very high proportion of invertebrates (Dobrovolskaya 2005). Analyses of Gravettian specimens from Brno-Fancouzská and Dolní Věstonice in the Czech Republic, Kostenki and Mal'ta in Russia, and Paviland in Wales, all dated to between 28-20 ka, suggests that by the Gravettian period there was a relatively heavy reliance on fresh aquatic food; as much as 50% in the Kostenki sample (Richards, Pettitt et al. 2001). This is a significant variance from the results obtained from the Vindija late Neanderthal remains from a mere 1,000 years earlier. The authors conclude that broadening the spectrum to lower-ranked game such as fish and fowl, and other fast moving and small animals became economical only with greater technological investment.

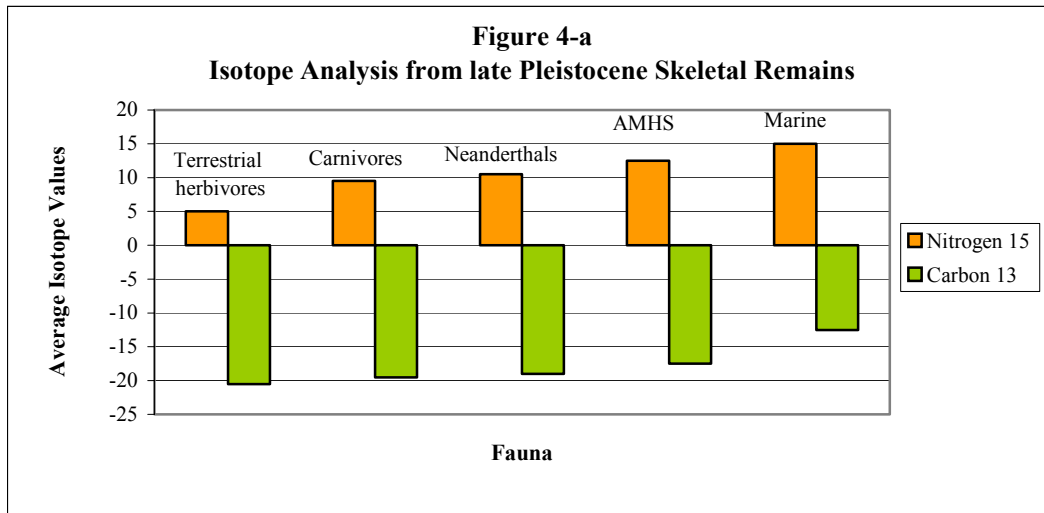
These dietary breadth findings are questioned by Drucker and Bocherens who maintain that differences in ^{15}N values amongst the Paleolithic prey could well account for the differences observed in human specimens (Drucker and Bocherens 2004). By measuring $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values from coeval taxa, they demonstrate that the variation

observed between Upper Paleolithic humans and Neanderthals could have been generated by consumption of a different selection of terrestrial herbivores. Middle Paleolithic mammoth register higher levels of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values than do reindeer, bison, and horse. Drucker and Bocherens, however, concede that anadromous fish, such as salmon, and some migrating birds are potential food resources, even in the case of continental human populations. These foods are more enriched in ^{13}C and ^{15}N than terrestrial food resources; therefore, a mixture of marine (anadromous or migratory) and riverine resources could explain the isotopic signatures of early modern humans, although no such tests have yet been performed to validate this.

Although isotope analysis indicates that vegetal matter may have contributed a significant portion of the Upper Paleolithic diet in certain circumstances (Dobrovolskaya 2005), the archaeological record does not preserve such remains except through indirect evidence such as the grinding stones and rounded granite stones resembling pestles found at Kostenki IV layer 9 and Molodova V (32-15 ka) (Dolukhanov 1982). However, absence of such items in the Middle Paleolithic does not necessarily indicate a lack of plant matter in the diet of the period (Farizy and David 1989).

The isotopic data shown in Figure 4-a were compiled from various sources including human (Neanderthal and Gravettian) and animal bones from Europe dated from 50 to 25 ka BP (Hockett and Haws 2003). These data support the suggestion that Neanderthals were top-level carnivores who consumed primarily large and medium sized terrestrial herbivores, whereas the modern human consumed a broader, omnivorous diet that also included significant quantities of fish or shellfish and perhaps

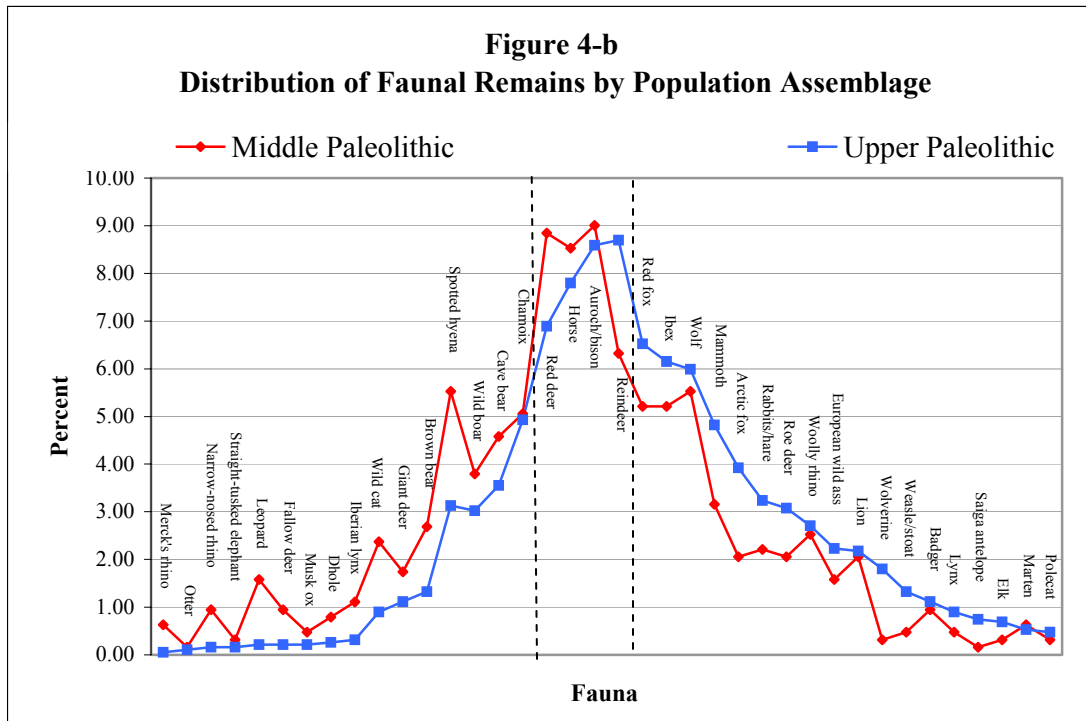
some meaningful quantities of plant foods (Hockett and Haws 2005). This suggests that anatomically modern humans (AMHS) executed a wider range of food acquisition tasks to accomplish this change in dietary habits.



- Diet Composition - Faunal Assemblages of what was Captured**

The Stage 3 Project mammalian database from 291 archaeological and non-archaeological sites shows the larger mammalian associations on Upper Paleolithic and Middle Paleolithic sites during OIS 3. I have constructed Figure 4-4 using data from Stewart's paper to illustrate the differing patterns of species in Middle and Upper Paleolithic assemblages (Stewart 2004). The data is a summation of presence or absence of taxa at each site and, as such, is useful in showing what species were found at the various sites but does not address the relative weighting of any one species.

A comparison of the Middle and Upper Paleolithic results in Figure 4-b shows that the species common to both Neanderthals and modern humans, horse, red deer and bison/auroch (indicated between the dotted vertical lines), and roughly equally represented in Upper and Middle Paleolithic sites, are wide-ranging and highly adaptable species.



Middle Paleolithic assemblages contained proportionately more remains from aggressive and large-sized carnivores or omnivores, the natural competitors for the common herbivorous prey species (as shown by the height of the curve to the left of the figure). These species are mainly associated with closed, deciduous woodland vegetation (and a few with open grassland) indicative of warmer and to some extent closed habitats. The caves and rock-shelters that dominate the Middle Paleolithic record occur usually on escarpments between open, limestone plateau and river valleys where mosaics of gallery forest, meadows and wetlands provide an attractive setting for a diverse animal community dispersed among discrete patches of vegetation (Burke 2004a). With the exception of the mammoth, which is not aggressive and takes up a defensive posture when attacked, Upper Paleolithic assemblages contained proportionately more, smaller and particularly fur-bearing species, such as the rabbit, red fox, arctic fox, and wolverine (as shown by the height of the curve to the right of the

figure). For these modern humans the association between open and closed habitats is more ambiguous; many of the taxa represented are ubiquitous and wide-ranging in their habitat preference. Stewart concludes that these patterns are indicative of climate and geographic conditions rather than prey preference (Stewart 2004)

The Upper Paleolithic saw a broad spectrum revolution in foraging involving a switch from harvesting large, k-selected game to a broader range of smaller, r-selected, and thus locally more abundant, species such as smaller mammals, birds and fish (Soffer 1989b). Niche-width statistics measuring the remains of economic species in stratigraphic units from Cantabria show an increase in niche-width from 2.54 in the Mousterian to 3.12 in the Aurignacian/ Perigordian and 3.10 in the Solutrean (Clark 1987). Analysis of fauna from eight strata from Le Flageolet I, dating from the early Aurignacian to the Perigordian, also show that diet breadth altered during this period based on changes in the environment (Grayson and Delpech 1998).

Fish and birds were not part of the diet during the Middle Paleolithic but were introduced into the diet once suitable acquisition techniques were developed (Bar-Yosef 2004). The archaeological record suggests that freshwater fishing was a significant food acquisition activity for Gravettians but not for Neanderthals, and made only a minor contribution, if any, to the Aurignacian diet. At least in central European Neanderthal sites there is an absence of bones of fish and birds as well as grinding stones for plant food (Hockett and Haws 2005). There is some evidence of mollusk exploitation by later Neanderthals in Gibraltar (Barton 2000), but it is not clear what portion of the diet it represents. Indications of increased dietary breadth that includes avian species from aquatic, roosting and raptorial birds are found in the Aurignacian

levels of El Castillo, although birds at another early site, Isturitz, are primarily raptors and cave roosting birds, probably not associated with human activities (Straus 1990; Straus 2005). Partially burned bones of swan and rock partridges, indicative of human agency, were found in the Aurignacian levels of Klisoura Cave in Greece (Koumouzelis 2001). Fish hooks were found in the Aurignacian layers at La Ferrassie dated to 29 ka (Mellars, Bricker et al. 1987). More recent excavations at La Madeleine, La Ferrassie and Le Flageolet have discovered remains of salmon but only in small quantities; this may be because fish bones are more susceptible to destruction than animal bones, or because, as in more recent cultures, fishing consumption occurred along the river banks where bones were discarded (Hayden, Chisholm et al. 1987). Mellars concludes that salmon was only a minor resource and must have amounted to only a small portion of the diet in southwest France (Mellars 1985); a conclusion supported by isotope analysis of later Magdalenian skeletal remains that show that salmon contributed a mere 5% to the diet of the region until the end of the Magdalenian (Hayden, Chisholm et al. 1987). Although not representing a large portion of the diet here, just as with the Slave Lake Indians, salmon may have been a reliable backup resource and significant activity in the fall in the event of failure or delay in the animal migration schedule (Jochim 1987). Evidence of waterfowl and freshwater fish exploitation during the Gravettian appears at Brillenhöhle, Höhle Fels and Geissenklösterle (Hahn 2000), in addition to the isotope evidence of a fish diet at Kostenki (Richards, Pettitt et al. 2001). Isotopic analysis of the faunal record supports the diet breadth expansion in the Upper Paleolithic, from medium to large mammals to smaller mammals, fish and avian species, and suggests a concomitant increase in the number of food acquisition tasks occurred at this time.

- **Foraging Methods**

There is considerable debate as to when hunting became more prominent than scavenging in the Middle and Upper Paleolithic. Separate analyses of faunal assemblages from Combe Grenal lead to different conclusions: Chase (1989) believes that Middle Paleolithic assemblages appear to be so similar to those of later Upper Paleolithic sites and that they indicate that similar hunting methods were used. Binford (1985), on the other hand, presents early Middle Paleolithic humans as obligate scavengers. However, the later Wurm II levels of Combe Grenal (in the Quina Mousterian sequence, layers 25-21) show a stronger representation of upper limb, meat-bearing bones than earlier levels. There seems to be a consensus between Chase and Binford that the exploitation of reindeer in these later Wurm II levels must have involved some component of systematic hunting (Binford 1985; Mellars 1989b).

A diachronic study of Neanderthal hunting activities at Grotta dei Moscerini and Grotta Guattari in west-central Italy suggests that there was a move from scavenging to hunting with the former dominating prior to 55 ka and the latter dominating thereafter (Stiner and Kuhn 1992; Stiner 1994). However, on further analysis of the remains from the five sites generally used to support the scavenging model (Klasies River Mouth, Combe Grenal, Grotta Guattari, Grotta dei Moscerini, and Grotte Vaufray), Marean concludes that the evidence offered to support scavenging is flawed. The long bones and other difficult to identify parts, typically used to indicate hunting access to prime parts, were often discarded during the course of excavation, and analysis of animal tooth marks did not distinguish whether these occurred before or after human consumption (Marean 1998). Some ethnographic studies show that modern hunter-

gatherers practice opportunistic scavenging: during 1985-1986 scavenging yielded 20% of all medium/large mammal carcasses acquired by the Hadza (O'Connell, Hawkes et al. 1988). There is no reason why prehistoric humans would not scavenge when the occasion arose.

The evidence from Iberia demonstrates no clear distinction between the Mousterian and Early Upper Paleolithic hunting methods. It indicates more generalized hunting in the Aurignacian with more specialized hunting (horse and rabbit at L'Abreda, rabbits at Gorham's cave) in the Gravettian, culminating in specialized technologies and hunting techniques typical of the Magdalenian - the fast, wary ibex was rarely hunted in Iberia during the Aurignacian and Gravettian, but became specialized prey later (Straus 1990). In Iberia, there is no evidence for extensive herd hunting of red deer, reindeer, ibex or horses in the Aurignacian/Gravettian and no evidence of exploitation of aquatic resources. Middle Paleolithic subsistence may have combined some scavenging with limited, encounter hunting of individual, relatively facile big game prey, while totally ignoring aquatic resources, except in Gibraltar. Straus concludes that Aurignacian and Gravettian subsistence probably lay somewhere between the opportunistic, low level strategies postulated for the Middle Paleolithic and the highly organized, elaborately technological, diversified, efficient strategies documented for the Magdalenian onwards. It is in this later period that certain technologies such as nets, traps, and weirs, which leave no tangible traces, may have been employed, judging from the consistent presence of burrowing animals, fish and birds in the faunal assemblages of the Solutrean – also the eyed needle, harpoon, leister and fish gorge appeared in Iberia at this late time. El Castillo appears to have been used

for short-term, sporadic stays by small groups during the summer and autumn and for larger aggregations during the spring. The faunal remains suggest year-round hunting by both Neanderthals and Upper Paleolithic humans with only minor changing seasonal patterns. Mousterians killed the majority of the animals in the late autumn to early spring but the modern humans did so from winter through spring, with prime aged animals dominating in both cases. None of the caves in the area show dramatic differences in subsistence practices between the Mousterian and the Upper Paleolithic (Cabrera, Pike-Tay et al. 2000).

Faunal data from the Middle and Upper Paleolithic sites on the Russian Plains indicate more opportunistic subsistence strategies during the Middle Paleolithic and a change over to foraging adaptations, which involved tracking resources over broader areas, and more seasonal mobility in the Upper Paleolithic (Soffer 1989a; Soffer 1994). On the Russian Plains, two contemporaneous Upper Paleolithic cultures show evidence of distinctly different food acquisition strategies: the Strelets culture appears more like the Middle Paleolithic model with local sourcing of tools, a greater diversity of harvested resources, and more opportunistic strategies, and the Spitsyn culture more closely represents the Upper Paleolithic model, with exotic flint from 150-300 km, reduction in diversity of harvested resources, and selective exploitation of locally abundant resources. Since both of these groups are attributed to the Upper Paleolithic, it suggests that any change from 'opportunistic' to 'specialized' hunting did not necessarily occur at the transition from Neanderthals to early Upper Paleolithic humans but more likely occurred at different times and places based on local ecological conditions (Mellars and Stringer 1989). Indeed, on the Russian steppes in the later

Upper Paleolithic, hunting practices are shown to have varied to suit the ecology - the steppes show evidence of two different hunting zones: the mammoth and the bison zones (Praslov, Stanko et al. 2000). Mammoth hunters to the north were more sedentary and congregated in large settlements such as at Kostenki, whereas to the south by the Black Sea the bison hunters were more mobile and adapted to the capture of more gregarious animals.

Predators may hunt opportunistically - hunting or scavenging prey on encounter, they may selectively hunt prey - chosen for their size, age, fat content or other desirable attributes, or they may selectively focus the hunt on a particular taxon - as with seasonally focused intercept hunting strategies. It appears that Middle Paleolithic hunters could choose at will from among these strategies, or they could combine them (Burke 2004b). Faunal evidence from El Castillo, Cueva Morín and El Pendo in Cantabria shows that Mousterians were able to exercise their preference for prime-aged animals (Pike-Tay, Cabrera Valdes et al. 1999). The faunal assemblages are representative of what was available for hunters in the local environment, depending on climatic conditions, the season of the hunt, and sometimes the requirement for animal tissues in a particular season, such as hides and pelts in the fall (Bar-Yosef 2004). If specialized assemblages are to be interpreted as a sign of hunting versus scavenging there seems to be little doubt that Neanderthals were successfully hunting medium-sized herding animals by the end of OIS 6: the dominant herbivore at Combe Grenal in the Riss II layers 23-27 is the reindeer (Chase 1989) – a pattern observed at both Middle and Upper Paleolithic sites.

Evidence from Middle Paleolithic sites from all over Europe indicate that Neanderthals were capable hunters, who not only concentrated on specific taxa but also sought prime aged animals, as at Salzgitter Lebenstadt, Mauran, Champlost, Coudoulous, La Borde, Wallerheim, and Il'skaya (Gaudzinski 2000; Gaudzinski and Roebroeks 2000). Although Middle Paleolithic sites with primarily monofaunal inventories, such as those listed below, are seen as supporting the case for the presence of specialized hunting (Chase 1989), the Saltzgitter Lebenstadt assemblages indicate that different hunting practices seem to have been practiced in the Middle Paleolithic, both specialized, long-term exploitation of prime adult prey and unselective short-term exploitation of only high quality nutritional resources (Gaudzinski 2000). Spiess (1979) shows that the evidence from the early Upper Paleolithic levels at Abri Pataud suggests that, although reindeer are the predominant species, the emphasis was on prime-aged animals and that mass driving was not taking place. It appears that the specialized drive was one food acquisition strategy used by both Neanderthals and modern humans, as illustrated in Table 4-3.

Table 4-3 Specialized Hunting Sites as defined by Dominant Species in Faunal Assemblages.

Site	Period	Location	Dominant Species	%	Source
Combe Grenal	Middle Paleolithic	Perigord	Red deer	70-80	(Chase 1989)
Combe-Grenal	Middle Paleolithic	Perigord	Reindeer	92-97	(Chase 1989)
Coudoulous	Middle Paleolithic		Bison	98	(Gamble 1999)
Il'skaya	Middle Paleolithic	Crimea	Bison	70	(Kozlowski 1990)
					(Hoffecker and Cleghorn 2000)
L'Hortus	Middle Paleolithic	France	Ibex	dominant	(Chase 1989)
La Borde	Middle Paleolithic	France	Auroch	93	(Gamble 1999)
La Cotte St-Brelade	Middle Paleolithic	Jersey	Mammoth rhinoceros	100	(Scott 1980)
La Quina	Middle Paleolithic	Charente	Bison, horse, reindeer	dominant	(Jelinek, Debenath et al. 1989)
Mauran	Middle Paleolithic	Pyrenees	Bison	100	(Farizy, David et al. 1994)
Prolom 2	Middle Paleolithic		Saiga tartarica	53.5	(Kozlowski 1990)
Repolust Cave	Middle Paleolithic	Austria	Ibex	dominant	(Chase 1989)
Saltzgirter	Middle Paleolithic	Germany	Reindeer	dominant	
Lebenstadt					
Shanidar	Middle Paleolithic	Kurdistan	Wild goat	75.1	(Rolland 1990)3
Starosel'e	Middle Paleolithic	Russia	Equus	90	(Kozlowski 1990)
Sukhaya	Middle Paleolithic	Russia	Bison	78	(Kozlowski 1990)
Metchetka					
Volgograd	Middle Paleolithic	Russia	Bison	78	(Chase 1989)
Abri Pataud	Upper Paleolithic	Perigord	Reindeer	98	(Chase 1989)
La Gravette,	Upper Paleolithic	Perigord	Reindeer	98	(Chase 1989)
Le Piage	Upper Paleolithic	Perigord	Reindeer	98	(Chase 1989)
Roc de Combe	Upper Paleolithic	Perigord	Reindeer	98	(Chase 1989)

Specialized hunting, focused on one or a few species, appears to have been quite frequent in Western Europe and the Central European Plains from OIS 7 onwards (Patou-Mathis 2000). Single-taxon dominated assemblages occur 61.5% of the time and overall between 70-80% of the sites contain three dominant species. These are mainly large, gregarious, and migratory; horse, mammoth, red deer, bison, ibex, Merck's rhinoceros and reindeer, depending on the ecology. It should be stressed that specialized hunting was not the sole mode of acquisition throughout the Middle to

Upper Paleolithic. Even in the Upper Paleolithic there are several examples of diverse assemblages, as at Isturitz, and La Ferrassie (Chase 1989).

Specialized hunting implies that humans selected specific animals from among a broader array of potential prey, yet the data on faunal suite and seasonality at many of these sites is not sufficient to indicate that a broader range of species was available (Grayson and Delpech 2002). Assemblages overwhelmingly dominated by a single species result from strategies, which may have been specialized only when the site was used, (i.e. at the time of resource procurement). The dominance of one species, such as bison at Mauran, indicates only that that species was taken at that location at that specific time. It tells us little about the overall annual strategy (Boyle 2000). Indeed, in areas of great seasonal fluctuation in the availability of key resources, there would be a narrowing of the resources base and concentration on one or two species. In regions with less seasonal variation but greater spatial differentiation in both the amount and kinds of foods, on the other hand, assemblages would appear to indicate an expansion of the resource base and broad spectrum feeding (Mellars 1996). Also, low-diversity indices in faunal assemblages in northern latitudes tend to reflect cold-season occupations, while high ones are symptomatic of occupations during warm seasons (Soffer 1989a).

The record indicates that there was not a clear distinction between Neanderthal and Upper Paleolithic foraging strategies. Strategies appear to have been dependent on ecological context for both groups. Many archaeologists consider that the major distinction between the Middle and Upper Paleolithic is the way that Neanderthals organized their food acquisition strategies, rather than any move from scavenging to

hunting and to more specialized hunting. Modern hunter-gatherers exploit their natural settings by operating out of camps, using home bases and special extraction sites: “cultural geography” (Binford 1987). Neanderthal behavior appears to be different; primarily based on mobility determined by resource availability and moving to places in the environment where they may obtain the resources they need (Lieberman and Shea 1994): “niche geography” (Binford 1987).

Migrating species were hunted seasonally, and Neanderthals sometimes set up their camps on the migration routes of these animals (Patou-Mathis 2000). Specifically, when seen in regional context, Middle Paleolithic sites do not show evidence for specialization in procurement but rather repeated visits to locations with a specific abundant resource; a pattern of foraging amply documented for a number of nonhuman primates (Soffer 1994). The lifestyle of pursuing migratory game is supported by analysis of sites in Germany that shows that, nowhere in the Rhineland, are sites indicative of long-term occupation. Compelling evidence for long-term occupations in Germany does not appear until the Magdalenian (Conard and Prindiville 2000). Studies of faunal assemblages in the Caucasus indicate that Neanderthals followed a seasonal strategy of hunting large bison and other ungulates at low altitude locations such as Il'skaya and Barakaevskaya Cave, and goat, sheep and bison at the higher locations of Mezmaiskaya Cave (Hoffecker and Cleghorn 2000). A similar pattern is observed in Mousterian Iberia, where Ermitons and 120 Cave are located in ecosystems where mountainous resources such as goat predominate, as opposed to Abri Rominí, and Roca dels Bous, which are located in strategic natural passages for migrating herds (Vaquero and Carbonell 2000). In Upper Paleolithic Cantabria there is evidence of a

move to a cultural-geography behavior with a large multi-purpose base camp at El Castillo and the appearance of special task camps, for ibex hunting, situated in rocky areas, as are the sites of Lezetxiki or El Conde (Pike-Tay, Cabrera Valdes et al. 1999). This lends support to the hypothesis that Neanderthals had greater residential mobility. A common feature of many Middle Paleolithic sites is the prevalence of repeated, short-term occupations by a variety of carnivores, including humans. The existence of 'swing shifts' of carnivores and humans at cave sites is fairly common and appears to be a very real distinction between site-use patterns of the Middle and Upper Paleolithic (Gamble 1986). These changes in behavior are not only reflected in hunting but also in settlement patterns. The absence of solid evidence for home bases and dwelling structures supports this view and is further explored in the camp maintenance section.

- **Hunting Technology**

The use of technology-assisted hunting in the Middle Paleolithic has implications for the hunting/scavenging debate. Implements from Clacton and Lehringen have been construed as artifactual evidence of hunting (Shea 1988), or merely as probes and digging tools for scavenging carcasses buried in the snow (Gamble 1986). It is proposed that more recent finds at Schöningen of 400 ka, two-meter long throwing spears, together with a throwing stick sharpened at both ends, provide evidence of systematic hunting and foresight in use of technology. These spears were made from 30 year-old spruce trees, have their maximum thickness at the front end with a tapered tail, and a center of gravity a third of the way from the sharp end - resembling a modern javelin. These spears may have been projectiles rather than thrusting spears or lances (Dennell 1997; Thieme 1997). A test reconstruction has

demonstrated a range of up to 60 m with good penetrating power, and Thieme (2005) believes that these were used to hunt very mobile and fast horse from a distance. Others suggest that spears are used differently depending on the environment: thrown short distances in open habitats and thrust downwards in dense bush and forest habitats (Kortlandt 2002).

For the Efe, thrusting is preferred over throwing if the prey is dangerous. Thrusting provides greater accuracy, and it may take multiple penetrating stabs to disable a large animal. The safety of the hunter would be maximized when he can deliver numerous stabs in rapid succession without releasing the weapon (Churchill 2002). Throwing capacity is disputed by experimental studies that indicate that Schöningen spears were too heavy to be thrown any distance and were solely used for thrusting downward (Shea 2003). The Schöningen, Lehringen and Clacton spears are relatively thick compared to ethnographically known thrusting spears. Smith, Churchill and associates (2003) examined fossil spears from Lehringen and Schöningen spears as well as modern thrusting, and throwing spears, and modern digging sticks, and measured length, thickness and maximum diameter. They determined that the fossil spears fall between ethnographically known thrusting spears and digging sticks, based on comparison of the thickness index ($100 \times \text{maximum diameter relative} / \text{spear length}$). The great length and width of the fossil spears suggests that they would have been heavy relative even to modern thrusting spears, and easily four to five times the weight of modern throwing spears.

However, there may be evidence for the Neanderthals' use of ballistic weapons at least in the Levant. A Mousterian point found embedded in the cervical vertebrae of

a wild ass suggests that late Neanderthals in Syria, at least at 50 ka, were using hafted projectiles for killing game (Boeda, Geneste et al. 1999). The amount of kinetic energy necessary to penetrate and damage the bone and the parabolic trajectory suggests a ballistic projectile with a hafted point solidly affixed with an adhesive such as bitumen. Interpretations of micro wear analysis of hafted, projectile spear points from Kebara indicate a continuity between the weaponry of late Neanderthal, Middle Paleolithic occupations of Kebara and similarly-damaged artifacts from the early modern human occupations at Qafzeh cave (Shea 1988). But there are cautions about generalizing from these examples since micro wear analysis indicates that these points showed wear on the sides as well as the points and could also have been used as cutting implements (Solecki 1992). In France, there is no evidence for the uses of stone projectiles from micro wear analysis of samples of major retouched stone tool types of the earlier Mousterian of Acheulean Tradition (MTA) tradition in Perigord. The oldest stone tools from that region, with micro wear traces demonstrating their use as projectile armatures, are certain Gravette points and backed bladelets from the Upper Perigordian site at Le Flageolet (Anderson-Gerfaud 1990).

Morphological comparisons may assist in the interpretation of how these weapons were used. The first observation when comparing the Neanderthal upper limb with those of all modern humans is that there is a decrease in muscularity and hence robusticity in modern humans. The decrease in muscularity of the upper limb is evident in the insertions on the arm and hand skeleton, especially those of the pectoralis major, the pronator quadratus muscle on the distal ulna, the opponens muscles on the first and fifth metacarpals and the extrinsic muscles on the distal phalanges (Trinkaus 1983).

Comparisons between Neanderthals and modern human postcranial anatomy focus on Western European Neanderthals (St. Césaire), Middle Eastern Neanderthals (Amud and Tabun), early anatomically modern humans (Qafzeh and Skhul), and European Upper Paleolithic remains from both pre-glacial maximum (Aurignacian, Gravettian), postglacial maximum (Magdalenian, Epi-Gravettian), and recent humans. The humerus in both West European and Middle Eastern Neanderthals shows impressive development for the crests for the insertion of deltoid and pectoralis major reflecting the strength of these muscles. The humeral shaft is flat mediolaterally and also very robust compared to modern humans, both in external measurement and in extreme cortical thickness. Differences in stress on the post cranial skeleton resulting from behavioral differences would be expected to be more emphasized in bone mass (cortical thickness) than in external bone measurements suggesting that male Neanderthals may have engaged in activities such as spear throwing or maybe thrusting that involved the use of considerable right arm strength. A distinct difference in humeral cortical thickness between males and females suggests marked differences in upper limb muscle mass between Neanderthals and modern humans. An increased degree of dimorphism in this feature is not observed in other areas of the Neanderthal post crania (Ben-Itzhak, Smith et al. 1988). The Neanderthal scapula supports well-developed musculature to counteract the equally well-developed adductors of the humerus (Trinkaus 1977). Reduction in scapular musculature and changes in the articular orientation of the elbow in modern humans imply a shift in the average habitual peak-loaded position from a more flexed one to a more extended one (Trinkaus 1983). The implied increase in strength at the Neanderthal shoulder, without any associated loss of manipulative

precision, would be consistent with the manufacture of Mousterian assemblages and the subsistence pattern associated with the Middle Paleolithic. The patterns characteristic of early modern humans indicate a steady decrease in biomechanical stress at the shoulder in agreement with corresponding increases in the level of culturally adaptive efficiency during the Upper Paleolithic (Trinkaus 1977).

Morphological examination of the upper limb in both Neanderthals and Upper Paleolithic may be linked to bimanual spear thrusting (Schmitt, Churchill et al. 2003). A right-dominant pattern of strength asymmetry indicates that Eurasian Neanderthals and early Upper Paleolithic hunters may have relied heavily on thrusting spears and close-range hunting. The authors believe that the stimulus caused by the use of the thrusting spear is the principal cause of this asymmetry and conclude that long-range projectile weaponry did not become a regular part of human predatory methods until the Late Upper Paleolithic (Solutrean), coincident with the first appearance of spear-throwers in the archeological record (Schmitt, Churchill et al. 2003). The importance of projectile velocity places a premium on speed leverage. More linear humans would have an advantage because of their ability to exploit the projectile (Brues 1959).

Evidence of a healed fracture in the skull of a Saint Césaire man resulting from the impact of a sharp instrument also suggests that Neanderthals were able to conceive of tools as weapons in interpersonal conflict (Zollikofer, Ponce de Leon et al. 2002). Upper arm muscular hypertrophy and strength is suggestive of up-close hunting or combat strategies as well as dimorphism, which might imply mating, sharing and division of labor strategies appropriate to more dimorphic species. Head and neck injuries are found on all reasonably complete Neanderthal skeletons over the age of 25

years (Berger and Trinkaus 1995), most of the injuries are in males. This is a level of trauma similar to that observed in modern rodeo riders. This suggests close-quarter predation or interpersonal aggression amongst robust males and maybe some level of sexual division of labor. However, it is shown that degenerative joint disease in the spine, shoulder, elbow, hip and knee is much higher in humans than in chimpanzees and bonobos, and this is probably due to the fact that humans are more involved with the peripheral joints as a consequence of biomechanical adaptations to bipedal locomotion (Jurmain 2000).

With the advent of the Upper Paleolithic, the archaeological evidence suggests changes in food acquisition weaponry occurred at this time. Split based and beveled bone projectile points of the Aurignacian (and the later the finely retouched Gravettian lithic points) are clearly distinguished from those of the Lower and Middle Paleolithic by their weight and dimensions, both of which were more appropriate for a weapon such as sagaies, spears or javelins, that were thrown or projected (Rigaud 1989b). By Gravettian times, for groups that became dependent on reindeer for both food and clothing, cooperative hunting and lane drives were probably a key fall strategy as is depicted in later Magdalenian cave art at Lascaux and Altamira (Kehoe 1990)

Other tools were developed to be used in the food quest at this time. The Aurignacian levels at Abri Pataud, a late fall, winter and early spring site, indicate that medium to large animals were caught in small numbers with the use of the thrusting spear and or pits or snares (Spiess 1979). The remains of salmon found at Abri Pataud suggest that early arriving occupants would have made the catch during the salmon run early in the fall. Analysis of Gravettian clay figurines from Pavlov I and Dolní

Věstonice dated to 27-24 ka show impressions of woven fabrics (Adovasio, Soffer et al. 1996; Pringle 1997) and in particular, impressions of cordage and weaver's knots, typically used to make nets. With a mesh diameter of 4 mm, such nets would have been quite effective for capturing fox, hare and other small animals whose remains are found in abundance in sites in the area, such as Mezin, Avdeevo, and Kostenki XIV (Klein 1973; Soffer 1985b; Hoffecker 1999). Soffer suggests that communal net hunting, such as practiced by the Mbuti, would have provided food resources at a low risk of injury. The remains of willow ptarmigan, grouse, teal and goose were found at a number of sites on the Russian plains, which probably represent the food debris of the Gravettians, although it is possible that some may have been deposited by predatory birds (Klein 1973). The bow was invented and brought into use on the Russian steppes between 30 and 25 ka (Praslov, Stanko et al. 2000) permitting access to fast running or flying species.

This suggests that Neanderthals encountered more opposition when hunting or scavenging but, by the Middle Upper Paleolithic, modern humans were able to avoid such close encounter conflict by using different hunting technologies, and, additionally, that modern humans were capturing fur bearing animals for clothing manufacture. But in terms of hunting effectiveness, a recent analysis of hunting returns in the southern Caucasus indicates little difference between food acquisition activities of Neanderthals and modern humans despite the technological differences (Adler, Bar-Oz et al. 2006). End-scrapers and, most likely wooden weapons, possibly tipped with stone, comprised the Neanderthal hunting tool kit, while the Upper Paleolithic kit included composite tools with microlith or bone/antler tips. The authors conclude that different human

populations were able to achieve similar returns with quite different technologies. (I do not distinguish return rates between Neanderthals and modern humans in my earlier calculations of food acquisition activity time – Table 4-1.)

iii. Summary of Food Acquisition Activities and Tasks

The isotopic and faunal data suggests that hunting versus scavenging is not one of the key distinguishing adaptations between Neanderthals and modern humans (Marean and Assefa 1999): the distinction between Middle and Upper Paleolithic food acquisition strategies is less one of hunting versus scavenging, and more one of dietary breadth and mobility. The artifactual and morphological data indicates that technology may have provided for less confrontational approaches to a broader range of prey through projectile weaponry, tended and untended traps, and snares. Table 4-4 lists the activities times and specific tasks in the food acquisition task repertoire.

Table 4-4 Food Acquisition Activities and Tasks

Activities, Task and Reference		Early Neanderthal	Late Neanderthal	Early Upper Paleolithic	Middle Upper Paleolithic
1. Food Acquisition Activities					
Men (mins)	(Table 4-2)	395	395	321	321
Women (mins)	(Table 4-2)	35	35	29	29
2. Food Acquisition Tasks					
Scavenging	(a,b)	Yes	Yes	Yes	Yes
Close-encounter opportunistic hunting with thrusting wooden spear of medium to large animals	(b, c)	Yes	Yes	Yes	Maybe
Specialized drive-hunting	(b)	Yes	Yes	Yes	Yes
Opportunistic hunting with tip-hafted thrown projectile spear	(d, e, f)		Maybe	Yes	Yes
Net Hunting	(g)				Yes
Fishing	(h, i, j, l)		-	Yes	Yes
Collecting mollusk and shellfish	(p)		Maybe	Yes	Yes
Birding	(k, l)			Yes	Yes
Hunting with tended facilities	(m)			Yes	Yes
Hunting with untended facilities	(m)				Yes
Gathering plant foods	(n, o)	Yes	Yes	Yes	Yes
Total Food Acquisition Tasks		4	5	9	11

References from Text in Support of Table 4-4

- a. Some ethnographic studies show that modern hunter-gatherers practice *opportunistic* scavenging - during 1985-1986, scavenging yielded 20% of all medium/large mammal carcasses acquired by the Hadza (O'Connell, Hawkes et al. 1988).
- b. Predators may hunt opportunistically, i.e. they may hunt prey as they encounter prey, they may selectively hunt prey chosen for their size, age, fat content or other desirable attributes, or they may selectively focus the hunt on a particular taxon (as with seasonally focused intercept hunting strategies). It appears that Middle Paleolithic hunters could choose at will from among these strategies, or they could combine them (Burke 2004b). See Table
- c. These spears may have been projectiles rather than thrusting spears or lances (Dennell 1997; Thieme 1997).
- d. In France, there is no evidence for the use of stone projectiles from micro wear analysis of samples of major retouched stone tool types of the earlier MTA tradition in Perigord. The oldest stone tools from that region, with micro wear traces demonstrating their use as projectile armatures, are certain Gravette points and backed bladelets from the Upper Perigordian site at Le Flageolet (Anderson-Gerfaud 1990).
- e. Split based and beveled bone projectile points of the Aurignacian (and the later the finely retouched Gravettian lithic points) are clearly distinguished from those of the Lower and Middle Paleolithic by their weight and dimensions, both of which were more appropriate for a weapon such as sagaies, spears or javelins, that were thrown or projected (Rigaud 1989b).
- f. The bow was invented and brought into use on the Russian steppes between 30 and 25 ka B permitting access to fast running or flying species (Praslov, Stanko et al. 2000).
- g. Analysis of Gravettian clay figurines from Pavlov I and Dolní Věstonice dated to 27-24 ka show impressions of woven fabrics (Adovasio, Soffer et al. 1996; Pringle 1997) and in particular, impressions of cordage and weaver's knots, typically used to make nets
- h. At least in central European Neanderthal sites there is an absence of bones of fish and birds as well as grinding stones for plant food (Hockett and Haws 2005).
- i. Analyses of Gravettian specimens from Brno-Fancouzská and Dolní Věstonice in the Czech Republic, Kostenki, Mal'ta in Russia, and Paviland in Wales, all dated to between 28-20 ka BP, suggests that by the Gravettian period there was a relatively heavy reliance on fresh aquatic food, as much as 50% in the Kostenki sample (Richards, Pettitt et al. 2001).
- j. Neanderthals were top-level carnivores, who consumed primarily large and medium sized terrestrial herbivores, whereas the modern human specimen reveal an omnivorous diet that also included significant quantities of fish or shellfish (Hockett and Haws 2003).
- k. Further indications of broadening of dietary breadth with the earliest modern humans to include avian species from aquatic, roosting and raptorial birds are found in the Aurignacian levels of El Castillo (Straus 1990): 287.
- l. Evidence of waterfowl and freshwater fish exploitation during the Gravettian appears at Brillenhöhle, Höhle Fels and Geissenklösterle (Hahn 1987).
- m. The Aurignacian levels at Abri Pataud indicate that medium to large animals were caught in small numbers with the use of the thrusting spear and or pits or snares (Spiess 1979).
- n. The adolescent boy and girl from Sunghir' showed signs of protein deficiency and stress; they consumed a low proportion of meat, a large proportion of plants, and a very high proportion of invertebrates (Dobrovolskaya 2005).
- o. Although isotope analysis indicates that vegetal matter may have contributed a significant portion of the diet in certain circumstances (Dobrovolskaya 2005), the archaeological record does not preserve such remains except through indirect evidence such as the grinding stones and rounded granite stones resembling pestles found at Kostenki 4 layer 9 and Molodova V (32-15 ka BP) (Dolukhanov 1982). Absence of such items in the Middle Paleolithic does not necessarily indicate a lack of plant matter in the diet of the period (Farizy and David 1989).
- p. Analyses of Gravettian specimens from Brno-Fancouzská and Dolní Věstonice in the Czech Republic, Kostenki and Mal'ta in Russia, and Paviland in Wales, all dated to between 28-20 ka, suggests that by the Gravettian period there was a relatively heavy reliance on fresh aquatic food; as much as 50% in the Kostenki sample (Richards, Pettitt et al. 2001). There is some evidence of mollusk exploitation by later Neanderthals in Gibraltar (Barton 2000), but it is not clear what portion of the diet it represents.

4.2 Food Preparation

i. Food Preparation Activities

There is little in the archaeological record that informs us about food preparation activities, except for the contents of the diet. Isotopic analyses (Bocherens, Billiou et al. 1999; Richards, Pettitt et al. 2000; Bocherens, Billiou et al. 2001) and evidence from faunal assemblages (Hockett and Haws 2003; Stewart 2004) show that the diet of both Neanderthals and modern humans was principally a diet of animal foods with at most a minor contribution from plant food (Drucker and Bocherens 2004; Dobrovolskaya 2005), although later, modern humans broadened this diet to include fish and avian species (Richards, Pettitt et al. 2001). Dietary requirements call for a balance of carbohydrates and protein (Speth and Spielman 1983; Cachel 1997). Too much protein in the diet is toxic, particularly for females and must be offset by carbohydrates. Calcuria, which results from a high protein intake, would have been less biologically tolerable by large-boned Neanderthals than by the more gracile, modern humans (Cachel 1997). But dietary carbohydrates are rare or seasonally nonexistent in high latitude environments, and humans are forced to counter the effects of maximal protein ingestion with fat. Whereas, in tropical zones plant resources preferentially supply these carbohydrates (Speth and Spielman 1983), in high latitudes fattened prey supply the necessary balance in the fall. In the spring, when the animals are lean and offer little fat muscle, one source of carbohydrate is the soft tissues of the head and neck that are the last to be depleted in animals since they are essential to sustaining life. Assemblages of spring-harvested head bones at Grotta dei Moscerini (Stiner 1994) suggest that

Neanderthals were seeking fat rich foods to supplement their lack of carbohydrates in the springtime, and probably at other times of scarcity.

The ethnographic record shows that the preparation of meat for consumption is a speedy and therefore minor task (Chapter 3.). Thus, one would expect that the amount of time spent in food preparation activities by all prehistoric humans of this period would be closer to the Inuit rather than that of the Efe and Machiguenga, based on the heavy meat diet; less effort would be spent in time-consuming preparation of plant foods as reflected in Table 4-5.

Table 4-5 Time Allocated to Food Preparation Activities

	Efe	Machiguenga	High latitude	All prehistoric humans
Men (mins)	23	18	9	9
Women (mins)	182	141	71	71

Food preparation time for all prehistoric groups is based equivalent to that projected for the high latitude groups in Table 3.7, Chapter 3.

ii. Food Preparation Tasks

Direct or indirect evidence of food preparation tasks is scant. Evidence of cooking remains is rare for Neanderthals, with only indirect evidence of cooking or smoking meat at Beauvais (Patou-Mathis 2000). Processing options available to Neanderthals seem to have been limited. There is a paucity of evidence of objects for grinding, pounding of animal and plant foods in the Mousterian, and cracked stones, associated with stone boiling, appear only in the Upper Paleolithic (Stiner 1994). Food preparation artifacts such as grindstones, mulling stones, mortars and pestles appear rarely in Mousterian sites, more frequently in Aurignacian sites, and most frequently in Gravettian ones. This suggests these technologies were sporadically present, if poorly developed, as early as the late Middle Paleolithic but were more intensively developed and utilized in the Upper Paleolithic (de Beaune 1993). Large Mousterian grindstones

were found at Cueva del Castillo and Cueva Morín, and a small cobble was found at Petit Abri de Laussel, but these forms are not consistently present until the Chatelperronian (Grotte du Renne, and Pair-non-Pair). Moreover, it is unclear for what purpose these implements were used; micro wear analysis of grinding stones from Barakaevskaia Cave in the Caucasus indicates that they were used for grinding pigment and not vegetal matter (Hoffecker 2002).

Major food preparation tasks for Neanderthals would have included cutting of meat with stone tools and splitting of bone to extract marrow with cobbles. There is little credible evidence for grinding, pounding, or cooking and smoking to preserve foodstuffs. Mastication may have played a part in food preparation: Neanderthal facial morphology has implications for the biomechanics of their masticatory system, and the attrition of their anterior teeth is related to consistent use in paramasticatory behaviors, such as mastication of food for infants, tool making, or leather preparation (Antón 1996).

Modern humans would have a more varied list of food preparation tasks to accommodate the greater variety of food sources sought - animal meat, fish, fowl, and plant foods. Aurignacian grindstones, grinders and mulling stones and pestles are found in Asturias at El Forno, in southwest France at Abri Blanchard, La Ferrassie, Roc de Combe-Capelle, Grotte de Saint-Jean-de-Verges, Grotte de la Font-Robert, Les Cottès, and in Italy at Grotte des Enfants. Gravettian ones have been found in southwest France at Pair-non-Pair, Grotte de Fontenioux, Isturitz, Laugerie-Haute, Laussel, Abri Pataud, Abri de Fongal, Grotte de l'Observatoire, Grotte Lacoste and Cirque de La Patrie, Seine et Marne, and in the Ukraine at Molodova I (Beaune 1993). Artifacts found in the

Russian Plains point to intensification in the use of plant materials during the course of the Upper Paleolithic, at least in the southern areas (Borziyak 1993): anvils serving as working surfaces for marrow extraction and the husking of mollusks, grain or seed, grinders and pestles used for pulverizing grains as well as for processing wild fruits, roots, and fibrous parts of plants. Upper Paleolithic technologies may have permitted access to new carbohydrate resources such as nuts and grains. Plant oils extracted from these resources may have reduced the need for dietary animal fat to balance carbohydrate deficiency in a high protein diet (Cachel 1997).

The higher intensity fire, possible in the more complex hearths of the Upper Paleolithic, suggests that cooking, and maybe smoking of food, was practiced more widely (Beaune 1993). Storage pits indicate that food may have been stored in a frozen state (Soffer 1989b; Hoffecker 2002). Heat-cracked stone, interpreted as mulling stones, are taken as indications that modern humans were boiling bones to extract grease and marrow or to defrost frozen supplies. Boiling has the advantage over splitting bone for marrow, since it can be an untended activity that takes place while other activities, such as hide working or childcare, are being pursued – an opportunity for multitasking. These activities and tasks are listed and summarized in Table 4-6.

Table 4-6 Food Preparation Activities and Tasks

	Early Neanderthal	Late Neanderthal	Early Upper Paleolithic	Middle Upper Paleolithic
1. Time allocated to Food Preparation				
Activities				
Men (mins)	9	9	9	9
Women (mins)	71	71	71	71
2. Food Preparation Tasks				
Cutting meat from bone	Yes	Yes	Yes	Yes
Cracking bone	Yes	Yes	Yes	Yes
Mastication (a)	Yes	Yes	No	No
Grinding and pounding plant foods (b)	No	No	Yes	Yes
Untended cooking or smoking (c)	No	No	Yes	Yes
Total Food Preparation Tasks	3	3	4	4

References from Text to Support Table 4-6

- the attrition of their anterior teeth is related to consistent use in paramasticatory behaviors, such as mastication of food for infants, tool making, or leather preparation (Antón 1996).
- Aurignacian grindstones, grinders and mulling stones and pestles are found in Asturias at El Forno, in southwest France at Abri Blanchard, La Ferrassie, Roc de Combe-Capelle, Grotte de Saint-Jean-de-Verges, Grotte de la Font-Robert, Les Cottès, and in Italy at Grotte des Enfants. Gravettian ones have been found in southwest France at Pair-non-Pair, Grotte de Fontenioux, Isturitz, Laugerie-Haute, Laussel, Abri Pataud, Abri de Fongal, Grotte de l'Observatoire, Grotte Lacoste and Cirque de La Patrie, Seine et Marne, and in the Ukraine at Molodova I (Beaune 1993). Artifacts found in the Russian Plains point to intensification in the use of plant materials during the course of the Upper Paleolithic, at least in the southern areas (Borziyak 1993): anvils serving as working surfaces for marrow extraction and the husking of mollusks, grain or seed, grinders and pestles used for pulverizing grains as well as for processing wild fruits, roots, and fibrous parts of plants.
- The higher intensity fire, possible in the more complex hearths of the Upper Paleolithic, suggests that cooking, and maybe smoking of food, was practiced more widely (Beaune 1993).

4.3 Childcare Activities and Tasks

The amount of time devoted to active childcare is small in current hunter-gatherer communities, and I hesitate to draw any distinctions between Neanderthals and modern humans in terms of their dedication to these activities.

There are suggestions that Neanderthal pubic morphology permitted the infant to develop *in utero* for as long as twelve months, that Neanderthal infants were born in a less altricial condition than modern humans, and thus would have demanded less parental support (Trinkaus 1984). Neanderthal pubic bones from Amud, Krapina,

Shanidar and Tabun are mediolaterally elongated, whereas early modern human pubic morphology is indistinguishable from current day pelves. Trinkaus argues that modern human neonates are unusually altricial and their gestation period ought to last longer than nine months, since mammals with similar brain volumes have gestation periods of between twelve to fourteen months. He suggests that Neanderthal pubic morphology would have permitted Neanderthals to carry their young for the full gestation period and thus deliver a more adaptive neonate, perhaps demanding less childcare. However, Rosenberg suggests that the pubis was large simply because Neanderthal babies were large. Neanderthal females were robust and heavy relative to their stature, and in recent humans maternal weight is an important factor of birth weight (Rosenberg 1998).

Analysis of dental growth from the remains from the Devil's Tower Neanderthal three-year old suggests that Neanderthals may have been specialized in such a manner to achieve rapid brain growth before birth, resulting in the need for a larger pelvic outlet (Dean, Stringer et al. 1986). Comparisons of dental enamel growth rates in early *Homo*, the Tabun Neanderthal, and *Homo sapiens* shows that enamel formation time was significantly less in early *Homo*, and that the Neanderthal specimen showed development rates within but at the lower end of the *Homo sapiens* range (Dean, Leakey et al. 2001). Furthermore, examination of the dental records of *Homo antecessor*, *Homo heidelbergensis*, *Homo neanderthalis*, and *Homo sapiens* indicates that Neanderthals had the shortest period of dental growth of all specimens examined (Ramirez Rozzi and Bermudez de Castro 2004). The authors conclude that Neanderthals were adapted to particular environmental conditions, where a high-calorie

diet and a high metabolic rate were able to fuel a fast somatic growth and a large brain. Young Neanderthals had faster developmental rates during their early years and thus would become independent of their parents at an earlier age. The survival value of reducing the growth period by reaching adult robustness and muscularity as early as possible would have been significant as a adaptation in the cold late Pleistocene period, especially when no other cultural buffering against the environment was available (Brothwell 1975). Upper Paleolithic peoples, on the other hand, would have had to provide similar parental support as today's parents, but possessed the cultural buffering tools to do so and, consequently, to provide their offspring the opportunity to learn from cultural and environmental stimuli.

However, there are cautions about relating mandibular growth rates to overall development rates. Neanderthal mandibular features grow at a faster rate than those of modern humans, but this may be the result of Neanderthal adult morphology (Williams and Krovitz 2004). Indeed, Neanderthal craniofacial morphology, and the growth processes that shaped it, differ from that of modern humans at every age (Krovitz 2003). By reconstructing the pattern of growth and development of Neanderthals using information from two developmental systems, the relation of dental maturation to actual age as determined by postcranial femoral growth, Thompson and Nelson (2000) conclude that, while elements of the Neanderthal dentition are advanced relative to some modern human populations, they may not be as advanced relative to other populations. Examination of growth in the femur indicates that an alternative explanation is that Neanderthals were characterized by a pattern of delayed linear growth relative to the modern human samples examined in the study. The Neanderthal

growth trajectory is consistent with either slow linear growth or advanced dental development.

Some of this might suggest that modern humans would have to spend more time than their Neanderthal counterparts in childcare for each individual infant. However, although the Neanderthal pattern of growth and development seems to be different from that of modern humans, Neanderthals do possess the same five stages of growth as do extant humans, i.e. infancy, childhood, juvenile, adolescence, and adulthood (Nelson, Thompson et al. 2003a). Secondary altriciality is a significant component of infancy and a period of dependency on childcare. It is not clear when secondary altriciality developed in the *Homo* lineage: some believe as early as *Homo habilis* and others argue that it did not appear until *Homo neanderthalis* (Nelson, Thompson et al. 2003b). In either case, there may not have been a significant difference in childcare responsibilities between Neanderthals and early modern humans. In addition, without any indications of inter-birth intervals and rates of fertility it is impossible to calculate the average time spent in this activity over time. In current hunter-gatherers, this activity consumes such a relatively small part of the daily time allocation and it should not significantly alter the results of my study. Table 4-7, therefore, shows the same allocation of time for all group and active childcare and inactive supervision tasks (Bailey and Peacock 1989).

Table 4-7 Childcare Activities and Tasks

Childcare Activities and Tasks	Efe	Machiguenga	High latitude *	All prehistoric humans *
1. Childcare Activities				
Men (mins)	5	3	4	4
Women (mins)	94	63	79	79
2. Childcare Tasks				
Active childcare	1	1	1	1
Indirect supervision	1	1	1	1
Total	2	2	2	2

* Childcare activities are estimated at the average of the Efe and Machiguenga.

4.4 Tool Making Activities and Tasks

The ethnographic record shows that indirect activities such as tool making, clothing manufacture, and shelter construction become more critical and more numerous in high-latitude environments. The use of skin and woven clothing, artificial living structures, and above all, abundance and reliable fuel supplies for camp fires may have been the most critical factors, since the effects of reduced temperatures may have virtually eliminated significant plant growth over large areas of the continent, at least seasonally (van Andel and Tzedakis 1996; Mellars 1998). Here, I am interested in identifying the various tool forms, their components and usage, each of which offer the potential for specialization. In addition, their function, to the extent that it is discernable, may indicate the breadth of tasks executed by the makers of those tools or their associates.

Although attempts to classify Mousterian stone tool assemblages have provided useful information on changes in frequency of various tool types during successive ecological cycles, they give us little insight into functional usage. François Bordes identified four Mousterian variants: Typical, Denticulate, Charentian, and MTA (Bordes 1961; Bordes and de Sonneville-Bordes 1970). Bordes himself considered his type-list as a systematic means for organizing data for further analysis, and not as an end in itself (Bisson 2000). The critics of Bordes' typology argue that Bordes assumed that there was a preconceived format for each of the tools types, yet in many cases retouch and reduction may act to blend the many types described by Bordes into a series of stages in the reduction process resulting from use, wear, and retouching (Rolland and Dibble 1990). Thus, the many types of side-scrapers may represent one tool type in various

stages of repair through reduction. A blank flake made for one use, may be modified for a second use, and later retouched for a third task (Frison 1968). Furthermore, as good material becomes scarcer, through distance or exhaustion of supplies, the parsimonious use and reuse of that material increases accordingly. Rolland and Dibble (1990) suggest also that the factors underlying variations in assemblages include the differences between open air sites, rock shelter or cave sites on the one hand, and rock size and scarcity on the other, which affect the intensity of use, retouch and differential attrition rates; all of which might impact the shape of racloirs more than denticulates. Rolland and Dibble reduce the typology to two extreme assemblage types. In one, good-quality local material is large-sized and abundant, and there is little need for reworking tools; these assemblages contain large cores and bifaces, with few retouched single-edged racloirs and more notches than denticulates. In the other, high quality raw materials are not available locally, and more intensive retouch is observed on the racloirs made from imported materials, but local materials are still used for denticulates and notches. Differences in environmental and settlement patterns create continuous variation between these two extremes. Regional and climate variation triggers dispersed resource patterns in interstadials and aggregated patterns during stadials, and faunal exploitation shows alternating patterns of tool use and animal exploitation with changing climate, such as is seen at Grotte Vaufrey. More heavily reduced lithic types are associated with increases in animal biomass at the sites, which occurs under cold steppic landscape conditions. Colder phases induce more reliance on hunting of migratory game herds and increased parsimony of lithics as a means of limiting quarrying for resources. Less intensely reduced assemblages (mostly denticulates) are

more common when milder woodland conditions prevail, reflecting more mobility and reliance on plant foods (Dibble and Rolland 1992).

These observations underline the difficulties in analyzing Mousterian tool classes. Furthermore, there is considerable debate about the diversity of the Mousterian toolkit. The further back in time one goes, the fewer clearly recognizable functional classes of tool exist. This might be the result of fewer kinds of tasks or, more probably, more multi-purpose tools in the earlier time ranges (Clark 1966). For this reason, I have focused my analysis of tool making on two aspects: diversity, technique and innovation, and the trend from general purpose to special purpose tools, in order to identify functional usage in the four population groups.

- **Diversity, Innovation and Technique in Tool Making**

There is considerable debate about the diversity of Mousterian and Upper Paleolithic tool assemblages. Since the only artifacts that preserve in significant quantities are the lithics, and since lithic typologies differ between the 63 Bordesian Mousterian types (Bordes 1961) and the 92 classes in the de Sonneville-Bordes Upper Paleolithic list (de Sonneville-Bordes and Perrot 1975), it is difficult to make direct comparisons. However, the size of Bordes' and Sonneville-Bordes' lists is not a true measure of diversity. While de Sonneville-Bordes' list encompasses a range of Upper Paleolithic industries with a wider range of types, no single assemblage comprises the entire range of de Sonneville-Bordes' types. However, the Upper Paleolithic does see the appearance of formal variation as well as regional variation in artifact morphology through time (White 1993b). In one study of lithic assemblages in the Perigord (Simek and Price 1990), two primary levels of richness are found; the Mousterian,

Chatelperronian, and Azilian assemblages have similar but lower levels of richness than the Aurignacian, Perigordian, Solutrian, and Magdalenian. However, in another study using assemblages from a wider geographic region, analysis of 164 French Mousterian, Chatelperronian and Aurignacian stone tool assemblages reveals that most of the perceived differences in typological richness between the Mousterian and Aurignacian are associated with differences in assemblage size (Grayson 1998).

Even though the frequency of distribution of tool types at any one site or ecological setting may vary, the basic Mousterian stone tool types remain stable throughout the period. Jelinek (1994) argues that marked differences in reduction and elaboration of tools correspond to the intensity with which a particular assemblage type was used. For example, the most intensively reduced facies (Quina/Ferrassie and Mousterian of Acheulian Tradition or MTA) might correlate with site contexts where habitation episodes were relatively intense and prolonged, or severe climate conditions made access to raw materials more difficult. The least reduced (typical, denticulate) with lots of expedient tools might represent activities correlated with much more ephemeral site use. In his analysis of MTA tradition tools in Southwestern France, Mellars (1992) proposes that the MTA tradition seems to represent an adaptation to variable but generally mild ecological conditions, equivalent to OIS 3, favoring the exploitation of predominantly bovid, horse, and red deer resources rather than the highly specialized exploitation of reindeer documented during the greater part of the Charentian sequence. This consistency of the technological and typological trends is documented in all the stratified sequences of La Ferrassie and La Quina and assemblages at Combe Grenal, Abri Chadourne, Abri Caminade, Roc de Marsal, Petit-

Puymoyen and Roc-en-Pail. The most significant observations are the consistent associations of classic Quina Mousterian industries with evidence of rigorous climatic conditions associated with OIS 4 and the similar association of MTA industries with the milder conditions of OIS 3. Thus, changes in Mousterian tool types appear to be associated with climate conditions rather than any temporal evolution or innovation.

Rather than address diversity and tool types, others have focused on technique. The Mousterian hand ax, characterized by a high degree of bilateral symmetry in the overall shapes and patterns of retouch, suggests the existence of mental templates in the minds of their manufacturers (Mellars 1989b). Similarly, mental templates might have existed for other distinct categories of other retouched tool forms in the Middle Paleolithic, yet the overall range of these distinct types is very much smaller than that represented in Upper Paleolithic industries.

Mellars and Stringer (1989) identified three characteristics of Upper Paleolithic lithic assemblages that are much less conspicuous in Middle Paleolithic assemblages: a) more standardized forms of lithics; b) a more defined difference in shape between distinct tool categories; and c) an apparent imposition of form in shaping the tool. Large-scale reduction of the original flakes created the active working edges of the finished tool but also affected its appearance to produce distinctive and standardized forms. Standardization offers benefits in terms of the availability of spare parts for brittle stone inserts and consequently increases maintainability and reliability (Bleed 1986), a critical requirement when the window of opportunity for acquiring key seasonal resources is narrow. Reliability and advanced curation is especially meaningful when unforeseen circumstances may demand a switch to fall back foods to

avoid starvation. Under these conditions the appropriate food acquisition tools must be ready and available. Standardized and composite technologies with separate subcomponents also provide the opportunity for specialization and exchange in the mass production of replaceable parts ahead of the need (Bar-Yosef and Kuhn 1999).

Upper Paleolithic tool categories can be distinguished by the various retouching techniques employed and the location of retouch on blanks. End-scrapers and backed pieces are created by steep and semi-steep retouch. The burin blow technique produced burins. Flat bifacial retouch and steep lateral blunting retouch constitute key diagnostic elements for specific Upper Paleolithic units. These techniques are occasionally found in the Middle Paleolithic but their frequency increases dramatically in the Upper Paleolithic (Kozłowski 1990). Still more specific are Upper Paleolithic tool types with high lamellar transversal retouch (on carinated and nosed end-scrapers) and with lateral scalariform retouch, diagnostic of Aurignacian industries (Kozłowski 1990). Later developments in Aurignacian tool making techniques saw the introduction blade technology, and soft, as opposed to hard hammer, and indirect punch techniques. Soft hammer and indirect percussion permit the production of more uniform and smaller prismatic blades, useful for hafting in composite tools; larger heavy hard hammer blades would not be ideal for hafting in complicated armatures. The first clear examples of lateral and complex hafting (usually inferred for backed bladelets) is found in the Upper Perigordian, and continues through the later Upper Paleolithic (Anderson-Gerfaud 1990). End-scrapers are usually hafted and micro-wear analysis shows that they were used for a variety of functions other than scraping, including graving, boring, chopping on wood, bone, hide and antler (Odell 1981; Siegel 1984).

By contrast, the outstanding feature of Mousterian stone tool industries is their apparent lack of innovation and general lack of complex tools through the period of the Neanderthal's existence in Europe (Mellars 1973; Jelinek 1988). The failure to implement new inventions and techniques over a long period of time suggests that the Mousterian technology was quite adequate to provide the requisite nutrition, clothing and shelter in a wide variety of habitats across Europe. Side-scrapers, points, backed-knives, notches and denticulates, bifaces or hand axes represent the Mousterian stone toolkit. Notches and denticulates are less frequent on the Russian Plains, where wood was scarce, but frequent in the Caucasus and Crimea (Hoffecker 2002). Other tool types represent less than 1% of the total.

The added variety of knapping techniques observed in the Upper Paleolithic offered expanded potential for the application of specialized skills to the task of tool making. Specialization and exchange offers opportunities for learning and the transfer of knowledge and thus increases the rate of innovation; a trend that is discernable in the archaeological record.

- **Functionality - General-Purpose versus Special-Purpose Tools**

Analysis of the Mousterian (Tuffreau 1984), Aurignacian (Delporte 1984), and Gravettian (Delporte and Tuffreau 1984), lithic sequences from La Ferrassie in the Perigord shows a clear movement away from side-scrapers (racloirs) and Levallois tools in the Mousterian towards end-scrapers (grattoirs) and burins in the Aurignacian. (Later, stone points predominate in the Gravettian when Gravette points replaced bone and antler points as the preferred material for projectile points.) This succession

illustrates the trend away from more generalized, multipurpose tools towards more specialized ones.

An archaeo-ethnography at a Mesolithic site in the Netherlands, is helpful in interpreting this trend (Odell 1981). At the Burgumermeer site, micro wear analysis of stone tools, which bore a striking resemblance to late Upper Paleolithic tools, gives further validation to this development and assigns specific functions to each tool type. This analysis validates that there were many multipurpose tool types, yet many of the new tool types were special purpose tools. Projectile points used to kill bison were then used in butchering and then serrated for use in skinning. Smaller tools were used as projectiles, and larger tools depended on effective edge and size suitable for holding in hand to exert pressure. Some blades were employed to cut skins, some triangular points were used as drills for wood or bone, some smaller points were used as awls, some broken flakes and fragments were used for graving wood and bone. Microlith points were used as projectiles (including points, triangles, trapezes, lanceolots, A, B, C points, crescents etc.). Projectile points include various types of flint blades and flakes (usually smaller ones), often retouched to blunt the hafted end for more secure binding and attachment. Knives and side-scrapers appeared to be multi-purpose and had low functional integrity. End-scrapers are usually hafted as projectiles or to get leverage as hand scrapers. It should be noted, from Table 4-8, that three multi-purpose tools (side-scrapers, notches and denticulates) are characteristic of the Mousterian, although they continued to be used in later periods; however the Upper Paleolithic tool types that emerged only in the Aurignacian were used for more specific and in some cases single-purpose functions.

Table 4-8 Use-wear Analysis of Retouched Flints at Burgumermeer Mesolithic Site, Netherlands

	Type	Function 1	Function 2	Function 3	Industry
1.	Microlithic points	Projectiles (hafted)	-	-	Upper Paleolithic
2.	Burins	Graving	-	-	Upper Paleolithic
3.	Backed blades - Longitudinal wear - Projectile	Cutting Projectiles (hafted)	-	-	Upper Paleolithic
4.	Knives	Projectiles (hafted)	Cutting	-	Mousterian and Upper Paleolithic
5.	Axes, hammer stones	Smaller tools used for graving	Larger tools for scraping, chopping	-	Mousterian and Upper Paleolithic
6.	Borers	Smaller tools as projectiles	Larger tools for cutting, scraping and boring	Largest tools used for scraping and graving	Upper Paleolithic
7.	End-scrapers	Multipurpose (hafted)	-	-	Mousterian and Upper Paleolithic
8.	Side-scrapers	Multipurpose	-	-	Mousterian and Upper Paleolithic
9.	Notches and Denticulates	Multi-purpose	-	-	Mousterian and Upper Paleolithic

Rows 1-8 from (Odell 1981), row 9 added. Right hand column added.

In the Upper Paleolithic, the decision to use bone or ivory was probably dependent on availability and possible alternate uses for bone, (e.g. for burning or extracting grease and marrow through boiling or splintering). In either case, bone may not always have been expendable for making spearheads (Knecht 1994). Selected use of specific elements of mammoth such as ribs and ivory demonstrates the importance of this material for the production of tools at Geissenklösterle and Höhle Fels (Münzel 2001). During the Aurignacian period craftsmen used antler for making weapons, and methods of hafting changed to meet their needs. The later lozenge- and spindle-shaped points were not only lethal but were more easily repaired without removal from the haft, and during the Gravettian they were readily interchangeable as well. The presence of

specialized standardized, and complex hafted lithic and bone tools in Aurignacian assemblages in frequencies higher than those represented by multi-purpose tools, is an indication of the greater number of tasks and subtasks undertaken by the Aurignacians.

i. Functional Analysis of Mousterian Tool Making Tasks

Early Mousterian wooden thrusting spears, found at Lehringen (Movius 1950), Clacton (Oakley 1949), and Schöningen (Thieme 1997), have fire-hardened tips but are not complex, hafted weapons. Beyries and Anderson-Gerfaud argue that, based on micro wear analysis, there is no unambiguous evidence for the use of hafted missile points by Mousterians (Beyries 1988; Anderson-Gerfaud 1990). However, Shea (1988) argues that microscopic examination of wear-patterns on Middle Paleolithic stone points from Kebara Cave suggests that these hafted projectile points were already in use in the Levant prior to the Upper Paleolithic in Europe. Other tools used for food acquisition such as the ubiquitous food acquisition weapons and instruments, such as digging sticks, clubs, carrying bags or baskets, which are basic tools for current hunter-gatherer groups (Oswalt 1973) do not preserve well, and I have assumed that they were present in the Mousterian tool kit. Wooden bowls, shovels and tripods found at Abric Romaní (Vaquero, Vallverdu et al. 2001) suggest that Neanderthals were quite capable at making tools for uses other than food acquisition.

Microscopic analysis of tool wear yields information on edge chipping, polish, striations due to tool use, hafting, retouch and post-depositional modification, as well as information on the cutting or scraping angle, even to the extent of determining the grip and handedness of the individual tool user (Semenov 1973). Analysis of residue materials on archaeological tools (mainly silicium, calcium, including phytoliths,

crystalline materials for wood as well as bone, and animal materials) may indicate whether tools were used for processing flesh, woody or soft plant materials such as sedges, rushes and grasses (Anderson 1980).

Micro wear analysis has associated other lithic tool types, not used for food acquisition, as used for woodworking, food preparation, and clothing manufacturing (Anderson-Gerfaud 1990). Woodworking seems to have been the most common activity even in sparsely wooded areas of the Perigord, Northern France, and the East European Plains. Experiments show that intensive woodworking necessitates frequent re-sharpening of the stone tool (Anderson-Gerfaud 1990), which would be consistent with the suggestion that many Mousterian tools represent but one stage in a successive reduction sequence (Rolland and Dibble 1990; Dibble and Rolland 1992). The majority of Mousterian scrapers and denticulates were used in adzing, whittling, stripping or scraping bark rather than chopping or sawing trees (Beyries 1988). Mousterian spears from Clacton, Lehringen and Schöningen and shaped wooden objects such as tripods and pseudo-morphs of bowls or shovels from Abric Romaní (Vaquero, Vallverdu et al. 2001) are rare preserved examples of what the Mousterians might have been making out of wood.

Analysis of tool assemblages of the MTA tradition from southwest France show that about 10% of the retouched tools were used in the early stages of preparation of skin and hides, and hide working was always performed using convex-edged tools, as opposed to the concave edged tools used for woodworking. Hide-scraping edges are necessarily different from cutting edges (Frison 1968). A cutting edge that is too thin will cut fast but will also nick easily. Then time and material is wasted in restoring the

tool to functional condition. Scraping edges must not be too sharp or they will ruin the hide or other material being worked on. It is also possible, through micro wear analysis, to distinguish early stages of hide working from the later finer stages. Scraping on fresh hide produces the same polish on the tool as cutting meat, but scraping tanned hide and leather produces a quite distinct, pattern of wear including a dull, highly pitted rugose surface, widespread coverage over the used edge, and extensive rounding of the working edge (Vaughn 1985). Significantly, there are no traces of the later stages of production of more finely-dressed hides (Anderson-Gerfaud 1990).

A few tools with siliceous phytolith residue have been examined from both Mousterian and Upper Paleolithic periods. Since wild seeds scatter when cut with a sickle type tool, these were probably not used for the collection of edible seeds, but rather to gather stems for maintenance uses such as basketry and matting (Anderson-Gerfaud 1990), or even bedding as is suggested from remains at Vanguard Cave (Barton 1997).

Micro wear analysis indicates that most Mousterian tools were simple, one-component implements that were hand-held. Hand grips on these tools show wear from sweat and dirt, and Semenov (1973) argues that this evidence might explain the strong development of the width of phalanges as seen in skeletal hand remains from Kiik-Koba, Krapina and La Ferrassie. Micro wear analysis of MTA tradition lithics from three sites in France shows no evidence for the use of projectiles and virtually none for butchery (Anderson-Gerfaud 1990). Recent findings of deliberately created small, unretouched flakes at Pech de l'Azé appear to be hand-held tools designed for specific purposes (Dibble and Mcpherron 2006). There is no evidence of hafting, and micro

wear analysis of a few flakes indicated that they may have been used for cutting soft materials. Experimental analysis on a Levallois point fragment found embedded in the vertebra of an equid from Umm el Tlel in Syria suggests that Middle Paleolithic humans living there may well have made and used hafted stone spear points (Shea 1988), but Solecki (1992) argues that the evidence for Mousterian hafting from the Zagros Mousterian is still an open issue. More complex, hafted side-scrapers are found at a few Mousterian sites, including several convergent side-scrapers from Biache-St-Vaast and Corbiac in France. Analysis of tools at Biache-St-Vaast, an early Neanderthal site, shows wood- and hide-working on the elongated and non-convergent side-scrapers, always on the retouched edge. Wrapped hafting is revealed on tools with convergent edges used for woodworking (Tuffreau and Somme 1988). Two late Neanderthal sites in the Crimea, Starasol'e and Buran Kaya III, have assemblages where half the scrapers, all the points, and one denticulate from Starasol'e, and half the scraper, and one scaled piece from Buran Kara show evidence of hafting. Wear from high-impact thrusting or throwing was also evident. Hafted tools were used as scrapers or for cutting animal and plant tissue. Woodworking is clearly indicated on the cutting edges. Tools functions are broadly similar at both places with a wide range of resources being exploited from animal and avian resources as well as woody and non-woody plants. Analysis of tool-wear at these sites indicates little change in activity despite changes in tool traditions (Hardy, Kay et al. 2001). These examples illustrate the hafting of a single stone tool at the end of a haft, the most complex Mousterian tool type, comprising at most three techno units, according to Oswalt's definition (Oswalt 1976): a stone scraper, adhesive or binding material, and shaft or handle.

There is little direct evidence of non-lithic instruments and weapons in the Mousterian. Some evidence for working bone exists but merely to modify the working edge and not to reshape the bone. Rare instances of simple bone working (retouch) have been found at Cueva Morín in Iberia, La Quina in France, and Kiik-Koba and Chokurcha Caves in the Crimea (Semenov 1973), and several notched objects of bone have been noted from Russian levels at La Chaise and Grotte Vaufray, but at no point was bone a common raw material (Rigaud 1989b), nor was it reworked to alter its original form.

In summary, the entire Mousterian sequence is one of stability and consistency, and few significant additional developments in tool technology are apparent in the late Mousterian. Generally hafted spear points (of flint or bone), ornaments, and standardized bone technology are not demonstrated in pre-Aurignacian European industries (d'Errico, Zilhao et al. 1998). The weight of the evidence favors the presence of a single Mousterian industry with reworked, general purpose tools, whose particular expression in archaeological sites was differentially influenced by functional preferences based little on evolutionary change but mostly on ecological conditions and intensity of utilization or occupation (Jelinek 1994).

ii. Functional Analysis of Early Upper Paleolithic Tool Making Tasks

Lithic micro wear analysis enables us to explain the actual use and purpose of each tool (Semenov 1973). Semenov lists the basic characteristics of work in the Upper Paleolithic, as:

- shaping of wood by whittling and chopping with a knife, axe, adze, and chisel
- digging with a stick, mattock, scoop, etc

- dismembering a carcass and cutting the meat with a knife
- treating skin with side-, end-scrapers and burnisher
- perforating skins and fur for sewing with stone or bone awls
- boring wood, bone and stone with drills
- dressing stone with strikers stones and retouchers of stone and bone
- working bone with a burin
- grinding and polishing stone with various abrasive agents
- sawing stone with stone saws
- pounding crushing and trituration of grain, coloring, matter and so on by means of pestles, mortars, plaques and querns
- reaping with stone sickle

The evidence suggests that, although Neanderthals performed some of the activities listed early in the list above, the range of Upper Paleolithic human activities expanded dramatically. In contrast to Mousterian tools that were used primarily on wood, Upper Paleolithic tools were used far more commonly on bone and flesh and especially on hide (Juel-Jensen 1988). Woodworking tools are less frequent in later Upper Paleolithic sites for which micro wear analysis has been performed. Butchery, hunting and hide working are the uses for the majority of tools. Detailed analysis tells us much about the usage and design of individual tools. Whittling knives from Kostenki I and IV were designed with retouched base for the index finger and with steep edge to avoid breakage. Mousterian side-scrapers were used for working on fresh skins (Volgograd) and Upper Paleolithic end-scrapers were used in later stages of skin dressing (Kostenki I). Shouldered points were used for dismembering game,

particularly tough mammoth flesh, and not as spear points (Kostenki I, Willendorf, Grimaldi, Sergeac, Avdeev). Burins show signs of graving bone and cutting the outline for breaking an ivory tusk, chiseling, and occasionally cutting meat (Semenov 1973). Plant harvesting seems to represent only a small part of tool usage in both the Mousterian and Upper Paleolithic - plant foods are quite effectively collected by hand.

Systematic use of grinding and pounding stone tools began during the Upper Paleolithic. This is best documented in the Mediterranean region and Africa where plant food was a major part of the diet. Rarely are these tool types were found in Middle Paleolithic contexts, although the consumption of vegetal substances during the Middle Paleolithic is known, for example, from Levantine sites (Bar-Yosef 2002). However, sandstone and quartzite slabs resembling grinding stones were found as far north as Kostenki IV, layer II and Chulatuvo, and rounded granite and quartzite objects similar to pestles were found at Kostenki IV, layer 9 and Molodova V (Dolukhanov 1982).

Complementary aspects of Upper Paleolithic behavior appear with the introduction of initial cutting, grooving, splintering, fine sawing, grinding, and polishing of bone, antler and ivory (Mellars and Stringer 1989). Split based and beveled bone projectile points of the Aurignacian (and later the finely retouched Gravettian lithic points) are clearly distinguished from those of the Lower and Middle Paleolithic by their weight and dimensions, both of which were more appropriate for a weapon such as sagaies and spears (Rigaud 1989b).

Additional tasks are evident in the preparation of bone, antler and ivory artifacts. Specialized tools for use in the manufacture of clothing include end-scrapers, burnishers, awls and needles. Specialized excavation tools for building subterranean

dwellings and storage pits are indications of additional major tasks and functions undertaken in the Upper Paleolithic. With the increase in the size of the toolkit and task repertoire additional opportunities for specialization and exchange arose. The evidence presented by White (1993a) for specialization in bead production at the sites of Vallon de Castel-merle in the Perigord suggests that the early Aurignacians were quite capable of delegating standardized subtasks to groups or individuals that were more skilled and practiced in those areas. If similar practices were employed in other tool-making pursuits, then the range of tasks and subtasks that could potentially be shared would have increased dramatically as the range of specialized tools and their complexity increased.

Finally, the proliferation of symbolic representation in personal ornamentation and the making holes in beads and pendants by gouging and drilling (White 1993a) and in the form of bas relief carving, three dimensional carving and parietal art (Harrold 1989) is indicative of the many additional uses for the Aurignacian tool kit. Orquera (1984) believes that Upper Paleolithic tools are more specialized in nature than Middle Paleolithic tools, and that these tools fall into distinct categories that represent intentional classes of tools and tool-function. It is quite possible that these represent greater specialization and consequently efficiency of function.

iii. Functional Analysis of Middle Upper Paleolithic Tool Making Tasks

The Gravettian is characterized by a shift from bone to stone projectile points with fine retouch. They include Font-Robert points from the Upper Perigordian in France, noailles burins from Italy, and East Gravettian shouldered points from Willendorf and Kostenki. In addition, microgravettes, or microliths, and geometric

elements appear which are used to make multi-blade tools such as saws and scythes. It is suggested that prehistoric hunters began using the atlatl as early as 22 ka (Knecht 1994) and the bow was brought into use between 30 and 25 ka in the steppes (Praslov, Stanko et al. 2000).

Non-lithic developments include the development of mattocks, picks, and shovels for excavation of subterranean dwellings and storage pits. A bone hafted-mattock found at Kostenki appears to have been used to excavate 25 cubic meters of thick loam; a task that could not have been accomplished with a simple digging stick (Semenov 1973). At the same site, tools for basketry and making netting (Soffer, Adovasio et al. 2003) were found. These include spindle whorls, combs for preparing grasses for spinning, and loom weights and battens for weaving (Semenov 1973). Wooden objects are preserved at the Upper Paleolithic site of Ohalo II (Nadel, Grinberg et al. 2006) suggesting that many articles of a perishable nature were being used by prehistoric humans.

Thus, the major change in the Gravettian was the introduction of microlithic tools and the development of multi-hafted tools. The significant functional developments in the application of technology for direct and indirect tasks include the development of the lighter throwing or projected spear, with attached bone and later finely retouched stone points, to aid in the capture of more wary and fleet-footed or winged prey. The development of end-scrapers, burnishers, needles and awls aided in the dressing of skins and preparation of clothing and tent coverings, and spindle whorls, grass combs, loom weights, and battens enabled the spinning and weaving of netting,

matting and basketry. Digging tools such as picks, shovels, scoops, and mattocks were created for excavating subterranean living floors and storage pits.

This extension of the application of technology to a wide range of purposes offered even more opportunity for specialization and exchange. A number of sites yield evidence for the participation of skilled and apprentice workers or skilled older worker and trainees. The Gravettian site of Les Etoiles, France (Dobres and Hoffman 1994) show evidence of differences in the competence of the knappers who made tools in discrete areas.

iv. Summary of Tool Making Activities and Tasks

Mousterian assemblages contain a high frequency of side-scrapers, notches and denticulates. Upper Paleolithic assemblages, on the other hand, contain few if any side-scrapers, and offer a more varied typological spectrum in which burins, end-scrapers, backed points, shouldered or stemmed points, and microliths appear or reappear (Rigaud 1997). Another characteristic of the Mousterian industries is the scarcity of technology related to the procurement of large game (Kuhn 1995). Mousterian pointed artifacts were not specialized weapons and were relatively uniform from the Levant to northern and eastern Europe (relatively large triangular retouched Mousterian points and un-retouched Levallois points with some suggestion of hafting). This is in sharp contrast to the array of bone and stone weapon points found in the earliest Upper Paleolithic.

A comparison of the differences between Neanderthals and Upper Paleolithic modern humans in the making of all types of tools, whether for food-getting or other purposes, is shown below in Table 4-9.

Table 4-9 Tools by Type, Function for Early and Late Neanderthals (EN, LN), and Early and Middle Upper Paleolithic humans (EUP, MUP)

Tool Type	Tool Function and Reference	EN	LN	EUP	MUP
<u>Wooden Tools</u>					
	(a, b)				
1. Spears	Thrusting Projectiles	✓	✓	✓	✓
	Throwing (ballistic) Projectiles	✓	✓	✓	✓
	(b, c, d, l)			Hafted	Hafted
2. Digging sticks	Multi-purpose (e)	✓	✓	✓	✓
3. Wooden Utensils	Bowls, shovels, tripod, domestic items (f)	-	✓	✓	✓
	(a, m))
4. Side-scrappers	Multipurpose	✓	✓	✓	✓
	Concave – woodworking		Rarely	Hafted	Hafted
	Convex – hide working		hafted		
	(a, g, h, j)				
5. Notches, denticulates	Multi-purpose (o)	✓	✓	✓	✓
6. Axes, hammer stones	Smaller tools – graving	-	-	✓	✓
	Larger tools - scraping, chopping (o)	✓	✓	✓	✓
7. End-scrappers	Multipurpose (k, n, o)	-	-	✓	✓
				Hafted	Hafted
8. Microlithic points	Projectile points (n, o, p)	-	-	-	✓
					Multi-Hafted
9. Burins	Graving (n, o)	-	-	✓	✓
10. Backed blades					
- Longitudinal wear	Cutting	✓	✓	✓	✓
- Projectile	Projectile points	-	-	✓	✓
	(o)			Hafted	Hafted
11. Knives	Larger tools - cutting	✓	✓	✓	✓
	Smaller tools - projectile points	-	-	✓	✓
	(o)			Hafted	Hafted
12. Borers	Larger - cutting, scraping, boring	-	-	✓	✓
	Largest - scraping, graving	-	-	✓	✓
	Smaller - projectile points	-	-		✓
	(o)			Hafted	Hafted
13. Microgravettes	Multi-bladed cutting tools	-	-	-	✓
	(o)				Multi-Hafted
14. Stone smoothing tools	Fine dressing of hides (q)	-	-	✓	✓
15. Stone pestles and mortars	For grinding ochre (r, s)	✓	✓	✓	✓
<u>Bone tools</u>					
16. Unshaped bone tools	Split or whittled as clubs, points, handles (i)			✓	✓
17. Bone Points	Split or beveled bone /antler points as projectiles (l)	-	-	✓	-
				Hafted	
18. Multi-purpose bone utensils	Pick/mattock/shovel (t)	-	-	-	✓
19. Needles	Sewing (u, v)	-	-	✓	✓
20. Bone burnishers	Leather finishing (v)	-	-	✓	
21. Loom weight, spindle whorls, grass combs	Basketry and netting (w, x, y)	-	-	-	✓
Total Tools		9	10	22	25
Total Hafted Tools	(z)	0	1	11	13
Tools & hafts		9	11	33	38

References from Text to Support of Table 4-9

- a. The majority of Mousterian scrapers and denticulates were used in woodworking: adzing, whittling, stripping or scraping bark rather than chopping or sawing trees (Beyries 1988; Anderson-Gerfaud 1990).
- b. Early Mousterian thrusting spears: Lehringen (Movius 1950), Clacton (Oakley 1949), and Schöningen, (Thieme 1997).
- c. Schöningen spears were too heavy to be thrown any distance and were used for thrusting downward (Shea 2003).
- d. There is no non-ambiguous evidence from micro wear analysis for the use of hafted missile points in the Mousterian (Jelinek 1988; Anderson-Gerfaud 1990).
- e. Tools such as digging sticks, clubs, carrying bags or baskets, which are basic tools for current hunter-gatherer groups (Oswalt 1973).
- f. Shaped wooden objects, a tripod for cooking, pseudo-morphs of bowls or shovels at Abric Romani (Vaquero, Vallverdu et al. 2001). Wooden objects are preserved at the Upper Paleolithic site of Ohalo II (Nadel, Grinberg et al. 2006)
- g. Micro wear analysis indicates that most Mousterian tools were simple one-component implements that were hand-held. Hand grips on these tools show wear from sweat and dirt and Semenov believes that this evidence might explain the strong development of the width of phalanges as seen in skeletal hand remains from Kiik-Koba, Krapina and La Ferrassie (Semenov 1973).
- h. Tools at Biache-St-Vaast, an early Neanderthal site, show wood- and hide working on the elongated and non-convergent side-scrapers always on the retouched edge. Wrapped hafting is revealed on tools with convergent edges used for woodworking (Tuffreau and Somme 1988). These represent the hafting of a single stone tool at the end of a haft, the most complex Mousterian tool type, comprising three techno units, a stone scraper, adhesive or binding material, and shaft/handle, according to Oswalt's definition (Oswalt 1976).
- i. There is some evidence for working bone but merely to modify the working area and not to reshape the bone - Kiik-Koba, La Quina and Chokurcha Cave in the Crimea (Semenov 1973), and from Russian levels at La Chaise and Grotte Vaufray, but at no point was bone a common raw material (Rigaud 1989b).
- j. Two late Neanderthal sites in the Crimea, Starasol'e and Buran Kaya III, have assemblages where half the scrapers, all points and one denticulate from Starasol'e and half the scrapers, one scaled piece from Buran Kara showed evidence of hafting (Hardy, Kay et al. 2001). Wear from high impact from thrusting or throwing was also evident. Hafted tools were used as scrapers or for cutting of animal and plant tissue. Woodworking is clearly indicated on the cutting edges.
- k. End-scrapers are usually hafted and micro-wear analysis shows that they were used for a variety of functions other than scraping, including graving, boring, chopping on wood, bone, hide and antler (Odell 1981; Siegel 1984).
- l. Split based and beveled bone projectile points of the Aurignacian (and the later the finely retouched Gravettian lithic points) are, by their weight and dimensions, more appropriate for a weapon such as sagaies, spears or javelins, that were thrown or projected (Rigaud 1989b).
- m. Mousterian tools were used primarily on wood but by contrast, Upper Paleolithic tools were used far more commonly on bone and flesh and especially on hide (Juel-Jensen 1988). Butchery, hunting and hide working are the uses for the majority of tools.
- n. Analysis of the lithic sequence from La Ferrassie in the Perigord shows a clear movement away from side-scrapers (racloirs) and Levallois tools in the Mousterian towards end-scrapers (grattoirs) and burins in the Aurignacian. (Later, stone points predominate in the Gravettian when Gravette points replaced bone and antler points as the preferred material for projectile points.) (Rigaud 1989b). Upper Paleolithic assemblages, on the other hand, contain few if any side-scrapers, and offer a more varied typological spectrum in which burins, end-scrapers (racloirs), backed points, shouldered and stemmed points and microliths appear and reappear (Rigaud 1997).
- o. Whittling knives from Kostenki I and IV were designed with retouched base for the index finger and with steep edge to avoid breakage. Mousterian side-scrapers were used for working on fresh skins (Volgograd) and Upper Paleolithic end-scrapers were used in later stages of skin dressing (Kostenki I) (Semenov 1973). Shouldered points were used for dismembering game, particularly tough mammoth flesh, and not as spear points (Kostenki I, Willendorf, Grimaldi, Sergeac, Avdeev). Burins show signs of graving bone and cutting the outline for breaking an ivory tusk, chiseling, and occasionally cutting meat. Also see Table 7.10 Use-wear Analysis of Retouched Flints at Burgummeer Mesolithic Site, Netherlands (Odell 1981)
- p. The Gravettian is characterized by a shift from bone to stone projectile points with fine retouch. They include Font-Robert points from the Upper Perigordian in France, noailles burins from Italy and shouldered points from Willendorf and Kostenki, East Gravettian. In addition, microgravettes, or microliths, and geometric elements used to make multi-blade tools such as saws and scythes (Semenov 1973).
- q. Aurignacian stone smoothing tools have been found at La Ferrassie, and El Pendo. Half-dressed hides

- undergo this burnishing after greasing and coloring (Semenov 1973).
- r. Systematic use of grinding and pounding stone tools began during the Upper Paleolithic. This is best documented where plant food played a major role in the diet such as in the Mediterranean region and Africa. None of these tools were found in Middle Paleolithic contexts, although the consumption of vegetal substances during the Middle Paleolithic is known, for example, from Levantine sites (Bar-Yosef 2002).
 - s. Sandstone and quartzite slabs resembling grinding stones were found at Kostenki 4, layer II and Chulatuvo, and rounded granite and quartzite objects similar to pestles were found at Kostenki 4, layer 9 and Molodova V (Dolukhanov 1982).
 - t. Non-lithic developments in the Gravettian include the development of mattocks, picks and shovels for excavation of subterranean dwellings and storage pits - a bone hafted-mattock from Kostenki I (Semenov 1973).
 - u. Isolated examples of stone awls or perforators are present in a few East European sites, including Ketrosy, Rozhok I, and Kiik-Koba and bone awls are reported from Chokurcha I and Prolom II in the Crimea, but there is a complete absence of needles despite the preservation and recovery of small bone fragments both in Eastern (Goebel 2000) as well as Western Europe (Mellars 1996).
 - v. Ten needles were found at Kostenki XV associated with the Gorodsev Culture dated to 30 BP. Hide burnishers of bone were found at Avdeevo, Kostenki I and Gagarino (Hoffecker 2002).
 - w. Tools for basketry and making netting (Soffer, Adovasio et al. 2003) were found at Kostenki I. These include spindle whorls, combs for preparing grasses for spinning, and loom weights (Semenov 1973).
 - x. Clay figurines from Pavlov and Dolní Věstonice show impressions of not only fabric and basketry but also netting with a mesh diameter of 4 mm, which would have been ideal for netting smaller fur-bearing animals as well as even larger prey (Adovasio, Soffer et al. 1996; Pringle 1997).
 - y. Other surviving implements from Kostenki include loom weights, spindle whorls, grass combs (Soffer, Adovasio et al. 2003).
 - z. Analysis of tools at Biache-St-Vaast, an early Neanderthal site, shows wood- and hide-working on the elongated and non-convergent side-scrapers, always on the retouched edge. Wrapped hafting is revealed on tools with convergent edges used for woodworking (Tuffreau and Somme 1988).

Mousterian tool kits are remarkably consistent through time and show a lack of technological innovation with few complex tool varieties. The Mousterian technology showed little change over the 200,000 years prior to about 50 ka, at which point innovative transitional technologies appeared. The rate of innovation accelerated even more throughout the entire Upper Paleolithic (Rigaud 1997). The gap between Neanderthals and modern human tasks seems to be consistent with the activities listed by Semenov (1973), and the technological assessment of Hoffecker (2005). Table 4-9 shows that, measured by function, the Neanderthals had about half the uses for tools of the Upper Paleolithic peoples, whether measured by lithics or by all tool types. In addition, half of the tools were hafted in the Upper Paleolithic, whereas hafting was rare in the Mousterian period. It is suggested that more sophisticated tools were not required in most Mousterian economies. Infrequent and rudimentary skin preparation tasks for

making simple cloaks would have required the simplest of generalized tools with no need for single purpose implements: few specialized tools would have been required (Hayden 1993). The most complicated Neanderthal implement known to date is the hafted scraping/cutting tool, which comprised three techno units. Assuming a variety of single component stone and wooden instruments and weapons – along with a number of hafted instruments – the total number of techno units for Neanderthal instruments, weapons, and facilities probably fell below one hundred, perhaps as low as fifty. Hoffeecker calculates that the total techno units for food-getting technology places Neanderthals well below the level of complexity of recent hunter-gatherers in cold environments and closer to the level of technology required in more tropical areas (Hoffeecker 2002).

Techno units for the subtropical groups range from 11 through 16 versus 34 for high latitude groups (Oswalt 1973; Oswalt 1976). Therefore, I project that early and late Neanderthals (with nine and eleven tool types respectively) spent about as much time as the Efe in tool production. Aurignacians and Gravettians did not achieve the sophistication of the Inuit nor did they have access to modern iron and steel implements. Nevertheless, they performed about triple the tool making tasks of the Neanderthals, and I allocate time for the Aurignacians and Gravettians based on the respective ratios of tools and hafts manufactured as shown in Table 4-10.

Table 4-10 Tool Making Activities and Tasks

Tool Making Activities	Efe	Machi-guenga	High latitude	Early Neanderthal	Late Neanderthal	Early Upper Paleolithic	Middle Upper Paleolithic
Men (mins)	51	72	139	42	51	135	151
Women (mins)	6	18	27	5	6	26	29
Techno units	11	16	34	-	-	-	-
Tools & hafts	-	-	-	9	11	33	37

Neanderthal time is based proportionately on Efe tool making time and techno units, Upper Paleolithic times are based proportionately on high latitude time and techno units.

4.5 Clothing Manufacturing Activities and Tasks

Neanderthals were physically better adapted to the colder climate in northern Europe than were modern humans (Churchill 1998), yet the early Upper Paleolithic humans were able to exist and prosper under even colder conditions with the help of manufactured and insulating clothing. Analysis of skeletal remains suggests that clothing was an important factor distinguishing Aurignacians and Gravettians from Neanderthals. As mentioned above, after morphological analysis of Neanderthal specimens, Holliday concluded that European Neanderthals were robust and hyperpolar in body shape, partly due to less effective cultural buffering against cold stress (Holliday 1997a; Holliday 1997b). However, there was a limit to the Neanderthal's cold-adaptation. An analysis of thermoregulatory requirements examining Neanderthal temperature tolerances and settlement sites throughout Europe shows that, from 37 to 22 ka, median winter wind-chill temperatures were -16° C for Mousterian sites, -20° C for Aurignacian sites, and -23° C for Gravettian sites (Aiello and Wheeler 2003). This suggests that Neanderthals, despite increased robusticity, muscle mass, elevated BMR and thermogenesis, and with simple clothing, were not able to survive in extreme cold. My own analysis of settlement patterns in the Russian Plains shows that Mousterians were not able to survive at temperatures below -10°C; once temperatures fell below this level they retreated to warmer southern refugia. Yet the arriving modern humans were able to settle in colder northern sites (Smith 2003). Bergmann's and Allen's rules imply that Neanderthals, in colder regions, will tend to have greater body mass and shorter extremities than do their conspecifics from tropical regions. Thus, the tropical, linear-body-shaped of the early modern humans rendered them physically less well

adapted to the cold. This forced them to develop more insulating clothing, as well as shelter, that ultimately enabled them to survive in even colder conditions. Significantly, more effective conservation of heat, which reduced the caloric input and metabolic activity necessary to maintain normal core temperature, would provide direct benefit in freeing up time from the direct procurement of caloric energy (Jelinek 1994).

i. Early and Late Neanderthal Clothing Manufacturing Tasks

Molecular clock analysis of mtDNA and nuclear DNA segments from human body lice indicates that body lice evolved from head lice around 107 ka (Kittler, Kayser et al. 2003; Kittler, Kayser et al. 2004). Since these lice feed exclusively on the body rather than the scalp and live in clothing, the authors suggest that humans donned some insulating clothing around this time. Thus, it appears that even early Neanderthals would have sported some kind of protective clothing. However, in contrast to the first modern human occupants of Eastern Europe, the Neanderthals apparently failed to develop any of the advanced technologies for cold protection (e.g. layered and tailored clothing and heated shelters) found among recent hunter-gatherers (Hoffecker 2002).

A look at the tool assemblages provides some insight into what type of clothing, if any, was manufactured by hominids during this period. One feature of the Mousterian tool assemblages is the high frequency of side-scrapers (racloirs), notches (encoches) and denticulates. Upper Paleolithic assemblages, on the other hand, contain few if any side-scrapers and offer a more varied typological spectrum in which end-scrapers (racloirs) dominate, followed by burins, backed points, shouldered and stemmed points, and microliths (Rigaud 1997).

While hides do appear to have been used by Neanderthals, micro wear analysis of side- and end-scrapers shows that hide working took second place to woodworking, and the absence of specific tools, other than side-scrapers and a few denticulates, suggests that the effectiveness of the treatment of hides and their employment for personal insulation as well as structural coverings may have been limited (Jelinek 1994). In the Middle Paleolithic, the convex-edged side-scraper, in particular, was the preferred tool for hide working, even though in its various forms it was a multipurpose tool used in many functions. Because the side-scraper is the signature tool throughout the Mousterian tradition, there is strong evidence that Neanderthals were habitual processors of animal hide, which could have been used for clothing, blankets, or other protective purposes. Some of the many variables in hide working can be identified in terms of micro wear. However, experimental studies in the preparation of hides indicate that the hand-held side-scraper was an effective tool only in the early stages of hide preparation (Anderson-Gerfaud 1990). Analysis of a Mousterian side-scraper from Volgograd indicates that it was used solely for working on fresh, damp skin to remove fat and grease (Semenov 1973). Only rawhide would have been made using these methods; the technology was not suitable for the heavy scraping needed for making finely dressed hides or leather (<http://www.pole-prehistoire.com/>). Although the presence of lubricants and abrasive agents has been demonstrated in several instances (Juel-Jensen 1988), there is no evidence of fine dressing of skins using end-scrapers and burnishers. The Neanderthals may have used other, non-technological means for processing hides. The high vertical, occlusal forces, made possible by the general facial morphology of the Neanderthals, suggest the use of the anterior teeth as a vise (Smith

and Paquette 1989), and this heavy occlusal wear in the large anterior teeth of the Neanderthals (Antón 1996; Aiello and Dean 2002) may indicate that chewing of hides to make them more supple was practiced among the Neanderthals, as it is among the Inuit women (Aksaakjuq Otak 2005). Even quite young Neanderthals show a degree of wear on their incisors that is excessive for modern humans (Tattersall 1995). However, this pattern of attrition may merely reflect the heavy occlusal loading resulting from the relatively large size of the anterior dentition (Rak 1986).

Neanderthal use of hides for cold protection seems to be confined to relatively simple items such as blankets and ponchos (Hayden 1993). Occasionally these may have been perforated for attachment: isolated examples of stone awls or perforators are present in a few East European sites, including Ketrosy, Rozhok I, and Kiik-Koba, and bone awls are reported from Chokurcha I and Prolom II in the Crimea. This would suggest that Neanderthals were quite capable of making rawhide garments similar to ponchos, skirts and shawls; one can presume that Neanderthal clothing could be secured around the shoulders and waist to permit hands-free movement. But Neanderthals seem to be incapable of making the finely dressed pliable leather needed for constructed and tailored clothing; there is a complete absence of needles and burnishers even despite the preservation and recovery of small bone fragments both in Eastern (Goebel 2000) as well as Western Europe (Mellars 1996). The Neanderthal's robust body shape may have enabled them to get by with simple clothing just as the robustly-built Yaghan canoe-fishermen of Tierra del Fuego are able to withstand air temperatures close to freezing, even when immersed in the icy waters of Antarctica with minimal clothing (Coon 1971). The Yaghan forewent anything more than a simple pelt tied to their backs

in order not to impede movement in their arms and hands, even though they knew how to sew skins together for bedding. For Neanderthals muscle mass may have compensated for technology both in terms of alleviating the need for food acquisition technology as well as the need for clothing.

ii. Early Upper Paleolithic Clothing Manufacturing Tasks

While only the early phases of hide preparation were carried out with Middle Paleolithic side-scrapers, the later phases of preparation are commonly inferred by micro wear traces, often from hafted end-scrapers, in the Upper Paleolithic (Anderson-Gerfaud and Helmer 1987; Juel-Jensen 1988; Anderson-Gerfaud 1990). Although butchery, hunting, and hide working are the uses of the majority of the tools in the Upper Paleolithic, working of hide is almost invariably the use documented for convex-edged end-scrapers (Juel-Jensen 1988; Anderson-Gerfaud 1990). The Aurignacian tool kit includes several items that relate to hide processing and use. The absence of the side scraper and its replacement by the end-scraper is a noticeable change in the inventory. Tools for hide working have a convex-shaped, blunt edge to avoid cutting the material. The early stage of hide working on fresher or wetter hides consists of holding the scraper at a low angle to the hide surface and pushing. Later, when working on dried hides the scraper is held almost perpendicular to the surface and pulled to achieve a finer finish (Hayden 1979a; Hayden 1979b). The end-scraper, sometimes hafted for greater leverage, is much better suited to the heavy scraping necessary to clean a hide for creating finer leather. Tools analyzed from Kostenki I, Timonovka, Předmostí, Gorge d'Enfer, Font Robert, and Lespugue demonstrate that even hand-held tools show wear from sweat and dirt, and indicate the heavy, right handed action needed for leather

preparation which caused the tools to be worn on the right side, often needing secondary trimming (Semenov 1973). The narrower retouched, blunt head, and the extra leverage achieved through hafting, permits greater pressure to be applied than could have been applied using the broader, hand-held side scraper, as shown by the Inuit leather-making tools kits (Aksaakjuq Otak 2005).

Tailored clothing provides a greater level of insulation than loosely fitting ponchos and shawls (Aiello and Wheeler 2003), a significant advantage during this period of climate fluctuation and deterioration. In addition, layers of clothing, which can be adjusted to avoid serious overheating, are shown to be most critical to the maintenance of normal body temperature in high activity situations in Arctic conditions (Rogers 1974). Layered and tailored clothing would permit early modern humans to venture forth in more severe climates than their poorly clad Neanderthal cousins and would have provided a clear adaptive advantage. It is during this period that bone implements appear, including needles, awls, burnishers, rods, points, and shovel-shaped tools among other novel bone artifacts. At least some of these implements (e.g. needles, awls, burnishers) were used in the production of more finely stitched and tailored garments, after substantial hide-preparation with stone end-scrappers (Hoffecker 2002). Ten needles were found at Kostenki XV associated with the Gorodsev Culture dated to 30 ka. Bone burnishers first appear indicating that extra effort was being made to polish the hide and give the leather a more lustrous appearance. Hide burnishers of bone were found at Avdeevo, Kostenki I, and Gagarino (Hoffecker 2002). Burnishing or rubbing the outer surface of the skin is one of the essential operations in fine skin dressing. The rubbing compresses the skins and gives its outer layer a luster, sheen or gloss, which not

only makes it more attractive but also tougher and more impermeable. The majority of half-dressed hides undergo this burnishing after greasing and coloring (Semenov 1973). Aurignacian stone smoothing tools have been found at La Ferrassie, and El Pendo. A schist plaque covered in fine incisions found at Grotte de Saint-Jean-de-Verges (Ariège), has been identified as a cutting board for hides as well as meat (Beaune 1993). Not only were Aurignacians manufacturing more effective insulating garments they were also going to extra lengths to make these garments decorative. The earliest evidence for the deliberate piercing of items for suspension as pendants or necklaces, or for attachment to clothing comes from Bacho Kiro (Kozlowski 1982). At Geissenklösterle Cave in Germany, ornamental objects are associated with clothing manufacture (Hahn 1986); this may also have been the case at Abri Blanchard, Abri Castanet, and La Souquette where early Aurignacian beads and pendants occur in contexts other than burials (White 1989b). Micro wear analysis of Aurignacian beads found in the Vallon de Castel-merle in the Perigord indicate that these beads were not only suspended in necklaces but also sewn into clothing (White 1989a; White 1989b; White 1993a), a second indication that needles and clothing are tightly associated.

The innovations in clothing provided additional buffering against the climate, offered further opportunities for specialization and exchange. They added significantly more time and effort and a considerable number of additional tasks to the repertoire of the early Upper Paleolithic humans.

iii. Middle Upper Paleolithic Clothing Manufacturing Tasks

In the Gravettian period, needles become even more prevalent and several of the figurines for the period from the Russian Plains appear to depict items of clothing, and

even headgear. Tools that could have been used in the manufacture of these items have been found at Gravettian sites in Eastern Europe. One needle fragment at Sunghir', one at Kostenki VIII, and fourteen at Gagarino are associated with later Gravettian cultures (Hoffecker 2002). Needles were also found in the Vallée de la Vézère in this period (Gamble 1986; Troeng 1993). Decorative beads were strung on lengths of sinew and attached to clothing for the highly decorated burials at Sunghir', in Russia (Bahn 1998).

The eyed-needle permitted not only tailored clothing but also the combination of fur from several animals so that the user could profit from the unique properties of each – wolverine to line the anorak hood and reindeer leg skins for leggings (Fagan 2004). Carved figurines from Buret' in Siberia, dated to 25 ka, depict human figures in complete, hooded fur suits (Hoffecker 2005). Faunal remains from Eastern European Gravettian sites such as Mezin, Avdevo, Kostenki I and Kostenki XIV (Klein 1973; Soffer 1985b; Hoffecker 1999) and Pavlov I (Musil 1997) have provided the oldest evidence of systematic fur trapping. At these sites, other than horse, mammoth and reindeer, the only other vertebrates represented in significant numbers are hare, wolf and arctic fox - 25% of the remains in the upper humic bed at Kostenki. Today, all three taxa yield valuable fur. The abundance of small fur-bearing mammals, such as arctic fox, is not characteristic of Mousterian sites (Hoffecker 2002). This evidence for the capture of fur bearing animals is supplemented by evidence from clay figurines from Pavlov and Dolní Věstonice that show impressions of not only fabric and basketry but also netting with a mesh diameter of 4 mm, which would have been ideal for netting smaller fur-bearing animals as well as even larger prey and fish (Adovasio, Soffer et al. 1996; Pringle 1997).

In the Gravettian, stone smoothing tools have been found in southwest France at Pair-non-Pair, Isturitz, Laussel, Grotte de la Forêt, Laugerie Haute, in Czechoslovakia at Předmosti, and in Austria at Willendorf, in addition to the hide burnishers of bone found at Avdeev, Kostenki I and Gagarino (Hoffecker 2002). Other surviving implements from Kostenki include loom weights, spindle whorls, grass combs (Soffer, Adovasio et al. 2003). Negative impressions in fired clay objects at Pavlov I provide evidence that a variety of textile, basketry, and netting items were produced in Upper Paleolithic Moravia by at least 27 ka, including perishable cordage and nets, loom weaving of textiles from plant materials, plaiting or twining and coiling of baskets (Adovasio, Soffer et al. 1996). Similar textile clay impressions have been found at Kostenki I and Zaraisk dating to 22 to 24 ka BP (Soffer 2000; Soffer 2004). They were likely used to meet both household and hunting needs and also served as clothing. In the Eastern Gravettian, at least three types of dressed female figurines appear. These suggest that Paleolithic women made and likely wore a great variety of cloth, including twined wear, spun-string, and non-heddle-loom-woven plain weaves (Barber 1994). Paleolithic imagery depicts attire including woven headgear (Avdeev figurine # 6 and Kostenki figurines) basket hats or caps, netted snoods (Dame à la Capuche, Brassempouy), bandeaux, string skirts (Venus of Lespugue), and belts (Venus of Willendorf). Soft, flexible thread is a prerequisite for making cloth but also can be used for tying, netting and carrying.

By Gravettian times, it appears that clothing was not limited to body garments but also might have included durable footwear. Morphological analysis of the proximal pedal phalanges of Middle Paleolithic and Upper Paleolithic humans from Western

Eurasia indicates that during the Gravettian period there was a marked reduction in the robusticity of the lesser toes. Reduced robusticity in the lesser toes is characteristic of current humans. The suggestion is that Gravettians, unlike their early Upper and Middle Paleolithic forebears, were using semi-rigid soled shoes or boots to protect and insulate the feet in localities as widespread as Barma-Grande, Cro-Magnon, Abri Pataud, Dolní Věstonice and Předmostí, by about 25 to 27 (Trinkaus 2005).

iv. Summary of Clothing Manufacturing Activities and Tasks

By applying the *chaîne opératoire* methodology to this sequence in string and clothing manufacture, I project that progressively more effort was applied to the manufacture of insulating clothing such that by the end of the period double the effort was expended on these tasks than at the beginning (Table 4-11).

Table 4-11 Clothing Manufacture by Type and Task within Population
(EN – early Neanderthal, LN, late Neanderthal, EUP – early Upper Paleolithic, MUP – middle Upper Paleolithic)

Process	Product	BL	PO	TC	FW	HG	DE	FU	EN	LN	EUP	MUP
		(a, b)	(c)					(d)				
<u>Prepare raw-hide</u> using knife and side scraper (e, f, g)		√	√		√				5	5	5	5
<u>Prepare untailored clothing</u> with attachment (punch)			√		√				2	2		
<u>Dress fine hide</u> using end scraper and burnisher (h, i)				√		√	√				4	4
<u>Prepare spun clothing</u> and headgear (j, k)				√		√					1	2
<u>Prepare body wear</u> , cut to measure and sewn (c)				√		√	√				2	3
<u>Insulate and decorate</u> (animal fur in faunal assemblages, and beads/shells) (l, m, n)								√			1	2
<u>Construct footwear</u> (hard-soled shoes -pedal morphology) (m,o)					√							1
Total Clothing Units									7	7	13	17

Products headings: BL – blanket, PO – poncho, TC – tailored clothing, FW – footwear, HE – headgear, DE decoration, FU – fur trim. The numbers refer to the number of steps or tasks for each process as described in the ethnographic section.)

References from Text in Support of Table 4-11

- a. Molecular clock analysis of mtDNA and nuclear DNA segments from human body lice indicates that body lice evolved from head lice around 107 ka. (Kittler, Kayser et al. 2003; Kittler, Kayser et al. 2004). Since these lice feed exclusively on the body rather than the scalp and lives in clothing the authors suggest that humans donned some kind of clothing cover around this time.
- b. The rudimentary skin preparation for making the simple cloaks used by the Neanderthals required only occasional piercing and scraping tools (Hayden 1993).
- c. Bone implements include needles, awls, rods, points, shovel-shaped tools and others appear. At least some of these implements (e.g. needles, awls) were used in the production of tailored clothing, after substantial hide preparation with stone end-scrapers (Hoffecker 2002).
- d. Faunal remains from Eastern European Gravettian sites such as Mezin, Avdeev, and Kostenki XIV (Klein 1973; Soffer 1985b; Hoffecker 1999) and Pavlov I (Musil 1997) have provided the oldest evidence of systematic fur trapping.
- e. Experimental studies in the preparation of hides indicate that the hand-held side-scraper was an effective tool only in the early stages of hide preparation (Anderson-Gerfaud 1990).
- f. A side-scraper from Volgograd was used solely for working on fresh, damp skin to remove fat and grease. Upper Paleolithic end-scrapers from Kostenki I were used in later stages of skin dressing (Semenov 1973).
- g. There are no traces of later stages of production of more finely-dressed hides in the Mousterian (Anderson-Gerfaud 1990).
- h. While only the early phases of hide preparation were carried out with Middle Paleolithic side-scrapers, the later phases are commonly observed by micro wear traces, often from hafted end-scrapers, in the Upper Paleolithic (Anderson-Gerfaud and Helmer 1987; Juel-Jensen 1988; Anderson-Gerfaud 1990). Although butchery and hunting or hide working are the uses of the majority of the tools in the Upper Paleolithic, working of hide is almost invariably the use documented for convex-edged end-scrapers (Anderson-Gerfaud 1990).
- i. Hide burnishers of bone were found at Avdeev, Kostenki I and Gagarino (Hoffecker 2002). The majority of half-dressed hides undergo this rubbing after greasing and coloring (Semenov 1973). Aurignacian stone smoothing tools have been found at La Ferrassie, and El Pendo.
- j. New focus on micro wear analysis of possible Aurignacian textile instruments has found weaving sticks of bird bone at Dolní Věstonice I and Kostenki IV that are ethnographically associated with the spinning of cordage. Lissoirs from Abri Castanet and Abri Blanchard bear similar edge wear and ostensibly represent fragments of batten, weaving sticks, mat needles and net spacers. Mammoth tusks from Vogelherd, fashioned into long thin needles, likely used for sewing mats and other textiles (Soffer 2004).
- k. In the Eastern Gravettian, dressed female figurines suggest that Paleolithic women wore clothing, including twined wear, spun-string, and loom-woven plain weaves (Barber 1994), including woven headgear (Avdeev figurine # 6 and Kostenki figurines) basket hats or caps, netted snoods (Dame au Capuche, Brassempouy), bandeaux, string skirts (Venus of Lespugue) and belts (Venus of Willendorf).
- l. The earliest evidence for the deliberate piercing of items for suspension as pendants or necklaces, or for attachment to clothing comes from Bacho Kiro (Kozłowski 1982). Micro wear analysis of Aurignacian beads found in the Vallon de Castel-merle in the Perigord indicate that these beads were not only suspended in necklaces but also sewn into clothing (White 1989a; White 1989b; White 1993a), a second indication that needles and clothing are tightly associated.
- m. The eyed-needle permitted not only tailored clothing but also the combination of fur from several animals so that the user could profit from the unique properties of each – wolverine to line the anorak hood and reindeer leg skins for leggings (Fagan 2004).
- n. Carved figurines from Buret' in Siberia, dated to 25 ka, depict human figures in complete, hooded fur suits (Hoffecker 2005).
- o. The suggestion is that Gravettians, unlike their early Upper and Middle Paleolithic forebears, were using semi-rigid soled shoes or boots to protect and insulate the feet in localities as widespread as Barma-Grande, Cro-Magnon and Abri Pataud, and Dolní Věstonice and Předmostí, by about 25 to 27 BP (Trinkaus 2005).

This data add further support to the proposition that better-insulated clothing, a prerequisite for long-term survival in the open plains, was an adaptive feature of the lifestyle of the period. Also, ethnography tells us that clothing manufacturing was

strictly in the women's domain and the invention of string and sewing in the Upper Paleolithic provides the first chapter in the story of women's long association with the fiber crafts (Barber 1994). Examination of the Venus figurines suggest that spinning and weaving were associated with women and that these tasks were in the female domain (Soffer, Adovasio et al. 2003).

In this analysis, I have assigned clothing manufacture as a women's task for both Neanderthals and Upper Paleolithic populations. By comparing the clothing processes and output of the Neanderthals and early modern humans to that of the Efe, Machiguenga, and high latitude groups I predict time allocations and tasks for clothing in Table 4-12.

Table 4-12 Clothing Manufacturing Activities and Tasks

Clothing Manufacture Activities	Efe	Machi-guenga	High latitude	Early Neanderthal	Late Neanderthal	Early Upper Paleolithic	Middle Upper Paleolithic
Time allocated by men (mins)	0	0	0	0	0	0	0
Time allocated by women (mins)	5	108	270	126	126	234	306
Clothing units or tasks	3	6	15	7	7	13	17

Clothing estimates for all except the Efe are based on 18 minutes per unit.

4.6 Camp Maintenance Activities and Tasks

An analysis of archaeological features and spatial distribution of artifacts found in late Pleistocene living sites might provide information about the time and task-effort that prehistoric humans invested in their living arrangements. The duration of occupation, the area of the site, the spatial distribution patterns, the complexity of hearth construction, and the nature of dwelling structures provide us with a view into the

practices and capabilities of different groups during the period, even though all sites may not exhibit exactly the same features.

Short duration sites with few permanent facilities would indicate a more nomadic existence, similar to the Efe, where frequent investments in recurring construction of temporary shelters constructed of perishable materials do not leave a strong imprint on the landscape. Longer duration sites with more permanent features (such as built by the Machiguenga) imply lesser, maybe seasonal, mobility and greater investment over time in organization of living spaces. I use the time allocations in Chapter 3 as the baseline for time devoted to camp maintenance activities. I examine the archaeological record to estimate the number of tasks in this activity. I look to the analysis of archaeological remains in three areas: duration of occupancy and spatial organization of the campsite, the presence and form of hearths, and the complexity of shelter and storage arrangements.

I recognize that there are some severe limitations in categorizing the camp maintenance activities of a geographic area that spreads from the more temperate Iberian Peninsula to the climatically more extreme Russian Plains. In some areas the record is so sparse that it is difficult to draw general conclusions from one or two isolated occurrences, and the absence of evidence does not indicate the evidence of absence. However, there appears to be a trend towards better organization of space and investment in more complex hearths and structures, maybe associated with lesser residential mobility and larger group aggregations at home bases, as time progresses.

- **Constraints of Excavation Techniques**

Excavation techniques limit the information that can be gathered on spatial distribution. Widespread *decapage*, as employed in the former Soviet Union on open-air sites on the Russian Plains and in some open-air sites in Western Europe, provides us with invaluable information on site layout and distribution of work areas and living spaces. But trench excavation techniques, more commonly executed in Western Europe and useful in examining stratigraphy to identify chronological trends from remains associated with different living levels, provide little information about the overall layout of a site. Additionally, cave and rock shelters constrain living space and therefore do not always present a clear picture of how prehistoric people preferentially organized their production, eating, and sleeping activities. Spatial analysis of Flageolet I indicates that the distribution of artifacts was governed more by features within the cave than by any organization of activities by area (Simek 1984a; Simek 1984b). In addition, one would expect different adaptations dependent on the local ecological conditions: rock shelter and cave dwelling in more karstic regions and open-air settlements on the loess of the plains. Indeed, cave and rock shelters are not seen as particularly desirable locations by current hunter-gatherers and this may also have been the case in the Middle Paleolithic (Jelinek 1988). Mousterian sites such as La Quina were most intensively used when open-air sites were untenable, other sites, such as Grotte XV, Vaufray, may have been used merely as temporary shelter against the elements.

- **Spatial Organization**

As a tool for analyzing site layouts and patterns in the archaeological record, archaeologists have looked to current hunter-gatherers to determine the traces left by

bands or groups as they move through the landscape. In his study of archaeological traces left by the living patterns of the Dobe !Kung, Yellen identified the nuclear hearth as a key signal of how the !Kung organized activities in the camp (Yellen 1977). The central hearth is the focal point for activities undertaken within the nuclear family, specifically for tasks relating to food and non-subsistence materials carried into the site. The scatter around the hearth is thus representative of the many varied activities that might have taken place in the vicinity. Larger base camps usually house several nuclear families, who generally group themselves in a circle. An inner ring comprises several nuclear hearths and shelters, each with their own private areas, and a central common area where community activities occur, such as for dividing large game, or dancing and other festivities. An outer ring encircles a much larger area that includes, a) work areas for activities that are too large or messy to be performed around the hearth, such as initial skinning and butchery, and hide preparation activities such as stretching and drying, and b) other public areas where many families may gather in the shade to socialize and complete activities normally performed around the nuclear hearth. This pattern leaves an archaeological trace of a central area devoid of any significant remains, an inner ring of hearths and huts or shelters with a scatter of small objects (tools and bone), and an outer ring with some assemblages that resemble hearth activities and some that are left by specific work activities (often with larger artifacts). Binford, from his work with the Nunamiut describes this pattern as a maintenance or base camp and distinguishes it from another kind of camp, the extractive camp, kill site, collection station, or quarry for usable lithic materials, usually occupied by specialized work groups (Binford 1978b; Binford 2001). In a small temporary, maybe overnight,

camp the hearth and its scattering of remains is all that remains for the archaeological record. Clearly, Yellen's ring model is dependent on local topography; cave and rock shelter sites offer only constrained space for organizing living arrangements and the ring may be circumscribed to accommodate the limited shelter space, whereas open-air sites provide better opportunities for the optimum utilization of space and thus more meaningful analysis by archaeologists.

- **Hearths**

Hearths are the critical focal point for the analysis of living areas and the associated tasks accomplished. The capacity for organizing living areas, building more sophisticated and efficient hearths and shelters is evident in the record. The mere concentration of burnt material does not indicate a constructed hearth, even if heat-discolored rocks are included; a true hearth is constructed and used for a specified purpose. Hearths have been categorized by their complexity ranging from the thin ash lens, observed in most Mousterian hearths, to the more complex hearths of the Upper Paleolithic (Sonnerville-Bordes 1989):

- *Foyers amorphes* – short duration, thin layer of ash – simple hearths
- *Foyers dalles* – surrounded by stone, for cooking meat and for repetitive use – constructed hearths
- *Foyers creuses* – deeper with a vent (queue) for ventilation (wind oriented) and high heat generation – high output hearths or kilns.

Hearth-centered activities are detectable in sites, whatever the type of hearth. In Eskimo hunting stands, the centers of major hearths are typically spaced at 3m (Binford 1978b), similar to the spacing observed at Molodova V, Kostenki and Pavlov I (Gamble

1986). Seating positions around the hearth are set such that the individual is back-to-the-wind and may change with changes in wind direction. Toss or drop zones lying from 2.75-3m from the center of the hearth, will reflect these positions. For example, the scatter pattern of seated knapper is about 20-50cm², and a standing knapper about 6 m² (Gamble 1986). At the hearth, a variety of activities take place, and the assemblages of generally small items may represent the accumulation *in situ* from several unrelated activities - the drop zone, as distinct from the toss zone where remains are intentionally removed from the domestic activity area as part of a domestic cleaning process.

- **Dwelling Structures**

Shelters and storage pits are another signal of the range of specialized tasks involved in camp maintenance. Simple windbreaks easily constructed from plants materials may not be observed in the archaeological record, but more sturdy and complex structures begin to appear during the period of the transition from Neanderthals to modern humans. Simple windbreaks are succeeded by enclosed, sometimes subterranean, living spaces or huts, followed by clusters of separate, perhaps connected dwellings.

Finally, domestic tools and utensils begin to appear in the archaeological record. Heated stones for mulling and grinding, shovels and tools for excavation, matting and lamps for illumination; all appear during the course of the transition.

- i. **Early Neanderthal Camp Maintenance Tasks**

Early Mousterian sites generally point to small group (10 individuals), short-duration occupation, often with frequent seasonal visits, Grotte Vaufray, La Quina, Combe Grenal (Mellars and Stringer 1989). These short-duration sites show no trace of

shelter (Grotte Vaufrey), and even longer-term sites from the early period show no evidence of shelter of any kind, even though simple hearths are present (Biache-St-Vaast, La Cotte de St Brelade). Occasional gatherings of up to thirty individuals are observed at large kill sites such as Biach-St-Vaast (Tuffreau and Somme 1988). The Biache open-air site (and the later Mousterian site at Mauran) seems to be associated with warmer climate episodes, and closed sites such as Combe Grenal and La Quina with colder periods (Jelinek 1988). Living areas within Middle Paleolithic caves and shelters in southwestern France rarely exceed 30 m², in contrast to the larger Upper Paleolithic areas (Mellars 1973). At Mousterian sites, living floors tend to display a concentration of lithic and faunal pieces pushed to the periphery, leaving a central area relatively uncluttered – as at Abri Lartet, Montgaudier, Hauteroche and Arcy-sur-Cure (Rolland 1981). Overall, these observations indicate less intensive site use and smaller residential groups than for the Upper Paleolithic, albeit with significant regional variations.

There are few indications of attempts to modify living areas from the early Mousterian period, although there does appear to be a deliberate effort at improving the living space of the cave site at La Quina, an early Mousterian site: the surface of one of the upper levels was deliberately leveled off by Mousterian occupants, almost certainly to produce a more regular and roomy living area in the diminished space available below the rock overhang (Mellars 1996). Specialized zones, adjacent to simple hearths, for specific activities such as cutting, butchering, and lithic reduction have been identified at Biache-St-Vaast (Tuffreau and Somme 1988), Beauvais, Tönchesberg and Kůlna (Patou-Mathis 2000). Distinct zones for faunal processing, consumption and

discard, and areas for lithic procurement, from within 100 m of the site, and zones for lithic reduction resulting from ephemeral, short-term occupations are identified at Wallerheim, which dates to OIS 5e (Adler and Conard 2005). Similarly Grotte Vaufrey (Mellars 1996) reveals a localized distribution of archaeological artifacts and occupation by no more than three to four individuals. Separate distribution of faunal remains with heavily fragmented splinters concentrated in one small area, maybe indicating an incidence of marrow extraction (Simek 1989). Also, the spatial organization of lithics points to gross butchery taking place at the periphery and domestic butchery, as indicated by notches and denticulates, in a central living area (Rigaud 1989a). The Saalian deposits at La Cotte de St. Brelade are segregated in two separate areas with simple hearths interpreted as a) an intensely occupied site with a dense concentration of small bone splinters from a variety of species with numerous artifacts, and b) a specialized kill or scavenging site containing mostly large, and mostly broken, mammoth and woolly rhinoceros bones with few artifacts (Farizy 1994b). This pattern conforms to Yellen's description of spatial arrangement among the Dobe !Kung with nuclear spaces where family activities occur versus specialized areas where messy or space-consuming activities take place (Yellen 1977), and Binford's distinction between maintenance camps where subsistence and raw materials already on hand are processed and work sites such as kill sites, quarry, or butchery locations (Binford 1978b).

Constructed hearths are relatively rare before the early Wurm, the beginning of OIS 3, and during the Riss, OIS 5, these hearths did not exist. The identification of a true hearth implies that there was some deliberate construction for specific usage. In

addition, a constructed hearth is a social location, where group activities and conversation takes place. Judging from the human-scale spatial layouts recognized in a social gathering, few indications of a social hearth appear in the Mousterian record (Gamble 1999). At La Cotte, although there is some indication of small fires, *foyers amorphes*, there is no concrete evidence of hearths. This is in contrast to Upper Paleolithic sites, which show more elaborate maintenance and periodic clearance of debris and refuse, illustrating what has been described as the “domestication of living space” (Leroi-Gourhan 1976).

As far as shelter is concerned the evidence is slim. Earlier reports of shelter at Le Lazaret and Terra Amata have been discounted (Villa 1982). Some middle Paleolithic structural remains have been excavated at the site of Rheindahlen Westwand. The position of a large oval pit 4 x 3 m sunk into the loess from the last interglacial associated with a concentration of artifacts, suggests an artificial origin (Gabori-Csank 1976). The pit was surrounded by three work areas: to the east an area of retouched tools and burned bone suggesting a hearth, to the northeast an area with a high proportion of roughly worked nodules and large flakes, and to the south an area for fine working with many small waste flakes. On the other hand, on the Russian Plains the majority of mapped occupation floors in Mousterian open-air sites reveal no traces of artificial shelter. Although hearths are present in many Mousterian caves and open-air sites on the Russian Plain, ranging from small scatters of charcoal fragments to ash lenses measuring several square meters in area and up to 5 cm in depth, most are less than one meter wide and 2 cm deep. The deep hearth pits of the Upper Paleolithic are absent (Hoffecker 2002). There is no sign of the use of bone as fuel.

In the early Mousterian there are no signs of shelter and storage pits. This may well be because most stays were in temporary camps, which left little trace in the record.

ii. Late Neanderthal Camp Maintenance Tasks

Late Middle Paleolithic settlements seem little more complex than earlier ones, in terms of number of occupants, features, contents, area, or period of occupancy (Gamble 1999). Short-term, repetitive visits by small family groups of ten or less seem to be the pattern at El Castillo in Iberia (Cabrera, Pike-Tay et al. 2000), southwestern France (Mellars and Stringer 1989), and the Caucasus (Hoffecker and Cleghorn 2000). Vanguard Cave contains a flat, open hearth with rushes collected for bedding materials for one or two adults and their offspring, and nearby Gorham's Cave suggests numerous occupation episodes, with deposits of artifacts, lithic knapped from local pebbles, shellfish, bone and charred remains of pine nuts (Barton 2000).

Perhaps the most intriguing later Middle Paleolithic site is at Abric Romani (Vaquero and Carbonell 2000). Earlier short-term occupations, maybe with stopover episodes (Pastó, Allue et al. 2000; Vaquero, Vallverdu et al. 2001) were restricted to small areas with accumulations around hearths that are generally flat and invariable – similar to the footprint of early Mousterian sites. In these lower layers, there is no evidence of secondary accumulation (cleaning) or intentional artifact transport between different areas. These visits seem to have occurred during periods of climate fluctuation around 52-50 ka (Soffer 1985a, 1985b). Later layers show signs of longer-term occupations, extending over most of the site with deliberate arrangements of internal elements, and with inter-zonal transport and secondary refuse remains. Functional

specialization is observed in certain areas at Abri Romaní, with movement of cores and retouched objects across the site and segmentation of reduction sequences between different areas. Preserved wooden planks may have been used in food preparation and wooded pseudomorphs may represent benches or seating arrangements (Pastó, Allue et al. 2000). Hearths show more intense combustion with greater variability. Three preserved sticks suggest a cooking tripod. Other pseudo-morphs may have been stores of wooden fuel (Castro-Curel and Carbonnell 1995). All this suggests longer-term occupation by larger groups, which occurred during the Hengelo interstadial 46-45 ka. The authors contend that there is no data to suggest that later hearth-related accumulations documented at the Abri Romaní are substantially different from those of ethnographic hunter-gatherers or Upper Paleolithic sites such as Abri Pataud, Le Flageolet I, Etoilles, Marsagny, or even the Magdalenian site of Pincevent.

Farizy and David (1992; 1994) analyzed the open-air sites of Maura and Champlost to seek information on organization and subsistence patterns. Both sites show accumulations of debris indicative of recurrent use for similar purposes over different lengths of time; Maura being a seasonal kill site where few animals were killed at any one time and from which parts were transported for consumption elsewhere, and Champlost being a base camp where killed animals were brought back for consumption. Maura appears to have been seasonally occupied over a prolonged period, maybe of several hundred years. Bison dominate the faunal assemblage. Small herds were killed by small groups of thirty individuals; men, women, and children (Farizy 1994b). At Maura, dated between 35 and 45 ka, the absence of spatial patterning is matched by the lack of hearths (Gamble 1999). The Champlost site

includes numerous highly specialized retouched scrapers and, although some spatial patterning is observed, there is no indication of any specialized areas or concentrations of specific forms of debitage or tools, which suggests that the archaeological deposit is a palimpsest (Farizy 1994b). The relative frequency of different varieties of lithic materials appears to be similar across the excavated area. However, these spatial patterns at Mauran and Champlost do not show a functional distinction of particular areas of the sites in the way that is evident in Upper Paleolithic settlements (Farizy and David 1992; Farizy, David et al. 1994).

A large number of sites were mapped during the period of the Soviet Union and the majority of the mapped floors indicate no traces of artificial shelter. The Mousterian occupation areas of the East European Plain reveal a recurrent pattern of randomly distributed artifact and or faunal debris concentrations of varying size and density (Molodova I - Mousterian layers 1-5), Molodova V - layers 11, 12a, 12), Ripiceni-Izvor and Ketrosy, Sukhaya Mechetka, Rozhok I, each with exposed areas ranging from 225 sq m to 1200 sq m.). Hearths are associated with some debris concentrations, but are also found in isolation; a consistent pattern between the two features seems to be lacking. The occupation layers reveal a low level of structure or organization in the use of space compared to the later modern human sites (Hoffecker 2002). The lack of organization of working areas (represented by debris concentration) around hearths is significant (Mellars 1996). This is particularly significant given the open landscape and harsh climate necessitating some kind of shelter from the elements.

While most Neanderthal hearths were less effectively structured than those of the Upper Paleolithic (Rigaud 1989b), the presence of a deliberate hearth at the Grotte

du Bison at Arcy-sur-Cure, that consisted of an ash-grey oval area containing bone fragments and burnt stones enclosed quite regularly by a circle of blackened and heated blocks (Farizy 1990), attest to the fact that, on occasions, they could be well-defined and effective heating structures. But the Middle Paleolithic layers of the Grotte d'Hyène at Arcy-sur-Cure show few signs of any such type of organization. At most, some areas reveal possible evidence of cleaning. Hearths are found generally at the entrance of the caves with the exception of one small hearth surrounded by stones discovered inside the Grotte du Bison (Gabori-Csank 1976). Later Chatelperronian occupations at the Grotte du Renne show spatial patterning more characteristic of the Upper Paleolithic (Farizy 1990). Hearth-related domestic areas represent a basic spatial unit in Middle Paleolithic settlement strategies, irrespective of occupation length or group size. Short-stay, small group visits are evidenced by Mousterian hearth related concentrations, with a predominance of small remains, as documented for Canalettes, Hauteroche, Fontmaure, Saint Césaire, Grotte XV, Karstein, Vanguard Cave, and Abric Romani (Vaquero and Pasto 2001).

Constructed shelters during the late Mousterian are limited to windbreaks or lean-tos. There is no concrete evidence for more sophisticated covered dwellings or huts. Evidence of the earliest kind of artificial windbreaks may come from the late Mousterian, and domestic space began to demonstrate some greater level of organization towards the end of the period (Patou-Mathis 2000). The most likely example of any Mousterian artificial shelter is at level 4 at the open air site of Molodova I, and maybe at Ripiceni-Izvor, but these lack clear evidence of structural debris, post holes, or central hearths, and probably merely represent windbreaks (Soffer 1989a).

The late Mousterian structures at Molodova- I layer IV, (rather than being mammoth-bone dwellings, as originally claimed) are more akin to a series of diachronically-utilized windbreaks analogous to those constructed for the late Mousterian layers at Ripiceni-Izvor in Romania. Detailed analysis of the Molodova structures indicates that they were not sufficiently high nor sufficiently sturdy to support a roof structure, and that they were merely windbreaks.

In excavations performed in the 1960-1970 timeframe at Ripiceni-Izvor three different kinds of habitation structures were found in five of the six Mousterian levels (Paunescu 1989) dating between 58 and 36 ka (Mertens 1996). The simplest structures consist of a temporary arcuate lean-to within which lithic and faunal remains are found. This short-term structure is believed to have been a fence of pine branches supported by rocks and trampled earth to shelter the inhabitants from the biting northeasterly winds. The largest (7 x 5 m) was constructed of about 70 limestone blocks supporting pine branches and mammoth tusks, with an enclosed hearth and a lithic workshop to one side. This has been interpreted as a possible shelter with three entrances and an open central area, since the structure could not have supported a roof overall, but once again situated to protect against the northeasterly winds. Oval concentrations of lithic and bone materials from 30-50 m in area, and sometimes with shallow hearths, often partially overlapping one another, are characteristic of late Middle Paleolithic sites along the Dnestr. The spatial integrity of these ovals is far from clear-cut, and it is more likely that they are palimpsests of repeated occupations (Soffer 1989a).

In Cantabria, at Cueva Morin, Mousterian level 17, a fragmentary structural feature was uncovered, and, as at Ripiceni-Izvor, it is suggested that, rather than a hut

structure, this wall supported an arcuate screen wall or similar physical barrier separating the well-lit and heavily utilized area closest to the cave entry from the dark cave interior that was seldom used (Gabori-Csank 1976; Freeman 1989). This alignment of stones isolated an enclosure of some 6.6 m² of arched contours, which closed access to the interior. Inside this enclosure are three work zones: one zone with a concentration of cleavers and bone remains, another near the entrance of the cave with side scrapers, notches, and flakes, and the third zone with an assemblage of blades, small flakes, and perforators. The entire enclosure within the cave could not have contained a large group of persons (Cabrera Valdes and Bernaldo de Quiros 1992).

Large numbers of deep pits, filled with bone and debris, are found in the treeless area of the central plains, but are generally absent in the southwest where wood is present. Since there is a strong correlation with bone ash and the large numbers of non-meaty parts, it suggests that they were most likely used for maintaining fuel reserves rather than meat (Hoffecker 2002)). However, the discovery of an obviously excavated pit covered with 90 kg of large rocks in the upper deposits at La Quina, and the presence of other enigmatic pits at Combe-Grenal, La Ferrassie, Le Moustier, and Pech de l'Azé, all suggest that the Neanderthals that inhabited these sites had some system of storage that would indicate that they were thinking ahead in terms of time and space, especially during colder intervals (Jelinek 1994).

In general, Neanderthal sites lack indisputable traces of artificial shelters and well-constructed hearths (Gamble 1994). There is also little evidence for Mousterian untended facilities that represent technological adaptations to cold environments among modern hunter-gatherers. Mousterian hearths tend to be isolated or associated with

randomly distributed artifact and faunal debris with no consistent pattern of linkage between the two (Soffer 1994), only rarely are there clear indications of hearth related activities (Farizy and David 1992; Farizy, David et al. 1994). It seems that Neanderthals did little housekeeping and spent little time constructing shelter or hearths (Soffer 1992). Mousterian occupational floors reveal a low degree of structure or organization in the use of space in contrast to later Upper Paleolithic sites with highly structured arrangements of dwellings, hearths, pits and debris concentrations (Hoffecker 2002).

Farizy (1994b) concludes that the analysis of Middle Paleolithic spatial patterns leads us to focus on the repetitiveness of behavior over generations, rather than the ways that people organized their space in any single occupation. A similar point is made by Koetje who notes that there is good evidence for the same type of general use of locations through time in sites ranging from the Lower and Middle Paleolithic to the later Magdalenian despite changes in the climate, environment, culture, hominid type, etc (Koetje 1994).

iii. Early Upper Paleolithic Camp Maintenance Tasks

Larger and more organized settlements appear throughout Eastern and Western Europe with the advent of the Aurignacian; campsites in excess of 15 m² are not uncommon and clusters of closely situated campsites are observed (White 1983). Settlements are characterized by distinct functional spatial organization around hearths and within campsites and hunting stations. Kitchen areas, butchering space, sleeping grounds, and discard zones are frequently observed in Upper Paleolithic sites. Such features are better preserved in the later phases (after 20 ka), but even the very early

Upper Paleolithic sites produced good examples of such organization (Bar-Yosef 2002). Longer duration occupation by larger groups probably necessitated more attention to housekeeping.

Needless to say, not all Aurignacian sites contain the complex habitation and hearth structures with indications of longer-term occupations as discussed here. Aurignacian assemblages are numerically small, and Aurignacian complex base camps are limited. The transport distances of quality lithic and exotics increase dramatically in the Aurignacian as does the evidence for manufacture of symbolic display items and representation, all suggesting more complex social networks (Gamble 1999). At Geissenklösterle-Höhle (Hahn 1988) there are two Aurignacian levels the upper – (levels II_n/II_b) and the lower – (levels II_d, III, III_a and III_b) – 30-36 ka, both of which indicate rather short occupations by fewer than ten individuals. The cave was not suitable for longer stays. This suggests that work groups used it as a temporary stopover during inclement weather, frequent in the spring and fall. The contents however, have many Aurignacian characteristics: the upper level was a spring occupation as suggested by eggshells and fish remains, and signs of carving bone, antler and ivory tools and pendants, and hide working. The site may have acted as a cache since some of the art objects were complete. However, unusually for the Aurignacian, raw materials sources of brown yellow chert, describe a territory of only 9,000 km sq., less than 1% of the materials come from distances greater than 20 km.

In Iberia, the Upper Paleolithic layer at Abric Romaní can be compared to coexistent late Neanderthal sites, which were limited to mountain areas, characterized by a limited array of resources and away from the main corridors where modern humans

settled in littoral and pre-littoral formations. The Upper Paleolithic layer is evidenced by a lower incidence of carnivore marks in the bone record suggests longer occupations during the Upper Paleolithic (Vaquero and Carbonell 2000). Bone is represented and perforated shells, teeth and perforated fish vertebrae are found.

The spatial organization of hearth, windbreak, and work areas in the Aurignacian layers at Le Flageolet I illustrates distinct differences from late Mousterian spatial layouts (Rigaud 1976). The Aurignacian layer includes an elliptic hearth (70 x 50 cm), with one large pebble, and several smaller ones with traces of burned bone and wood, and surrounded by rubified silex in one area and heated stones in another. In the narrow corridor created by the natural rock is a constructed pile of rocks and together with several larger blocks. These contain *cupoles*, which have been interpreted to be the base support for a framework of tree trunks that enclosed in the shelter. There appear to be separate work areas for working cores and *bois de renne*, separate internal and external butchery areas, as well as an eating area, and a peripheral area for the disposal of bones broken for extracting marrow (Koetje 1994). K-means analysis of clustering of artifacts shows temporally separate occupations, demonstrating similar use of the limited space, constrained by rock falls which determined the spatial patterning (Simek 1984a).

Although the early hearths of Le Flageolet I, as described above, are extremely modest, other Aurignacian sites (Abri Pataud and Abri du Facteur) have more discrete constructed hearths. Excavations at Abri Pataud in the Perigord found a complex series of hearths with selected river stones, some heat-cracked, in the intermediate Aurignacian levels A and B that were dated to about 30 ka (Movius 1966; Movius

1974). Two distinct Aurignacian levels contain hearths, the earlier one built without river stones, and the latter one more complex and constructed with built of river stones (Movius 1974; Movius 1975; Movius 1977). The living area of 4 x 5.3 m is projected to have supported a single extended family, or a micro band of one to three nuclear or extended families to maximum of seven persons (Spiess 1979). The open air site at Solvieux-Ouest - level IV contains an Aurignacian level, in which there are a series of limestone block structures, one of which is associated with a shallow basin filled with charcoal-charged earth (Sackett and Gaussen 1976). The presence of constructed hearths at these sites is in stark contrast to Mousterian open-air site at Mauran (Gamble 1986), where, at the most, only ephemeral fires were observed.

The earliest evidence of sophisticated use of fire, *foyers creuses*, is demonstrated at Klisouri in Greece. Here about 90 hearths were uncovered in the middle and lower Aurignacian layers (Koumouzelis 2001). Many just consist of a sequential accumulation of burnt remains, but fifty-four hearths have basin-like, clay-lined structures that were sunk in the ground to a depth of 10 to 20 cm into the cave sediments. Microscopic examinations have shown that the basin walls were lined with specially prepared daub, containing clay brought from an area about 1-3 km distant. No such clay deposits are in the cave area. Further examination of the thermally altered minerals in the clay lining indicates that it was fired at about 600–650° C. One hearth contained starches typical of seed grasses found in phytoliths, which suggests that the structures were possibly used for roasting grains or wild grasses. It has also been suggested that the structures are probably the oldest evidence for the emergence of ceramic technology (Karkanas, Koumouzelis et al. 2004). In the upper Aurignacian

layers, the excavations have revealed seventeen, well-preserved clay hearth structures with pronounced thickened rims implying a long tradition of producing such structures (Karkanas, Koumouzelis et al. 2004).

There is little evidence of more complex structural shelter in Western Europe, although, behind the massive rock fall in level 3, at Abri Pataud, are the remains of a 'long house', marked by a line of five hearths with a possible collapsed wall of limestone blocks (Spiess 1979). In level 4, there is a semi-circular hut foundation with a group of hearths and concentration of bone remains within the stone circle. Aurignacians may have carved *annules* into the rock-shelter or cave overhang to support hanging screens. Examples of Aurignacian *annules* may be seen at the Musée Castanet, Sergeac and at Font de Gaume, Les Eyzies.

Further east there is much stronger evidence of clusters of constructed, subterranean dwellings, indicative of larger social gatherings during harsher times. In Slovakia, the early Aurignacian site of Barca II contains four complexes of independent habitations consisting of pear-shaped depressions, surrounded by a series of postholes, with a stairway leading from the base to the surface (Sackett and Gaussen 1976). These depressions are on average 4 m long, 3 m wide around and 50 – 60 cm deep, with one as large as 18 x 3.4 m and 80 cm deep. Surrounding these are some pits for provisions. This arrangement has been interpreted as a series of independent cabins, maybe linked by passageways, or may have been totally covered with a tent-like structure as evidenced by the placement of postholes and stones, perhaps for anchoring the cover. Refitting of tools found in the different habitations evidences the contemporaneity of the settlements. At Barca I, three complexes have been excavated dating to the later

Aurignacian; the largest being 24 m long and 3 m wide with seven hearths, linked by a central corridor. These sites are interpreted as winter camps where groups congregated once they had completed their autumnal provisioning. It is estimated that each dwelling could support 4 to 5 individuals, with the entire cluster having about 25 occupants. In Eastern Europe lower (40-39 ka), and upper (37-28 ka) humic bed occupation floors contain former hearths and debris concentrations, the hearths range from 0.25 and 1.0 sq m in area and 5-15 cm in thickness. At Kostenki XV (Gorodtsovskaya), excavation revealed an oval pattern of debris, which is believed was demarcated by an ancient structure (Klein 1969a). Remains of two hearths and two storage pits were uncovered. In one of the pits were found bone paddle-shaped shovels, in the other the remains of a five year-old child. Altogether eleven whole or fragmentary shovels (26 cm long with a 6 cm blade) were found as well. Mapping of the occupation layers at Molodova V reveals concentrations of debris, many associated with formal hearths (Hoffecker 2002). Nearby in Kulichivka, three shallow oval depressions with traces of artificial structures, each containing one or two central constructed hearths lined with small stones. However, the site at Molodova is particularly instructive since it contains lower Mousterian levels that show little effort placed into construction of dwellings compared to the more developed structures of the Upper Paleolithic Molodova Culture. Here in one geographic location, albeit with different climatic conditions, the comparison between the Mousterian and Aurignacian approach to habitation is quite striking.

In addition to structural developments, this period saw the introduction of domestic tools and utensils, parietal, and portable art. The Upper Paleolithic, Molodova Culture (30-25 ka) at Molodova and Kulichivka contains small sandstone cobbles

interpreted as grinding stones and an antler haft at Kulichivka. At Mezin, dated to about 32 ka, five concentrations of mammoth bones were uncovered and have been interpreted as house ruins, three of which encircled one or more hearths and were associated with pits and high concentrations of cultural debris, including portable art: birds with folded wings, phallic symbols and mammoth bones painted with red ochre line and dot patterns (Klein 1973).

New focus on micro wear analysis of possible Aurignacian textile instruments has found weaving sticks of bird bone at Dolní Věstonice I and Kostenki IV that are ethnographically associated with the spinning of cordage. Lissoirs from Abri Castanet and Abri Blanchard bear similar edge wear and ostensibly represent fragments of battens, weaving sticks, mat needles and net spacers. Mammoth tusks from Vogelherd, fashioned into long thin needles, likely used for sewing mats and other textiles (Soffer 2004).

Compared to the stability and lack of innovation shown by the Neanderthals across Europe, the Aurignacians extended their lithic sourcing, their exotic and social networks, and developed many different ways of organizing the campsite within their local ecologies, whether on the open plains of Russia or the caves in the valleys of southwestern France, a trend that would continue into the Gravettian period as the climate deteriorated.

iv. Middle Upper Paleolithic Camp Maintenance Tasks

Middle Upper Paleolithic sites of the Upper Perigordian and later periods show much clearer evidence for highly structured internal organization than any of the sites so far documented from the Lower and Middle Paleolithic. This almost certainly

reflects an greater investment in camp structures in the expectation of much longer periods of occupation (Mellars 1973; Soffer 1985a; Soffer 1985b; Gamble 1986). Clusters of dwellings at Dolní Věstonice, Pavlov, Kostenki, and Avdeevo may have supported 100 to 200 inhabitants (Banesz 1976; Vandiver, Soffer et al. 1989). At Sunghir', on the Eastern Plains More than 40 hearth pits mostly associated with debris concentrations were mapped (Hoffecker 2002). There appear to be significant differences in the spatial organization and use of occupational surface in the middle Upper Paleolithic, involving the segregation of artifact categories, surface cleared of refuse, and more clearly structured hearths (Jelinek 1994); this kind of evidence is not yet obviously so evident in the earliest Aurignacian (Rigaud 1989b). Later in the Upper Paleolithic, increasing organization of space and the appearance of truly differentiated activity areas is evident, as much in open-air sites (Pincevent, Etoilles, Verberie, Villereest) as in rock shelters (Le Flageolet) (Rigaud 1989b).

Clearly structured, dug-out Gravettian hearths are encountered at Isturitz, and, more elaborately, at the rock shelter sites of Abri Pataud and Le Facteur (Straus 1990). The Abri Pataud has three Perigordian levels, dating from 27.7 ka to 23 ka. Each level contains bonfire type hearths indicating occupation by larger social groups (Movius 1966). The earliest level excavated intruded on the earlier Aurignacian horizon, in order to make more headroom. The later two levels indicate a "long house" arrangement (7 m x 3 m) of five and six hearths with semi-circular stone surrounds (Movius 1974; Movius 1975; Movius 1977). The space is sufficient to support a larger social group than that of the lower Aurignacian levels, which was only sufficient for a single extended family. At Corbiac, an Upper Perigordian, open-air site near Bergerac

in the Dordogne, there are two highly structured living floors, defined by postholes and containing a distinctive type of deep hearth with a ventilator shaft (Bordes 1968).

The most sophisticated but unusual use of fire is to be found in the Eastern Gravettian complexes of Dolní Věstonice, I, Pavlov, and Předmostí (Vandiver, Soffer et al. 1989). Two kilns, *foyers creuses*, were excavated at Dolní Věstonice, one inside a circular hut and the other surrounded by a horseshoe shaped wall. Firing temperatures are estimated to be above 700° C. These were used to create ceramic objects that were mysteriously broken after firing. These were expensive constructions, since in order to achieve the high temperatures necessary for ceramic production, a kiln must be insulated and enclosed, the draft must be controlled to optimize the spread of heat within the oven, and the kiln must have shelving to support the ceramic-ware.

In the Middle Upper Paleolithic, even more complex, excavated, hut-like dwelling structures appear. A unique site at Barca –Svetla III contains an aboveground Gravettian structure (5.4 m x 4.3 m) surrounded by a raised embankment of 30 cm, placed so as to contain the base of the tent-like structure (Sackett and Gaussen 1976). A Gravettian site at Spadzista Street in Poland includes two Gravettian, oval dwellings constructed of tusks, ribs, and jaws from 20 mammoth. The site of Dolní Věstonice encompasses five tent-like dwellings, in the center of which is a pit where the Venus of Věstonice was found. At this site, one sees well-constructed winter dwellings, seasonally alternating with large, uncovered summer dwellings or lean-tos with several hearths. It is suggested that there were 20 to 25 occupants per dwelling for a total of between 100 and 200 individuals in all. However, the richest Gravettian site in this area is that of Pavlov. Eleven circular or oval dwellings, each with between one and four

hearths with additional hearths placed between the dwellings. Each dwelling has evidence of postholes and is circumscribed by stones and animal bones. All these represent long duration sites (Vandiver, Soffer et al. 1989).

Widespread use of bones as building material (Kozlowski 1990), and as fuel (Hoffecker 2002) is recorded only with the Gravettian techno complex. The East Gravettian offers the most convincing examples of shelter: at Kulichivka I, and Kostenki I/1 shallow circular or oval depressions, measuring several meters in width, contain a centrally placed hearth and large quantities of debris (Hoffecker 2002). Micro wear analysis of mattocks found at Kostenki I, indicates that they may have been used to excavate at least 25 cubic meters of thick loam to create a subterranean dwelling (Semenov 1973). The occupation floor of Kostenki VII layer 2 contained traces of up to five artificial shelters (which may also represent working areas), with oval concentrations of debris measuring roughly 5-7 m in diameter surrounding formal hearths (Klein 1969a). Special attention was given to the foundations of the huts, which were often reinforced by stone slabs or mammoth tusks; extensive studies of the house-building technology at the Kostenki sites indicate that all the construction elements were designed for the maximal insulation of the dwelling during this period of extreme cold (Masson 1993). The so-called longhouses at Kostenki I/1, Spadzista Street, Mezhirich, Barca I and II, and Avdevo are most likely clusters of small dwellings (Gamble 1986). These dwellings may have supported from 100 to 200 inhabitants (Sackett and Gaussen 1976).

At Kulichivka (30-25 ka), probable traces of artificial shelters with interior hearths are observed, and small sandstone cobbles have been interpreted as grinding

stones. Mapping of the occupation layers reveals concentrations of debris, many associated with former hearths (Hoffecker 2002).

Small cache pits and larger (5 m²) pits are found at open-air sites such as Avdeevo, Pavlov, Dolní Věstonice, Khotylevo II, Kostenki I-1 and 2, and Spadzista. These sites are all associated with the Pavlov or Kostenki-Avdeevo cultures and are interpreted as storage pits (Soffer 1987a). There is, however, no direct evidence for the use of permanent storage in Western Europe; some underground pits were found at Corbiac but were empty and therefore do not provide evidence of food or fuel storage (Soffer 1989b). Soffer believes that these pits indicate that these sites in the Dnepr-Desna basin represent longer-term sedentism even during the glacial maximum.

Finally, objects described as lamps definitively appear only late in the Upper Paleolithic. The earliest uncontested lamp comes from the Gravettian at Laugerie-Haute. It is possible that two Aurignacian artifacts from La Ferrassie, one Gravettian artifact from Arcy-sur-Cure, and one from Saint-Jean-de-Verges are lamps. Other Gravettian lamps have been identified from Pair-non-Pair, Isturitz, Abri de Flageolet, Abri Labattut, and Grand Abri de Laussel (de Beaune 1993). Gravettian lamps carved from mammoth femur are found at Kostenki I (Hoffecker 2005).

My analysis of camp site layout and structures identified the following features that represent the outputs of distinct production processes that could be executed by specialists working within a cooperative group (see Table 4-13).

Table 4-13 Camp Maintenance Features

Feature	Early Neanderthal	Late Neanderthal	Early Upper Paleolithic	Middle Upper Paleolithic
<u>Spatial Organization</u>				
Floor leveled	✓	La Quina (a)	✓	✓
Subterranean area excavated	✓	Rheindahlen (b)	✓	✓
Debris concentrated	✓		✓	✓
Specialized areas organized	✓	Biache-Saint-Vaast, Beauvais, Tönchesberg and Kulna (d)	✓	Le Flageolet (h)
Storage pits	✓	Combe-Grenal, La Ferrassie, Le Moustier, Pech de l'Aze (i)	✓	Pincevent, Etoilles, Verberie, Villereest (h)
Debris cleared	-	Russian Plain (j)	✓	France (k)
<u>Hearths</u>				
Simple hearth	✓	Russian Plain (l), Les Canalettes, Hauteroche, Fontmaure, Saint Césaire, Grotte XV, Karstein, (m)	✓	✓
Complex hearth constructed or excavated	-	-	✓	Le Flageolet I (o), Abri Pataud (p)
Hearth ventilated (kiln)	-	-	✓	Klisouri (r), Corbiac (s)
<u>Shelter</u>				
Stone wall/windbreak	✓		✓	✓
Complex windbreak with post hole, cupole for support	-	Molodova V, Korman' IV, Ketrosy, Sukhaya Mechetka, Rozhok and others (v)	✓	✓
Hanging screen with annules	-	-	✓	Blanchard Font de Gaume (x)
Hut/tent-like structure with supporting roof	-	-	✓	Abri Pataud (z), Barca II (aa), Kostenki XV (bb)
Clusters of dwellings	-	-	-	✓
Lamp	-	-	✓	La Ferrassie (ff)
Total	6	7	14	15

References from Text in Support of Table 4-13

- a. A deliberate effort at improving the living space of the cave site at La Quina (Mellars 1996).
- b. Middle Paleolithic structural remains have been excavated at the site of Rheindahlen Westwand. The position of a large oval pit 4 x 3 m sunk into the loess associated with a concentration of artifacts, suggests an artificial origin (Gabori-Csank 1976).
- c. An enclosure of reindeer antler at Raj Cave, Poland suggests an early artificial shelter and semi-subterranean dwellings are suggested in Slovakia and Moravia but may be the effects of erosional processes. (Kozłowski 1990).
- d. Specialized zones for specific activities such as cutting, butchering and lithic reduction have been identified at Biache-Saint-Vaast (Tuffreau and Somme 1988), Beauvais, Tönchesberg and Kulna (Patou-Mathis 2000).
- e. Functional specialization is observed in certain areas at Abri Romani: movement of cores and retouched objects across the site, segmentation of reduction sequences between different areas. Preserved wooden planks may have been used in food preparation and wooded pseudomorphs may represent benches or seating arrangements (Pastó, Allue et al. 2000). Hearths show more intense combustion with greater variability. Three preserved sticks suggest a tripod.
- f. Domestic space demonstrates some level of organization towards the end of the Mousterian period (Patou-Mathis 2000).
- g. Spatial patterning at Mauran and Champlost did not show a functional distinction of particular areas of the sites in the way that Upper Paleolithic settlements do (Farizy and David 1992; Farizy, David et al. 1994).
- h. Later in the Upper Paleolithic increasing organization of space and the appearance of truly differentiated activity areas, as much in open-air sites (Pincevent, Etoilles, Verberie, Villerey) as in rock shelters (Le Flageolet) (Rigaud 1989b).
- i. The discovery of a clearly excavated pit at La Quina, and the presence of other enigmatic pits at Combe-Grenal, La Ferrassie, Le Moustier, and Pech de l'Aze all suggest that the Neanderthals had some system of storage (Jelinek 1994).
- j. Neanderthals did little housekeeping and spent little time constructing shelter or hearths (Soffer 1992).
- k. Upper Paleolithic sites show more elaborate maintenance and periodic clearance of debris and refuse, illustrating what has been described as the "domestication of living space" (Leroi-Gourhan 1976).
- l. Mousterian hearths tend to be isolated or associated with randomly distributed artifact and faunal debris with no consistent pattern of linkage between the two (Soffer 1994).
- m. Mousterian hearth related concentrations, with a predominance of small remains, are documented for Les Canalettes, Hauteroche, Fontmaure, Saint Césaire, Grotte XV, Karstein, Vanguard Cave, and Abri Romani (Vaquero and Pasto 2001).
- n. Structured hearths with or without the use of rocks for warmth banking and parching activities were recorded in Upper Paleolithic sites. Variable types of hearths are known from both Middle and Upper Paleolithic contexts, although the use of rocks is almost exclusively documented from contexts of the latter period (Bar-Yosef et al. 1992, Meignen et al. 1989, Rigaud et al. 1999, Pastó et al. 2000).
- o. The site of Le Flageolet I contains several Aurignacian (couche XII to VIII) and Gravettian (couche III to 0) layers (Rigaud 1976). The layout includes an elliptic hearth (70 x 50 cm), with one large pebble and several smaller ones and with traces of burned bone and wood and surrounded by rubified silex in one area and heated stones in another.
- p. Excavations at Abri Pataud in the Perigord found a complex series of hearths with selected river stones in the intermediate Aurignacian levels A and B that were dated to about 30 ka (Movius 1974). Two distinct Aurignacian levels contain hearths, the earlier one built with river stones and the latter one more complex and built of river stones (Movius 1974; Movius 1975; Movius 1977). A living area of 4x5.3m is projected to have supported a single extended family.
- q. In eastern Europe lower and upper humic bed occupation floors contain former hearths and debris concentrations, the hearths range from .25 and 1.0 sq m in area and 5-15 cm in thickness. More than 40 hearth pits were mapped at Sunghir' mostly associated with debris concentrations (Hoffecker 2002): 188. Widespread use of bones as building material is recorded only with the Gravettian techno complex. (Kozłowski 1990). Bone fuel (Hoffecker 2002).
- r. At Klisouri, in Greece about 90 hearths were uncovered in the middle and lower Aurignacian layers (Koumouzelis 2001). Fifty-four hearths have basin-like, clay-lined structures that were sunk in the ground to a depth of 10 to 20 cm.
- s. At Corbiac, an open-air site near Bergerac in the Dordogne from the Upper Perigordian there are two highly structured living floors, defined by postholes and containing a distinctive type of deep hearth with a ventilator shaft (Bordes 1968).
- t. The most sophisticated but unusual use of fire is to be found in the Eastern Gravettian complexes of Dolní Věstonice, I, Pavlov, and Předmostí (Vandiver, Soffer et al. 1989). Firing temperatures in two kilns are estimated to be above 700° C.

- u. In Cantabria, at Cueva Morin, Mousterian level 17, an arcuate screen wall separated the well-lit area closest to the cave entry from the dark interior (Gabori-Csank 1976; Freeman 1989).
- v. No traces of artificial shelter (Molodova V, Korman' IV, Ketrosy, Sukhaya Mechetka, Rozhok and others) (Hoffecker 2002).
- w. Detailed analysis of the Molodova and Ripiceni-Izvor structures indicates that they were not sufficiently high nor sufficiently sturdy to support a roof structure and that they were windbreaks (Paunescu 1989).
- x. There is little evidence of structural shelter in western Europe but Aurignacians may have carved 'annules' into the rock-shelter or cave overhang to support hanging screens: Musée Castanet, Sergeac and at Font de Gaume, Les Eyzies.
- y. The majority of mapped occupation floors in Mousterian open-air sites on the Russian Plain reveal no traces of artificial shelter. Although simple hearths are present in many Mousterian caves and open-air sites, most are less than one meter wide and 2 cm deep. The deep hearth pits of the Upper Paleolithic are absent. (Hoffecker 2002): 108.
- z. Behind the massive rock fall in level 3 at Abri Pataud are the remains of a 'long house', marked by a line of five hearths with a possible collapsed wall of limestone blocks (Spiess 1979). Mobiliary art, groups of incised reindeer incisors are among over 1600 lithic artifacts found here. In level 4 a semi-circular hut foundation with a group of hearths and concentration of bone remains within the stone circle.
- aa. In Slovakia the early Aurignacian site of Barca II contains four independent habitations consisting of pear-shaped depressions with a stairway leading from the base to the surface. Surrounding these are pits for provisions (Sackett and Gaussen 1976).
- bb. At Kostenki XV (Gorodtsovskaya) excavation revealed an oval pattern of debris, which is believed was demarcated by an ancient structure (Klein 1969a). Remains of two hearths and two storage pits were uncovered. Altogether eleven whole or fragmentary shovels (26 cm long with a 6 cm blade) were found as well as 10 fragmentary needles.
- cc. A unique site at Barca -Svetla III contains an aboveground Gravettian structure (5.4 m x 4.3 m) surrounded by a raised embankment of 30 cm, placed so as to contain the base of the tent-like structure (Sackett and Gaussen 1976).
- dd. In the East Gravettian Upper Paleolithic the most convincing examples of shelter are found at Kulichivka I and Kostenki I/1. - shallow circular or oval depressions, of several meters in width, containing a centrally placed hearth and large quantities of debris (Hoffecker 2002).
- ee. Clusters of dwellings at Dolní Věstonice, Pavlov, Kostenki, and Avdeevovo may have supported 100 to 200 inhabitants (Banesz 1976; Vandiver, Soffer et al. 1989).
- ff. Objects described as lamps definitively appear only late in the Upper Paleolithic. The earliest uncontested lamp comes from the Gravettian at Laugerie-Haute. It is possible that two Aurignacian artifacts from La Ferrassie, one Gravettian artifact from Arcy-sur-Cure, and one from Saint-Jean-de-Verges are lamps (de Beaune 1993). Gravettian lamps carved from mammoth femur are found at Kostenki I (Hoffecker 2005)

In addition to the apparent lack of tailored clothing, there is no evidence in the Mousterian for the special technological, buffering adaptations (e.g. structured hearths, insulated shelters, untended facilities, or storage devices) among recent hunter-gatherers to living in cold environments (Torrence 1983). Variable types of hearths are known from both Middle and Upper Paleolithic contexts, although the use of rocks is almost exclusively documented from contexts of the latter period (Bar-Yosef et al. 1992, Meignen et al. 1989, Rigaud et al. 1999, Past'ó et al. 2000). Structured hearths, with or without the use of rocks for baking and parching activities are present in Upper Paleolithic sites.

The trend towards larger and longer-duration campsites that would warrant investment in construction of subterranean shelter with constructed hearths, which may have been used for several seasons, first appears tentatively in the Aurignacian and is clearly evident in the Gravettian.

v. Summary of Camp Maintenance Activities and Tasks

As far as the allocation of time to camp maintenance is concerned, Neanderthals appear to have been more mobile and have built less structured dwellings. Their pattern resembles that of the Efe with frequent building of temporary shelters. The Aurignacians and Gravettians resemble the high latitude groups with fewer residential moves but much more extensive constructed dwellings often with repeated visits. The effort invested on the camp maintenance activities in the Upper Paleolithic may well have been spread over many seasons, as is the case with the Machiguenga. In that case, although the range of tasks performed are about double those performed in the Mousterian, the time allocated within any one year to heavy camp maintenance activities for men would more closely resemble the residential Machiguenga pattern, and for women the time allocation requirements seem to resemble the Efe pattern, albeit with a different range of tasks. I have assigned the times accordingly in Table 4-14.

Table 4-14 Camp Maintenance Activities and Tasks

Time Allocations for Camp Maintenance	Efe	Machi-guenga	High latitude	Early Neanderthal	Late Neanderthal	Early Upper Paleolithic	Middle Upper Paleolithic
Time allocated by men (mins)	27	52	40	27	27	52	52
Time allocated by women (mins)	74	26	100	74	74	74	74
Camp maintenance tasks	-	-	-	6	7	14	15

4.7 Projected Time Allocations for Major Activities and Number of Associated Tasks

Neanderthals may have needed to spend considerably more time in food acquisition activities than their modern human counterparts; their robust bodies demanded high intakes of calories for survival in the harsh climate of Northern Europe. Clothing would not have mediated these intake demands, since genetic changes cannot occur that rapidly: it took 20,000 years after arriving in Europe for modern humans to begin to develop the more robust cold adapted body shape similar to current Europeans. Therefore, it made sense for the Neanderthals to concentrate on food acquisition rather than tailored clothing. These requirements are reflected in smaller tool inventories. For instance, given the rudimentary skin preparation required for making the simple cloaks likely to have been used by the Neanderthals, only occasional piercing and scraping tools would have been needed (Hayden 1993). Un-retouched pointed flakes and side scrapers could easily have performed all the functions required in these tasks. Due to the infrequent performance of these tasks and the minimal nature of the work involved, no specialized tools would have been required.

Upper Paleolithic humans on the other hand, who were physically less cold adapted and more gracile, did not require the same intake of calories but needed to devote their efforts towards clothing and shelter. They tended, at least initially to move into more open areas that were not occupied by the Neanderthals, maybe to avoid competition from the ensconced locals. They also stayed in northern areas that were much colder than those typically occupied by the Neanderthals who tended to move south into refugia during colder interstadials and left the northern plains uninhabited. The Upper Paleolithics humans needed to broaden their diet and to develop new food

acquisition techniques to deal with the seasonally fluctuating fauna. There is increasing evidence that Upper Paleolithic groups may have occupied certain key locations on a more stable, semi-permanent basis, which would almost inevitably act as a further incentive to the definition of more sharply defined social territories, and to a more formalized pattern of reciprocal relationships between the occupants of adjacent territories (Mellars and Stringer 1989). Not surprisingly, innovations in clothing and settlement design seem to appear first in northern areas and then progress southwards.

- **Technology, Efficiency and Total Time Available**

These preliminary data indicate that early modern humans and high latitude groups would spend considerably more time than Neanderthals in the performance of their daily routine, and especially in the supportive indirect activities. However, it does not make sense that these groups would expend that additional time in tool making and clothing manufacture without achieving some benefit in efficiency. Orquera (1984) believes that Upper Paleolithic tools are more specialized in nature than Middle Paleolithic tools, and that this increased specialization implies greater efficiency. These tools to fall into distinct categories that represent intentional classes of tools and tool function; it is quite possible that these represent greater specialization and consequently efficiency of function. Therefore, one would expect that efficiencies, achieved from these indirect tasks, would be more than offset by reductions in direct tasks such as food acquisition and food preparation. Tools are created for many purposes: specialized tools may be used to create other, even more effective, tools. For example a denticulate may be created for stripping wood for a thrusting spear, a burin for fashioning an antler point, or a side scraper for dressing skins for creating shelter. Ultimately these

improvements affect direct activities, such as making food acquisition less energetically expensive, reducing the need for additional food to offset thermogenesis, or increasing the rate of infant survival. It is impossible to assign a specific benefit to technology with the limited information that we have, but economics tells us that technology must pay for itself. I have therefore used the preliminary data (in minutes) collected in the chapter as an indication of the relative weight allocated to the major activities in each population. Since all groups are constrained by limited hours in the day, albeit with seasonal differences, I have normalized the time efforts by proportionally adjusting the activity time estimated to a basis of 100 work units. Thus for each population, all activities retain their proportional weightings relative to each other and technological efficiencies are spread over all activities. These work units, as shown in Table 4-15, are the activity parameter inputs to the model.

Table 4-15 Time Allocations for Current Hunter-Gatherers and Prehistoric Groups.

Men's Allocation Category Name	Efe		Machi-Guenga		High latitude		Early Neanderthal		Late Neanderthal		Early Upper Paleolithic		Early Upper Paleolithic	
	Mins	Work Units	Mins	Work Units	Mins	Work Units	Mins	Work Units	Mins	Work Units	Mins	Work Units	Mins	Work Units
Direct Activities														
Food acquisition	276	73	267	65	367	67	395	82	395	81	321	61	321	59
Food preparation	23	6	18	4	9	2	9	2	9	2	9	2	9	2
Childcare	5	1	3	1	4	1	4	1	4	1	4	1	4	1
Indirect Activities														
Tool making	51	14	72	17	139	25	42	9	51	10	135	26	151	28
Clothing manufacture	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Camp maintenance	27	7	52	13	40	7	27	6	27	6	52	10	52	10
Total (Excluding Leisure)	382	100	412	100	559	100	477	100	486	100	521	100	537	100

Women's Allocation Category Name	Efe		Machi-Guenga		High latitude		Early Neanderthal		Late Neanderthal		Early Upper Paleolithic		Early Upper Paleolithic	
	Mins	Units	Mins	Units	Mins	Units	Mins	Units	Mins	Units	Mins	Units	Mins	Units
Direct Activities														
Food acquisition	48	12	84	19	33	6	35	9	35	9	29	6	29	5
Food preparation	182	45	141	32	71	12	71	18	71	18	71	14	71	12
Childcare	94	23	63	14	79	14	79	20	79	20	79	15	79	13
Indirect Activities														
Tool making	6	1	18	4	27	5	5	1	6	2	26	5	29	5
Clothing manufacture	5	1	108	25	270	46	126	33	126	32	234	46	270	52
Camp maintenance	74	18	26	6	100	17	74	19	74	19	74	14	74	13
Total (Excluding Leisure)	409	100	440	100	580	100	390	100	391	100	513	100	552	100

Activity data compiled from the following tables in earlier text: food acquisition from table 4-1, food preparation from table 4-5, childcare from table 4-7, tool making from table 4-10, clothing manufacture from table 4-12 and camp maintenance from table 4-14.

In this chapter I have identified tasks based on those outlined for the Eskimo (Giffen 1930). Although techno units (Oswalt 1976) is used as a meaningful method of analyzing end-product tools, I have chosen Giffen's approach rather than the techno unit approach, since the archaeological record does not provide the level of information

required to construct a detailed techno unit description, and techno units were applied specifically to tool manufacture and not other activities. Where processes are evident, I have used the *chaîne opératoire* approach to identify the various steps that might have been susceptible to task specialization. The tasks and processes described here are examples of opportunities for specialization. When compared to the differences in number of techno units between tropical and high latitude groups for tools, as shown in the tool making section, the tasks identified below seem to reflect an accurate depiction of the differences between Neanderthals and Upper Paleolithic humans. The task repertoire for the four groups is summarized in Table 4-16 below:

Table 4-16 Tasks by Activity

	Early Neanderthal	Late Neanderthal	Early Upper Paleolithic	Middle Upper Paleolithic
Activity	Tasks	Tasks	Tasks	Tasks
Direct				
Food acquisition	4	5	9	11
Food preparation	3	3	4	4
Childcare	2	2	2	2
Indirect				
Tool making	9	11	33	37
Clothing manufacture	7	7	13	15
Camp maintenance	6	7	14	15
Total	31	35	75	84

Task data compiled from the following tables in earlier text: food acquisition from table 4-4, food preparation from table 4-6, childcare from table 4-7, tool making from table 4-9, clothing manufacture from table 4-11 and camp maintenance from table 4-13.

Time management and the task repertoire are on key elements for determining the behavioral differences between Neanderthals and early modern humans. The next issues to be addressed by individual-based specialization model are whether the increased number of tasks, the group size, and skill spread together provide the potential for increased cooperation and specialization to offset the additional time expenditures required for meeting the needs of the changing climate.

Chapter Five

Group Size and Composition

Several archaeologists have discussed how group size might affect social transmission and learning. Mithen proposed that in small groups the opportunities for social learning would be relatively limited (Mithen 1996a), and may be restricted to vertical transmission within the local group (Gamble 1986). Smaller populations are both biologically less fit and less attractive as examples for imitation, since small populations are more likely to maintain within them only small innovations, which are less beneficial reproductively and less attractive to copy (Shennan 2001). Larger populations offer more opportunities for the transfer of cultural innovation processes through horizontal, vertical, and oblique transmission, even beyond immediate kin. Consequently, larger populations offer more openings for the introduction of specialization and exchange activities between members. Mathematicians have developed an individual-based, prisoner's dilemma model for cooperation strategies among unrelated individuals within larger groups that shows that interactions amongst players must be frequent, by mutual consent, and players must have a sufficiently large memory of other's behavior over previous rounds (Cox, Sluckin et al. 1999).

Both Neanderthals and modern humans have the brain capacity to support such cooperation strategies, but modern humans alone seem to have developed the regional networks, and seasonal patterns of aggregation, as observed in regional styles and symbolism, necessary to coordinate the release from proximity (Gamble 1998), and sustained cooperation in a larger and geographically extended group, while maintaining the level of contact and mutual trust necessary to preserve cooperative interactions

within the larger groups. I examine current hunter gatherers and archaeological data from Neanderthal and Upper Paleolithic settlements in order to determine group size and composition parameters for the ICA model.

5.1 Group Size in Current Hunter-Gatherers

In the ethnographic record, the band society is regarded as the underlying system from which specific cultural behaviors emerge, and is the model that is usually used for explaining the major changes that occurred in the Late Pleistocene (Gamble 1999). Band societies became associated with closed mating networks, which may have originated only with the Upper Paleolithic (Wobst 1976). However, mating systems are but one element of society; other relationships of production alliances necessary for survival, not necessarily based on kinship, involve individuals negotiating partnerships and alliances within a broader regional framework, where the circulation and exchange of persons and goods establishes a range of enduring social commitments (Gamble 1986). The emergence of complex society was initially attributed to the maritime societies of the Northwest of North America and to agricultural Neolithic societies, rather than more nomadic hunter-gatherers. However, examination of group size and craft specialization among recent hunter-gatherers shows that a settled, agricultural society is not necessarily more highly developed than the more mobile hunter-gatherers (Naroll 1956). Mobile hunter-gatherers are able to survive in areas that are hostile to sedentary groups (Arnhem Land, Efe). Complexity incorporates more parts, and more differentiation or specialization of these parts (Price and Brown 1985), and may have become a major factor in the social life in the Upper Paleolithic (Gamble 1999). Complexity is recognized in maximum settlement size, and permanency of settlements

as indicated by dwelling structures, storage facilities, ceremony, symbolism, and exchange. Brown and Price conclude that the potential for social and cultural complexity resides in all hunter-gatherer economies (Price and Brown 1985).

i. The Nuclear Family and the Local Group

The nuclear family is the focal unit and elemental form of human society, a fact that anthropologists have been slow to recognize: the existence of the family level was long denied (Service 1962). Identification and analysis of the family level organization of the !Kung San corrected this perception (Lee 1979). The key to family level societies is their freedom from higher political or hierarchical controls, allowing flexibility, mobility, and the ability to react opportunistically to natural circumstances. The preferred state is for one family or several siblings' families to live and forage during the favorable times of the year. Ideal conditions for this small family unit are patchy and dispersed sessile resources and animals that roam individually that can be stalked by one or two hunters. The small, local family unit avoids competition from others for patchy resources. Several factors, besides foraging, affect the optimal group size (Smith 1981a). In primates, the size of the working group (Birdsell 1966a) and the resource area to be managed and defended are determinates of group size, which may change from season to season depending on the distribution of resources. Larger groups may congregate for cooperative hunting, when resources are transient and highly concentrated, or for social festivities. In social groups, flux appears to be the key for assembling the appropriate group composition for seasonally varied foraging tasks as well as for dispelling dissent and relieving tensions within larger groups (Turnbull 1966).

But, although the family unit is the essential economic unit, organization above the family level is essential for the family's survival (Johnson and Earle 2000). In an unpredictable environment, the small local group is at risk of extinction without these broader networks for mating and provisioning in times of hardship. At the family level, the need to minimize risk is primary. A varied diet, an extensive network of kin, friendship ties, and mobility, involving the opportunistic aggregation and dispersal of families into larger and smaller camps, is the model for low-density foragers (Johnson and Earle 2000). The Hadza seem to maintain the lowest group size and the least social bonding or load bearing relationships. People are able to, or forced to because of weak social ties, survive solo or in small groups, always with a fall-back to the settlements (Woodburn 1966a). Indeed, it is argued that, among the Hadza, movement provides little advantage in terms of access to resources but rather acts to diffuse tensions that might lead to social strife (Woodburn 1972). On the other hand, the Mbuti net hunters are one of the few groups that consistently perform cooperative hunting. Net hunts occur during the middle of the day, but it is significant that individuals may hunt solo earlier in the morning or later in the afternoon. It is also noteworthy that the women participate actively in these net hunts, beating the bushes and making noise to drive the prey from the undergrowth into the nets where the men do the killing (Turnbull 1983). Most groups surveyed, whether from the rain forests of Africa to the arctic north, spend a considerable part of the year in small family groups with small hunting parties of two to four hunters.

All current hunter-gatherers follow an annual cycle that is driven by climate, the migration of fauna, the seasonal availability of plant foods and water. As a result most,

with the exception of some coastal groups, are semi-nomadic and live in a constant state of flux between large, seasonal aggregations and nuclear family groups, driven by both seasonal constraints, social pressures and benefits of large group gatherings (Turnbull 1966). Camp sizes vary by season depending on the resource availability. Times of aggregation are frequently driven by the need to congregate around limited, often low-quality, seasonal resources and the need for cooperation in times of need. Times of dispersal, when seasonal resources are dispersed and patchy, provide a release of the tensions of living in larger groups. This pattern of aggregation and dispersal has provided modern humans with a unique ability to maintain contact with their extended family or tribe, even without constant proximity. This release from proximity enables groups to develop extended networks of kin and namesakes, who provide support in times of stress.

Most hunter-gatherer camp sizes fluctuate even from week to week. Nunamiut camp sites are structured by the organization of the workforce and consumers (Binford 1991). While a camp remains in one place, families or individuals may move in or out of the camp. Mobility is a function of dispute and dissent as well as a one of resource depletion. However, it is not always possible just to leave. Living solo outside of the regular camping areas is risky. In the forest, it is dangerous (Mbuti). In the desert, it is perilous since water sources are not dependable and risk of dehydration is high (!Kung, Pintupi). On the ice, the risk of a fall or hypothermia is real (Saqqaq, Coastal Inuit). Anyone choosing to move away from cached winter supplies faces the risk of achieving low foraging returns and starvation (Shoshone). In all cases, foraging returns may be far less predictable away from the group. People move in or out for a variety of

personal reasons: the generosity of a skilled foraging group, tension or dissent within the group, mating and networking opportunities, as well as local surplus or depletion of resources. Subsistence is one part of a multi-faceted definition of hunter-gatherers; social organization and cosmology are the others (Lee and Daly 1999).

ii. The Larger Seasonal Group

The size of human groups at any specific time seems to be strongly related to the abundance and spatial patterning of resources. The larger the group is the greater the number of food procurers, the larger the size of game to be killed, and the less the danger of competition from other predators or competitors. The advantage of larger groups depends on food sharing: food sharing tends to increase towards the north and decreases towards the equator. However, equally important is the need for flexibility as far as resource conditions as well as social reasons, such as conflict resolution (Jochim 1976). Thus, families may chose to join larger groups for risk avoidance purposes or remain in small sibling related groups separated from other groups to avoid competition for patchy resources: the larger the group the more quickly are local resources depleted. Large groups incur increased travel costs as patches get depleted, and hunter-gatherers have to travel further to find resources and avoid overlap with others. In this regard, humans are like other animals that gather in large groups where resources are clumped, and temporarily abundant but depleting, but remain in smaller groups where patches are small or patch density is dispersed (Steudel 2000). But there are always opportunities for successfully adopting contrarian strategies. In the Serengeti, two populations of wildebeest adopt different foraging strategies: one migrates during the dry season to richer pastures, whereas the other avoids the risks of migration and faces the challenge of

extracting the few low-quality resources remaining in the now-depopulated area (Sinclair 1983). Humans make similar choices on a daily basis depending on season and local environmental conditions and even social relationships. Group size is neither stable nor static.

Larger cooperative foraging groups assemble in seasons because access to large game or easily startled herding game requires a bigger group of hunters or because of predation. For the cooperative hunt to stand a chance of being successful prey species should exhibit certain characteristics: *predictability*: the location of concentrations of prey during seasonal migrations or at limited feeding areas should be predictable, *technique*: different hunting techniques and technologies are demanded for solitary or herding animals, and *quality*: high fat content and hide quality make hunting worth the communal effort. However, large-scale communal hunts are relatively rare, occurring once or twice per annum for short periods; but these events become extremely important in high latitude environments, where the acquisition of a surplus for winter storage is a critical function for survival. Very large groups aggregate during annual herd migrations, salmon runs, or fruit harvest when rich resources become abundant for a limited period of time. Everyone gathers to participate in the bounty before the resource is depleted, in the case of sessile resources, or moves on, in the case of migrating animals. Families join the larger gathering because cooperative hunting groups are required to accumulate the temporarily abundant food resource (i.e. cooperative hunting is more productive or more predictive than solo hunting during these times) and these events offer the opportunity for social contact and festivities (Riches 1982).

Also, large groups may gather during lean times when there are limited resources or when mobility is limited by inclement weather (e.g. monsoon flooding, drought, or snow and ice bound). The Dobe Ju/'hoansi gather at the permanent water holes during the dry season, since these are the only areas where water is available (Lee 2003). The Cape York aborigines gather in the dunes during the wet season while the rest of the area is inundated by the monsoons (Chase and Sutton 1998). The Shoshone gathered in large residential groups of five to ten families close to pine nut storage caches during the winter (Steward 1938; Murphy and Murphy 1960; Thomas, Pendleton et al. 1986). The Inuit become cabin-bound during the cold and dark December and January and feast on stored foods gathered in the fall (Dahl 2000). In these instances diet is restricted to local staples or cached foods, which are often lower-quality food items. This is a time of deprivation and also a time of tension, since so many are forced to live in close proximity, and mobility is no longer a solution for the resolution of conflict.

Immediate return groups generally do not store foods but consume the day's catch within the day: foraging continues until the daily requirement is met, there is little incentive to gather more than is required. Delayed return groups are more frequent in higher latitudes, where seasonality limits resources availability and surplus must be collected and stored for the winter. In delayed return societies, the storage facilities attract large groups during periods when wild resources are not available for immediate return. During this period, production activities are few and social activities predominate. These gatherings take place in areas where the limited wild resources or cached supplies are relatively accessible compared to other locations. Information is an

important resource to be shared, especially at these critical times, during periods of seasonal aggregation and cooperative foraging. Information gathering is more significant where resources are highly mobile and regional availability of resources is highly unpredictable (Mithen 1990).

iii. Egalitarianism and Sharing

Generally, a contributing member of the camp is considered part of the economic group and in many cases is named and treated as a blood relative (Turnbull 1962). Thus, although the nuclear family is the basic productive unit, economic activity incorporates members outside of this kin group; the practice is essential to survival (Johnson and Earle 2000). All food is shared, grudgingly or not, among those in the camp, and there must be a strong undercurrent of personal dynamics. Do you join a group because of local abundance, because of the known skills of the local camp hunters and gatherers, or to participate in communal activities and avoid scroungers?

Most groups have strong ethical rules about not accumulating excess, and those that have are obligated to give to those that have not, if asked. Among the aborigines, generosity's corollary is demand sharing. Arguably, in small groups demand sharing, rather than being a negative behavior, is a way of testing another's behavior to assure the state of a relationship in social situations where relationships have to be constantly maintained and cannot be taken for granted (Peterson 1993). Personal prowess is outwardly undervalued (Ache), and in many cases a hunter's contribution is denigrated to preempt any sense of superiority – insulting the meat (!Kung). There are generally defined rules of ownership and how captured prey should be shared. Among the Saqqaq Inuit, the sharing procedure is a collective activity that is overseen by the entire

community. Ownership rules leave much room for discussion and argument during the sharing process. There is often heated discussion as to the division of the spoils under the discrete supervision of an informal hunting leader before a consensus is reached (Dahl 2000). Nevertheless, tensions do arise. Individuals keep their own mental record of who contributed what and, although the accounting is not a precise one-for-one ledger, individuals have their own concept of what is appropriate and what is stingy. Free loaders are discouraged by various cultural means including jokes, insults, and even banishment (Howell 2000).

iv. Social Networks

Periodic, larger regional congregations are a necessity for assuring mating opportunities and group survival, not only for maturing adolescents, but also to maintain the integrity and productivity of the band: the loss of any one productive individual will have significant negative consequences on the survival of the group. In hunter-gatherer groups, where infant and juvenile mortality rates are very high, 23.16% and 43.74% respectively in the case of the Hadza (Marlowe 2005), it is critical to assure reproductive viability through mating opportunities, to offset mortality, to maintain the integrity of the economic unit, and to transfer knowledge about the location or movements of unpredictable resources (Wobst 1974). These latter factors are critical even in the dead of winter when economic activity is almost at a standstill (Damas 1972). This network is additionally important where resource fluctuations occur over an area larger than the group's home range (Whallon 1989), a significant consideration when modern humans moved into the open, and tundra plains of Northern Europe.

Information on availability and accessibility of resources are important prerequisites before committing to distant migration of the local group. Primate studies show that movement between groups is extremely risky, involving lengthy displays, aggression, and often injury, with great uncertainty to the outcome (Whallon 1989). Moving to distant locations raises the possibility of aggression from hostile, resident groups, failure to find abundant resources, and lack of access to resources where available. The ability to acquire and communicate this information is critical to building this information database. Language with conditional, past and future modality was probably a vehicle in this informational process (Whallon 1989; Bickerton 1990). Ethnography shows us that there are traditions for the requesting of permission and obligations for the provision of reasonable access to local resources to members of the broader network.

The building of widespread kin relationships through marriage, the practice of naming conventions, and *hxaro*-like exchange networks are examples of this kind of delayed reciprocal altruism and cooperation. Traveling, visiting, *hxaro*-like systems, and ceremonies facilitate and cement these relationships. Groups spend considerable time and effort (Wiessner 1977) maintaining these ties by visiting distant neighbors, presenting gifts, and arranging festivals in order to reinforce these bonds. Wiessner reckons that the majority of possessions owned by the !Kung come from, or are destined for, the *hxaro* network, but ethnographers have not accounted for this effort in their time allocation studies, which count 'productive' time only.

Some societies, such as the Machiguenga (Johnson 2003) and Cape York inhabitants (Chase and Sutton 1998) have been able to dispense with these networks,

either because local resources are rich and reliable enough or because of overproduction or bulk storage, in which cases such insurance is not necessary. However, this insurance is especially important when environmental conditions are unpredictable: this is further discussed in Chapter 7.

These extended networks also become critically important in marginal environments where the loss or incapacitation of a single individual in a group could be disastrous for the group, potentially leading to extinction (Whallon 1989). In small groups, and especially those living in high latitudes, the loss of any productive adult male or reproductive female is potentially threatening to the integrity and survival of the group. This applies whether the individual is kin or not since, in the event of the loss of a mate, a non-kin member of the group is always a potential replacement. But such losses do not only apply solely to mating opportunities; a skilled hand is a welcome addition to a small group. A study of pathology risk among Yora and Shiwiari hunters (Sugiyama and Chacon 2000) concludes that these groups recognized a variety of critical foraging, blow gun manufacture, and other social skills such as strategic decision-making in individuals, and that serious injury to an individual possessing any of these skills results in the loss of irreplaceable economic benefits to the groups that warrants aid and support during the period of incapacitation. I examine the effect on local group survival of losing a productive member, or of having to support an incapacitated producer until he/she recovers the ability to be fully productive.

v. Local, Seasonal, and Regional Groups

Many anthropologists have examined current forager groups and their varying group sizes. The local group, recognized as the productive unit and among current

hunter-gatherers, is generally composed a few related families and comprises twenty-five to thirty individuals. This figure seems to occur so often in the literature that it has been called the “magic number” (Jochim 1976). Marlowe suggests that there are typically three types of groups among foragers: a) the regional tribe, which may never congregate as a whole in one place, b) the local group which is the productive unit, and c) the daily foraging party, which returns to camp at day’s end (Marlowe 2005). His analysis of 478 societies indicates that the local group has a median population size of thirty across a variety of habitats. He suggests that free-rider problems probably set an upper limit on optimal, or equilibrium group size. The upper limit is constrained by the fact that above 30, conflicts and bickering between families may cause the group to split up. He postulates that below about twenty-five, with most adults out foraging, there might often be too few people available to baby-sit. Binford (2001) analyzed 333 forager groups to look at how groups might aggregate and disperse to accommodate to seasonal fluctuations in resource availability. His data shows that, excluding mounted foragers and sedentary pacific fishing communities, local group size was fifteen to sixteen at the most dispersed, when separated into the smallest, productive units, and seasonal groupings amounted to fifty-two individuals, at the most aggregated. For these societies, seasonal groups appear to be about three times the size of the most dispersed group. Periodic regional aggregation amounted to one hundred and fifty. Whallon (1989) suggests a group size of twenty-five to thirty members is supported by the fact that, in an egalitarian society, group size would be limited by decision-making constraints and that six units or nuclear families constitutes the optimal decision-making group. However, he is reluctant to project these numbers too rigidly into the past.

Wobst (1976) suggests that local groups consist of several families, which at least for part of the year share a settlement and a given range of cultural activities. During the year, group size ranges from fifteen to seventy-five people and, Wobst concludes, there is no evidence from Paleolithic settlements in northern Eurasia to indicate higher modes in local group size during any time in the Pleistocene.

Dunbar examined group size based on the cost of maintaining social ties within the social group of primates (Dunbar 1992; Dunbar 1995). In a local group size of fifty to fifty-five individuals, baboons spend up to 20% of their time grooming. With group sizes any larger than this an inordinate amount of time must be expended just in maintaining group cohesion which would become a constraint on group size. Dunbar argues that language in humans developed as a more efficient grooming mechanism. He measured the neocortex ratio (neocortex size: size of the rest of the brain) of monkeys and apes and showed that there was a strong association between the neocortex ratio and mean group size. For humans, with a neocortex ration of 4:1 he predicts an extended group size or clan of 150 (Dunbar 1996). It turns out that the figure of 150 is roughly the number of living descendents, children, grandchildren, great-grand children that a Paleolithic couple would produce in four generations at the birthrate of hunter-gatherer peoples. Dunbar believes that larger clan size is driven by the need for wider and more dispersed home ranges that carry the risk of failure of finding resources in distant territories. This highlights the importance of information and insurance networks. Clans meet periodically, maybe once a year, for ceremony, information exchange, and rituals, associated with group cohesion and mating. He suggests that above this size groups tend to become hierarchical and below this size

groups lack structure of any kind and rely on personal contact to oil the wheels of social intercourse. Within these groupings, there are ad-hoc working groups of some five or six families that may pool resources for hunting and food finding. Dunbar's data matches that gathered from ethnography for current hunter-gatherers: it may apply to Upper Paleolithic groups but may or may not be applicable to Neanderthal populations. Although some early researchers have suggested that Neanderthal brains were more primitive in respect to their frontal lobes, Holloway (1985) states categorically that he has no confidence in any unambiguously convolutional patterns that are suggestive of a primitive condition. This suggests that factors other than a lower neocortex ratio may have been operating to account for smaller Neanderthal local groups, more local networks for the acquisition of raw materials and exotics, the lack of regional symbolism, and possibly the concentration on smaller closed habitats. If Neanderthals lacked the ability to forge large reciprocal networks and alliances, they might have been unable to range over wide areas containing dispersed and less predictable resources. Many believe that they preferred to settle in closed, resource rich, vertical ecotones (Hoffecker and Cleghorn 2000; Finlayson 2004). The larger groups, wider networks, and symbol-based organizations predicted by Dunbar are first observed throughout Europe in the Upper Paleolithic (Mellars 1996; Gamble 1999; Hoffecker 2002).

The crucial numbers derived from demographic studies of hunter-gatherers (Gamble 1999) are:

- The nuclear family consisting of 5 - 6 persons – the productive unit
- A local group of 30 with ranges from 20-70 people normally associated with a named locality, with seasonal aggregations of three to four local groups

- An effective breeding unit or extended group with ranges between 150-200 persons, and where population numbers are of sufficient size to cope with any stochastic fluctuations in sex ratios, mortality and fertility
- The tribe of 500

5.2 Early and Late Neanderthal Group Size

Most early Neanderthal sites indicate short-term occupations by small, local groups consisting of one or at most two family units. Intra-site spatial patterning at the Grotte XV at the Abri Vaufray suggests small-scale, short-term but spatially repetitive occupations (Koetje 1994). The rock shelter at La Cotte de St Brelade has an area of 35-40 m² and layers 3 and 6 represent two separate, short visits by small groups (Scott 1980). Even at the deeply stratified site of Combe Grenal, only small numbers of faunal remains were present in any one layer, suggesting that animals were stalked individually by small groups during repeated visits (Chase 1986). Later Neanderthal sites excavated throughout Europe seem to indicate that the same pattern persisted through space and time.

The features and density of faunal remains at Middle Paleolithic sites at Tönschesberg, Wallertheim, and other sites in the Rhineland suggest repeated, brief occupations of several family groups or smaller, rather than seasonal base camps; none show solid indications of long-term occupation (Conard and Prindiville 2000: page 304). In the East, oval concentrations of lithic and bone materials from 30-50 m² in area, sometimes with shallow hearths, and often at least partially overlapping one another, are characteristic of late Middle Paleolithic sites at Molodova I layer IV, and Ripiceni-Izvor along the Dnestr/Prut rivers (Paunescu 1989). These assemblages most

likely represent palimpsests of sequential occupations over several years (Soffer 1989a). One of the few Mousterian sites of unusual size and complexity was excavated at Sukhaya Mechetka on the Volga River. Six hundred and fifty m² was mapped and over 8,000 stone artifacts were recovered, which were accumulated as separate and overlapping scatters of debris and ash (Hoffecker 2002). The site was occupied repeatedly for a variety of activities, but it is difficult to estimate group size during each individual episode. In the Northern Caucasus, Barakievskaya Cave has a tightly circumscribed area of 35 m² and it is unlikely that more than ten to twelve individuals occupied it (Hoffecker and Baryshnikov 1998).

In Iberia, excavations at Cova Negra suggest a series of short-term, sporadic occupations by small groups, since each occupation area included a simple hearth, but was limited to 10 -12 m² and contained a low density of lithic remains (Arsuaga, Villaverde et al. 2007). Cueva Morín, Mousterian level 17 has a smaller, circumscribed area of only 6.6 m² (Cabrera Valdes and Bernaldo de Quiros 1992) indicative of a small-sized group. El Castillo is characterized by short-term, small group, sporadic stays during the summer and autumn and by larger aggregations during the spring (Cabrera, Pike-Tay et al. 2000). Remains of a short term visit by 5-6 individuals are found at Vanguard Cave (Barton 2000). There is some evidence for larger groups of twelve or more in the late Middle Paleolithic. Early occupations at Abric Romaní appear to have been short-term occurrences by small groups (Pastó, Allue et al. 2000; Vaquero, Vallverdu et al. 2001), but the later layers with occupation areas of 120 square meters, during the Hengelo interstadial 46-45 ka, indicate longer-term occupation by larger groups (Castro-Curel and Carbonnell 1995; Vallverdú, Allue et al. 2005).

In the Perigord most of the documented Mousterian sites appear to be modest, indicative of small social groups of six to twelve individuals. While heavily analyzed, and deeply stratified cave sites, such as Combe Grenal, Pech de l'Azé, Le Moustier, and La Ferrassie, are seen as typical Mousterian sites, they are not representative of the more frequent open-air Mousterian sites (White 1983). Apart from the above mentioned, few sites reach the depth and size dimensions of the largest Upper Paleolithic ones such as Laugerie Haute, Abri Pataud, Laussel, La Madeleine etc. (Mellars and Stringer 1989).

Large open-air camp sites are unusual in the Middle Paleolithic (Farizy 1994b), maybe because of they are more likely to have been destroyed by erosion or agriculture. Mauran, a kill site, seems to have been used by a group of thirty people over many generations, during the autumn when one to three bison were killed and eaten (Farizy 1994a). Champlost, a consumption and living site as opposed to a kill site, probably represents the accumulation of deposits from many short stays by the same or similar sized groups over a large area and over several generations. This suggests that the local group consisted of a single-family group, but that periodic aggregations of several families may have occurred at particular times for specific purposes.

In summary, there is little evidence for large Mousterian multi-family aggregations. This is generally reflected in the simpler patterns of spatial organization and associated structural features and suggests more short-term and transitory episodes of occupation than those documented in the larger and more structured Upper Paleolithic sites. Size of living areas within Middle Paleolithic caves and shelters in southwest France rarely exceeds 30 m², similar to that of Barakaevskaya Cave in the

Caucasus, in contrast to larger areas in the Upper Paleolithic (Mellars 1973).

Mousterian group size, at ten, is small by recent hunter-gatherer standards (Mellars 1989a; Hoffercker, Baryshnikov et al. 1991; Hoffercker and Cleghorn 2000). But even these estimates may be high: Naroll suggests that, based on eighteen small current societies, the population of a prehistoric settlement can be roughly estimated on the order of one-tenth the floor area in square meters (Naroll 1962), which would put the size at three to four occupants in many of the above sites. Dunbar, on the other hand, posits that a conversing group of seven individuals could stay within earshot and be seated in a 2 m circle around the hearth (Dunbar 1996), suggesting a slightly higher numbers for a brief stay in camp. Nevertheless, these records, from across Europe, suggest that Neanderthals differed from current hunter-gatherers: they lived in small one- or two-family groups of less than ten individuals and might congregate in larger task groups of maybe thirty individuals at the season of the herd migration. But, the limited range of local, lithic sourcing transport suggests that they did not maintain extended clan-type relationships and networks. Such small, dispersed groups may not have benefited from horizontal or oblique transmission of knowledge, and this may account for the stasis in technological innovation observed during the 200,000 years of occupation of Europe (Mithen 2006). If Neanderthals habitually lived in more closed and ecologically varied habitats that were contained within their home range, and migrated southward to similar habitats when conditions in the north deteriorated, then larger seasonal aggregations and extended social and economic networks may not have been so important to them.

5.3 Early Upper Paleolithic Group Size

The Aurignacian offers some evidence for larger, multi-family groups and strong evidence for the development of extended networks with the introduction of symbolism and the distance transport of materials, particularly exotics. One fifth of Upper Paleolithic sites cover over 1500 m², whereas few Mousterian sites reach this coverage (White 1983).

Individual sites throughout Europe indicate that some Aurignacian sites may be more permanent base camps, while others may just be temporary stopovers for small work groups, very similar to the earlier Neanderthal sites. At Geissenklösterle-Höhle (Hahn 1988), there are two Aurignacian levels dated to 30-36 ka, both of which indicate rather short occupations by fewer than ten individuals. The cave was not suitable for longer stays, which suggests that it was used as a temporary site during inclement weather, frequent in the spring and fall. In the Russian Plains, there is a significant number of sites with limited faunal and lithic assemblages, that suggest short duration occupations for a limited range of activities – Korman' IV layers 1 and 8 and Molodova I layers 3, 10a-10b, Kostenki I layer 4 and Kostenki VI. These are suggestive of small family groups or specialized task groups.

Some larger occupation sites appear in the Aurignacian, suggesting that larger, multiple family groups are settling together. At Le Flageolet, a living area of 4 x 5.3m is projected to have supported an extended families of seven persons (Spiess 1979), but in level 3 at Abri Pataud, the remains of a 'long house', marked by a line of five hearths with a possible collapsed wall of limestone block, encompasses a living area of 28-30 m², which is projected to have supported a single extended family to a maximum of 20-

30 persons (Spiess 1979). About 15 hearths were uncovered in the middle Aurignacian layers at Klisouri in Greece (Koumouzelis 2001), suggestive of extended family residency. Here, as with most trench excavations, it is difficult to measure the size and extent of the dwelling area and consequently the group size.

However, individual archaeological sites alone do not tell the whole story, since clusters of archaeological sites in close proximity might better represent how groups were composed and settled across the landscape. Clusters of shell bearing sites are found in the Perigord, Castel-merle, Isturitz and Totu de Camalhot, and the Midi-Mediterranean and lower Rhone Valley at Abri Rothschild, La Laouza (lower Aurignacian), and La Salpetrière (final Aurignacian) (Taborin 1985). This suggests that Aurignacians were gathering in extended family groups, and even establishing local trade centers. It is possible that synchronous occupation of a string of several sites along the Abri cliff face occurred at Castel-merle, as is indicated by analysis of bead manufacturing processes at Abri Blanchard, Abri Castanet, and La Souquette (White 1989a; White 1993a). Decapage excavation at Barca I, in Slovakia, appears to offer an example of several families grouped together (Banesz 1976). Here, three late Aurignacian complexes have been excavated, the largest being 24 m long and 3 m wide with seven hearths, linked by a central corridor. It is estimated that each dwelling could support 4 to 5 individuals, a nuclear family, with the entire complex having 25 occupants.

Further east, large scale excavations of clusters of early Upper Paleolithic sites suggest long-term, multi-activity occupations with traces of possible dwelling structures and central hearths (Hoffecker 2002). Kostenki XVII layer 2, XIV layer 2, and VIII

layer 2, cover 66, 60, and 530 m² respectively. In the Dnestr/Prut region, large occupation floors ranging from 100 to 750 m² have been mapped at Molodova V/8-10, and Kulichivka layer 2 and 3. At Kulichivka, there is credible evidence for multiple dwellings that are reminiscent of current hunter-gatherer settlements, and many sites in the Dnestr/Prut region seem to represent multiple activity locations and relatively long-term habitation sites (Molodova I and V, Korman' IV, Stinka, and Ripiceni-Izvor). These sites represent the closest analogue to a modern hunter-gatherer base camp (Hoffecker 2002). Classification of sites around the Central Russian Plain indicates that sizeable groups (over thirty individuals) resided in base camps in both cold and warm seasons in the Upper Paleolithic and used temporary camps for special purposes (Soffer 1985b).

All of this suggests that Aurignacians were beginning to settle in multi-family groups with extended social networks. Larger transport networks are indicated by Aurignacian lithic assemblages from Kostenki XVII layer 2, which contain large quantities of black flint sourced from 150 km. In the Aurignacian layers at Bacho Kiro, 53% of the flint was imported from distances over 120 km (Kozlowski 1990). Large-area networks first became widespread in the Upper Paleolithic though the evidence of transport of lithics and exotics. Groups operated extensive lithic exchange networks in southern France (Geneste 1988; Geneste 1989; Féblot-Augustins 1993; Féblot-Augustins 1997), Germany (Hahn 1986; Hahn 1987; Rensik, Kolen et al. 1991), Moravia (Svoboda 1983; Oliva 1993), and Russia (Klein 1973). Prehistoric seashell and bead exotic exchange networks in France (Taborin 1985; White 1989a; Taborin 1993), and Russia (Soffer 1985b) indicate that these *hxaro*-like behaviors were part of

the routine of hunter-gatherer groups in the Upper Paleolithic. Whether these resulted from transport of trade, it suggests a more widely dispersed, social network. Such transport networks were not apparent in the Middle Paleolithic. Maybe the Neanderthals' habitat was sufficiently rich and diverse to enable them to dispense with such networks.

This archaeological data indicates that the overall patterning of groups and settlements in the early Upper Paleolithic is more similar to that of modern hunter-gatherers, with groups of twenty-five to thirty individuals, with smaller teams for specialized working expeditions, and extended networks of ninety or above. At times they foraged in single, family groups, at times they congregated with several families and they maintained a wide network of associations, probably for mating and insurance purposes.

5.4 Middle Upper Paleolithic Group Size

By the middle Upper Paleolithic there are more definitive signs of larger extended families of 50 to 200 individuals and widespread networks up to 500 km. The variety of site sizes in the middle Upper Paleolithic indicates that there were different kinds and sizes of social units. Many of the larger sites, such as Laugerie-Haute appear to be located at places suitable for efficient exploitation of seasonally abundant resources, such as migrating reindeer or fish (White 1986). At Abri Pataud, the later two levels indicate a "long house" arrangement (7 x 3 m) of five and six hearths with semi-circular stone surrounds (Movius 1974; Movius 1975; Movius 1977). The space is sufficient to support a larger social group than that of the lower Aurignacian levels, which is only sufficiently large enough for a single extended family.

Large-scale settlements housing over one hundred individuals have been unearthed in Eastern Europe; maybe as a result of application of decapage methods of excavation used in the East. These sites contain more definitive evidence of complex hut-like dwelling structure. The Gravettian site of Dolní Věstonice encompasses five tent-like dwellings. Here, one sees well-constructed winter dwellings alternating with large, uncovered summer dwellings or lean-tos with several hearths. It is suggested that there were twenty to twenty-five occupants per dwelling for a total of between 100 and 200 individuals in all. However, excavations at the rich Gravettian site at Pavlov uncovered eleven circular or oval dwellings, each circumscribed by postholes and stones enclosing one and four hearths with additional hearths placed between the dwellings. This amount of investment in dwelling structures implies long duration sites inhabited by over 100 individuals (Vandiver, Soffer et al. 1989).

The arrangements at Kostenki I and Avdeevo, originally interpreted as long-houses, probably represent a group of smaller dwellings or an open air area surrounding a central hearth (Hoffecker 2002). These dwellings may have supported from 100 to 200 inhabitants (Banesz 1976), although there are many different interpretations of the nature of groups that lived here (Grigor'ev 1993). Sunghir' has an excavated floor plan of 3400 m², which might indicate even larger groups.

The Aurignacian marks the first turning point in procurement and exploitation patterns, and, while higher-grade raw materials are preferred and transported over larger distances as finished products or pre-cores, poor quality local material is still used. In the Gravettian there is a more selective attitude towards raw materials and transport of large quantities of un-worked cores over long distances becomes common. The

Gravettians no longer used inferior quality local materials. Their thin blade technology demanded homogeneous and fine-grained flint that was actively sought from far a field. Transport of raw materials achieved unprecedented distances (up to 500 km) suggesting significantly greater foraging distances or widely dispersed cooperative networks (Hoffecker 2002). It was not until the Epi-Gravettian and later Magdalenian that more versatile production techniques permitted the use of more local and, if necessary, inferior quality rocks (Féblot-Augustins 1997).

Upper Paleolithic sites show more elaborate maintenance and periodic clearance of debris and refuse, which seems to coincide with larger groups and more intensive residence. The middle Upper Paleolithic sees the first manifestation of large settlements with 75 to 200 residents and significant long-term investments in structural features and social networks and consequently further opportunities for specialization and exchange.

5.5 Group Composition

For this economic analysis, I am principally concerned with those active adult members that are the economic engine for the group and most likely to be involved in cooperative, specialization and exchange activities. Studies of current hunter-gatherers show that from ten to twenty years of learning are required before an individual becomes an efficient hunter or gatherer (Gurven, Kaplan et al. 2006). Mortality and reproductive rates govern the proportion of productive to non-productive members. With a 50% mortality rate before the age of 21 (Vallois 1961; Marlowe 2005) and with a mean age at first/last birth of 18.79/34.35 years respectively based on !Kung data (Howell 2000), and a birth interval of 4 years (Fisher 1992), families would need to

produce many more offspring than the two necessary to maintain a stable population. However, accounting for the mortality rates, I calculate that, at any given point in time, the average family composition will be 40% adults and 60% minors and infants to maintain population equilibrium. Thus, a group of 10 would contain four adults and six juveniles and infants. A group of twenty-five would have ten productive and fifteen non-productive members. A group of seventy-five would have thirty productive adults that support forty-five dependents. These ratios apply to the local group as well as to any group participating in a longer-term winter aggregation. The ratios do not apply to short-term working parties for cooperative hunting or resource gathering or extraction, as these are composed primarily of productive team members, but these short-term groupings are too ephemeral to be addressed within the scope of this paper.

5.6 Summary of Group Size and Composition

Maximum Mousterian group size, as observed from the area occupied in the small caves in Western Europe (Mellars 1996) and other sites throughout Europe, may have been consistently smaller than that of a typical residential band of recent hunter-gatherers (Hoffecker 2002). The Upper Paleolithic settlements suggest, on average, larger group composition. The group size analysis for Neanderthals, early and middle Upper Paleolithic groups is summarized in Table 5-1 below.

Table 5-1 Neanderthal and Upper Paleolithic Sites and Group Size

Neanderthal Group Size	<p>Mousterian group size is small (roughly ten) by recent hunter-gatherer standards (Mellars 1989a; Hoffercker, Baryshnikov et al. 1991; Hoffercker and Cleghorn 2000) Large camp sites are unusual in the Middle Paleolithic (Farizy 1994b).</p> <p><u>Short-stay Sites for Small Groups (10 individuals or less)</u></p> <ul style="list-style-type: none"> • Grotte XV, Abri Vaufray (Koetje 1994) • La Cotte de St Brelade (Scott 1980) • Cueva Morin (Cabrera Valdes and Bernaldo de Quiros 1992) • El Castillo (Cabrera, Pike-Tay et al. 2000) • Cova Negra (Arsuaga, Villaverde et al. 2007) • Abric Romani (Pastó, Allue et al. 2000; Vaquero, Vallverdu et al. 2001) • Barakaevskaya Cave (Hoffercker and Baryshnikov 1998). • Tönschesberg, Wallertheim in the Rhineland (Conard and Prindiville 2000) • Molodova I, Ripiceni-Izvor (Paunescu 1989). <p><u>Larger Group Sites (up to 30 individuals)</u></p> <ul style="list-style-type: none"> • Abric Romani (Pastó, Allue et al. 2000; Vaquero, Vallverdu et al. 2001) • Mauran, Champlost (Farizy 1994a).
Early Upper Paleolithic Group Size	<p>The Aurignacian offers some evidence for slightly larger family...One fifth of Upper Paleolithic sites cover over 1500 m², whereas few Mousterian sites reach this coverage (White 1983).</p> <p><u>Short-stay, Special-purpose Camp Sites for Small Groups (10 individuals)</u></p> <ul style="list-style-type: none"> • Geissenklösterle-Höhle (Hahn 1988) • Korman' IV, Molodova I, Kostenki I, Kostenki VI (Soffer 1985b) <p><u>Longer Term Base Camps and Multi-family groups (20-30 individuals)</u></p> <ul style="list-style-type: none"> • Molodova I and V and Korman' IV, Stinka, Ripiceni-Izvor (Hoffercker 2002). • Le Flageolet, Abri Pataud (Spiess 1979) • Kostenki XVII, XIV, VIII, Molodova, Kulichivka (Hoffercker 2002). • Cluster Camps: Castel-merle, Isturitz and Totu de Camalhot, Abri Rothschild, La Laouza, and La Salpetrière (Taborin 1985), Barca I (Banesz 1976).
Middle Upper Paleolithic Group Size	<p><u>Multi-family Groups (20-30 individuals)</u></p> <p>Abri Pataud (Movius 1974; Movius 1975; Movius 1977).</p> <p><u>Long-term - Large Sites (100-200 inhabitants)</u></p> <p>Dolní Věstonice (Vandiver, Soffer et al. 1989).</p> <p>Kostenki I and Avdevo, Sunghir' (Hoffercker 2002) (Banesz 1976),</p>

The nuclear family, with four adults and ten individuals in total, seems to have been typical of the Neanderthal local group size with occasional aggregations of up to thirty individuals at seasonal kill sites. There is no evidence for extended networks beyond this. The lack of large social networks extending over wide areas could have been a critical constraint to Neanderthal occupation of the more extreme cold and dry environments of northern Eurasia (Gamble 1986; Whallon 1989).

For Aurignacians, the record is unclear as regards group size. In the east, the normal settled group size appears to be closer to the modern hunter-gatherer group of five related families with an average of ten adults and fifteen dependents, although there is considerable evidence for smaller, perhaps specialized, work groups having brief stays in other regions. In Western Europe, trench excavation methods may not have uncovered the full surface area of occupation in each settlement. However, throughout Europe larger networks are indicated by lithic and exotic sourcing patterns and symbolism. These probably indicate periodic large aggregations. Gravettians have considerably larger settlements comprising several, co-resident local groups and significantly larger networks.

The breakdown between productive adults and dependents in various groupings is shown below. Minimal group size is the smallest group that left traces in the archaeological record and may represent local Neanderthal groups or specialized work groups in the Upper Paleolithic. The local group is the basic economic unit of one or more family units. The seasonal groups represents the larger aggregations noted from the record. In the Mousterian these larger groups are found in the context of fall and spring cooperative hunting groups and probably represent relatively short-term groupings. In the Upper Paleolithic these may represent longer, wintering sites with stored or cached supplies. The local group and seasonal group size numbers, shown as shaded in Table 5-2, are the parameter input to the ICA Transition model in order to determine the scope of sharing in day-to-day activities and the potential for specialization in my model.

Table 5-2 Group Size Estimates by Population

Group Size	Minimal group		Local Group		Seasonal Group	
	Total	Adults	Total	Adults	Total	Adults
Neanderthal (early and late)	7-10	4	7-10	4	30	12
Early Upper Paleolithic	7-10	4	20-30	10	90	30
Middle Upper Paleolithic	30	12	50-100	30	225	90

I use the local group size as the principal determinant of specialization and exchange activities, since it is in the economic unit that most activities occur. However, I introduce tests to assess the additional benefits to a small group that would accrue from seasonal aggregation with other local groups in times of seasonal scarcity.

Chapter Six

Individual Skill Spreads

In the previous two chapters, I examined task repertoire and group composition. The remaining population parameter needed for the model is that related to the quality of productive resources that might be applied to these tasks: a qualitative measure of individual skill proficiencies. The range of individual skill variation, together with size of the group and the repertoire of critical tasks to be performed set the bounds for the scope and extent of specialization and cooperation within the context of Ricardo's law of comparative advantage. The subject of this chapter is to determine skill spreads for individuals in each of the four groups that are the subject of this dissertation. Division of labor by skill proficiency, age, and sex are addressed here.

6.1 Individual Skill Variation and Specialization and Exchange

The ethnographic record shows that, in current hunter-gatherers, individuals frequently perform tasks that can be exchanged directly for the product of one or more other individuals. Each individual specializes in those roles in which he or she is most proficient and exchanges the end product for goods and services produced by others more adept at those other tasks. The aim is to maintain output productivity by minimizing time and energy inputs.

Alternatively, a group of people may pool resources to accomplish a task that cannot be performed individually or can only be performed with a high risk of failure, or when the window of opportunity is narrow. Cooperative hunting for large, difficult to trap or migrating game is an example of this mode. Often individual hunting may be more efficient but more risky. Therefore, hunters will trade-off high reward but risky

procurement strategies for lower reward less risky ones. Many people of different skill sets pool their resources to minimize the risk of failure. The cooperative hunt requires organizing ability, knowledge of where and when to hunt particular species, coordination of specialist skills in ambush, beating, pursuit, capture, and kill, and a host of other skills, all of which contribute to the final success of the hunt. Skill specialization occurs within the hunting groups, and the spoils of the hunt are shared on completion. Another foraging technique is separation of labor (Whallon 1989), in which separate teams search in different locations for the same dispersed, resources to avoid committing all efforts to one search, and thus lessen the risk of failure. In both cases, spoils are divided among the families of those that participate. Viewing cooperative hunt as a pooling of diverse skills may resolve the question of why the best hunters do not get the greatest rewards (Kaplan, Hill et al. 1984). Hunter-gatherers know what the anthropologist seldom recognize: that the so-called superior hunter, that finally makes the kill, is dependent on and indebted to the many others that contributed to a successful and less risky hunt (Roberts 2005).

Another mode of cooperation involves long-term, and often long-distance, reciprocal relationships with others that inhabit niches that are ecologically anti-cyclical to that in which the individual lives. These networks occur, where resources are dispersed and unpredictable from season-to season and year-to-year. They offer a safety net to those in the areas affected by the local drought or lack of resources. This establishes an insurance network across landscapes, where climate is erratic and variable between patches, so that a failure in the home patch can be overcome by moving to the reciprocal patch. These networks also offer opportunities for exogamous

mating relationships. These networks are less about individual skill specialization and more about establishing long-term, trustworthy, reciprocal relationships that can be called upon to gain access to more abundant resources in other areas in time of need. These relationships need to be continuously nurtured since the cycle of need will be immediate when it arises, but may not arise for several years. Unfortunately, although many of the tasks that contribute to the maintenance of these *hxaro*-type networks, such as travel and gift making, are time-consuming (Wiessner 1977), they are not counted in the daily “productive” time allocations developed by ethnographers. Although the costs of these networks are incurred on a weekly and monthly basis, the benefits may not be reaped until seasons, or even years later. I have not included these insurance activities when computing the benefits of cooperation in my model. This is a conservative approach, since their inclusion would tend to increase the potential for the benefit from cooperation and bias the results.

i. Inter-Individual Skill Variation

In the ICA model the driving force is the unique skill proficiency of each person. In performing daily tasks an individual within a group may decide to perform his/her requisite tasks alone without the cooperation of others – the solo scenario. Or the individuals may chose to cooperate with other group members in the performance of those tasks, each performing those tasks most suited to that individual’s abilities, and then share the resulting output so that each achieves the same complement of end-products that he/she would have achieved by working solo – the cooperative scenario. In this scenario, work is effectively outsourced to others, and each member of the group becomes dependent on all other members of the group. In the cooperative scenario, the

key factor in the decision-making process is the individual's unique skill proficiency for each task. This determines who, among all those in the group, might best perform each required daily task. Within the model, tasks are allocated to the most proficient individual within the group, with the proviso that no one is expected to spend more time in total than would have been spent working solo. Where that is the case, the task is assigned to the next best performer who has time available. (This decision-making algorithm is explained in more detail in the model description in Chapter 2.) The potential benefits of specialization and cooperation are measured by comparing the time spent in the cooperative scenario versus the time that would have been spent in the solo scenario.

ii. Inter-individual Variability by Task

Archaeologists recognize the impact of individual action in examining archaeological traces through actions ranging from day-to-day social interactions, to technological innovation and changes, and to behavioral strategies such as hunting or scavenging techniques (Hosfield 2005). Unfortunately, too often in studies of group behavior inter-group variance is emphasized and intra-group variances are discounted, and an individual's sensitivity and contribution remains hidden (Wobst 1999). With few exceptions, most ethnographic studies have not specifically addressed inter-individual skills and the impact of individual skill variation on group activities outside the family, except for sexual division of labor. There are no qualitative data on individual specialization and division of labor except by sex and age, although almost all hunter-gatherer groups recognize that some individuals have special skills. The Ache recognize specialists in such tasks as tracking versus collection of honey: a

specialist tracker will call on other specialists to extract honey if he finds a bees' nest, or to dig out armadillos, if he has run one to ground, so that the tracker may resume his expert role of tracking the more valuable and preferred peccary (Hill, Kaplan et al. 1987). The Efe acknowledge the specialized skills necessary for the hazardous task of making poison for arrows and the amount of specialist training effort required for handling tracker dogs (Bailey and Peacock 1989). The Machiguenga concede that some create higher quality work than others; one makes a better bow, another makes fine, woven garments, and these may be exchanged for other favors (Johnson 1998; Johnson 2003). The Inuit hunter achieves status from his hunting prowess (Damas 1966), and the Nganasan believe that an individual's inclination to an occupational role is developed from childhood (Popov 1966).

Halperin (1988) argues that there is too much focus on the sexual division of labor between hunting and gathering and not enough attention is given to other critical activities such as the processing of food, clothing manufacture, tool making. Her analysis of !Kung, Ona, Tolowa, Shoshone, and Eskimo societies shows that gender roles and responsibilities vary dramatically by season, and that one cannot understand the organization of labor without considering all of these factors. My analysis attempts to address this by looking at the six basic activities (food acquisition, food preparation, childcare, tool making, clothing manufacture and camp maintenance) and how roles might vary by season.

By inserting individual skill variation by task into the model to differentiate between individuals and their activities in the group, I focus on the individual's unique skills, economic decision-making, and his/her contribution to and interaction with the

social structure. Without variation in skill levels there is no potential for economic specialization and exchange, since each individual would be able to perform all tasks with the same aptitude; conversely, with greater spread of skill variation more opportunities for specializations arise.

Inter-individual variability has long been recognized in nature. Darwin identified variation under nature as one of the key ingredients for natural selection and believed that it was pervasive – “I am convinced that the most experienced naturalist would be surprised at the number of cases of variability, even in important parts of structure, which he could collect on good authority, as I have collected during a course of years” (Darwin 1859; Darwin 1979: p. 102). The causes of variation among human individuals are many (Williams 1992): differences in age, in sex, in response to environmental factors, in genetic load, in epigenetic load due to trauma or deficiency, and differences from mutation, recombination, gene flow, or natural variation. Nevertheless, two individuals with different responses to different stimuli can also be equally fit. Significantly, not only are individuals distinct from other individuals, but also this variability is observed trait by trait (Williams 1998). A tall individual is not necessarily fat or blond, etc. Williams, a biochemist, contrasts two populations of ten men each of average height, foot size, body fat, eye-sight and teeth, and with an average digestive tract, sex urges, tolerance for alcohol, and emotional reactions, with a second population that yields similar average values. But, out of the second group, one is very tall, one has long, narrow feet, one is fat, one has uncontrollable sex urges, one is myopic, one has severe tooth decay, one is alcoholic, and one is subject to fits of anger and depression. The second group, (each one of which is an outlier in some manner)

may be much more representative of the real population than the first “normal” group. The message is that the norm is not the average. Such variability also occurs between specific task proficiencies. The good hunter may not be the best toolmaker, rarely is one individual the best performer of all tasks. Individual variability is expressed at both the individual and process or task level.

Variation may arise from genetic specialization as a result of natural selection on the genotype, developmental or ontogenetic adaptation, and plasticity. Plasticity, which reduces the necessity for adaptive natural selection, is the ability of organisms to respond physically or behaviorally to changes in the environment, particularly when these are stressful. Humans are, perhaps the most plastic of all species, and hence the most variable (Mascie-Taylor and Bogin 1995). Individual acclimatization through physiological and behavioral responses that are reversible help individuals adapt to the immediate environment (Roberts 1995; Schell 1995). Culturally learned behavior, such as how to make a tool, select edible plant food, or speak languages, causes a more or less permanent change in the brain, which may last for a lifetime, but is transmitted culturally rather than genetically (Lasker 1995). Cultural evolution has several features different from genetic evolution. It is Lamarckian: traits may be inherited through cultural transmission, and traits may be inherited from others than parents. Cultural transmission is able to spread characteristics through a population much more speedily than genetic transmission. Cultural evolution also has some of the characteristics of genetic evolution (Solbrig and Solbrig 1979). Cultural traits may differentiate between populations, and cultural drift works alongside genetic drift. Cultural transmission and

genetic flows produce similar results, and some suggest that natural selection works on in both cases.

iii. The Range or Spread of Skill Proficiencies in Modern Humans

Developmental adaptation resulting in inter-individual variability of the phenotype has been measured in living humans in a number of ways. The general model of population dynamics is that every individual can take no more than so many units of resources (the satiation level), and an individual requires at least a minimal number of resources to survive through the reproductive period (maintenance cost). Resources not used for maintenance are used for reproduction (Lomnicki 1988). In a group of genetically identical individuals of the same age and sex, some distributions are skewed towards smaller individuals. The level of variability of body size differs among populations, and with increasing body size variation usually increases but sometimes decreases; weight distributions are usually skewed, but they may sometimes be symmetrical (Uchmanski 1985). However, it is usual to ignore the skew of the distribution of individual weights and apply a much simpler model of binomial or normal distribution so that other aspects of individual variability becomes clear (Lomnicki 1988). Thus, an individual is not viable with muscle strengths or IQ scores below maintenance or above satiation limits. Typical biological processes show a similar normal distribution (Lomnicki 1988). These biological measurements suggest that, for completing life's critical tasks, a minimum amount of time is necessary, even for the most proficient. On the other hand, if the organism cannot complete the task within the maximum time, then it is not viable and will not survive.

In living organisms, the Gaussian distribution, characteristic of most biological processes, is exemplified below by the distribution of measurements of maximal muscle strength and IQ in Figure 6a.

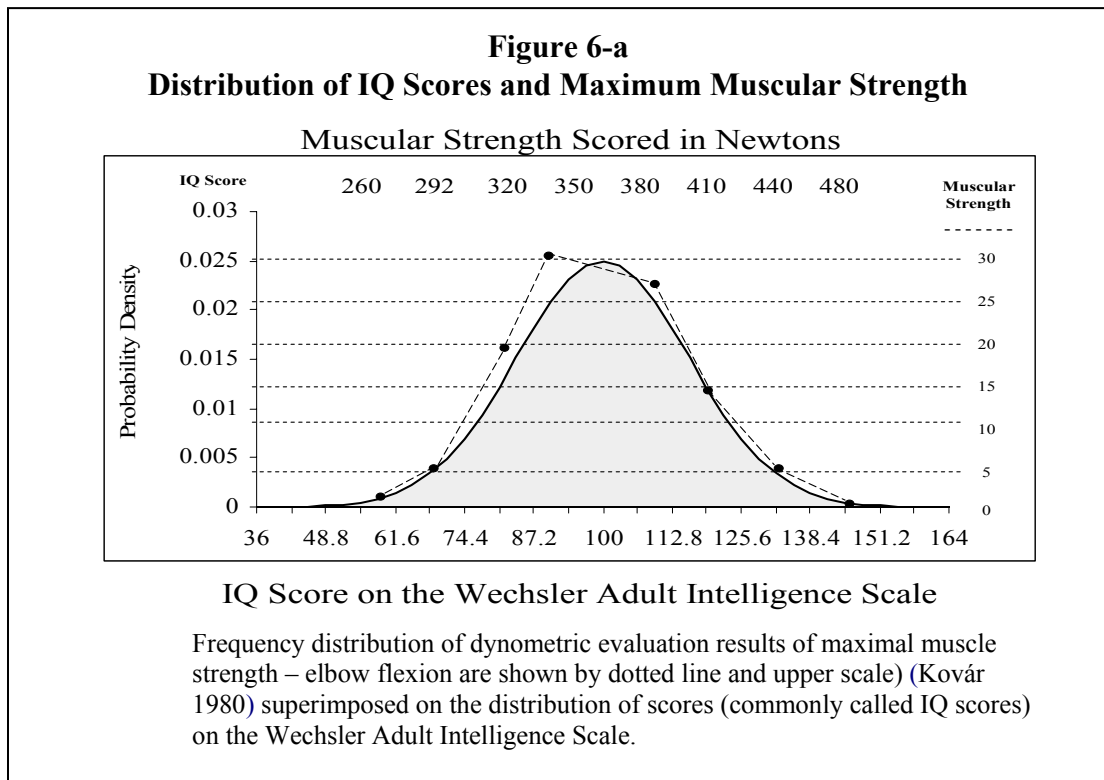


Figure 6a shows that the spread of muscle strength in modern humans is a normal distribution around a mean of 370 Newtons. A similar observation can be made with IQ measurements, which reflect skill at visual problem solving, verbal and arithmetic skills, and logical reasoning. IQ measurements are normalized at 100 and have a standard deviation of 16. Four standard deviations, two on either side of the mean, define width of this bell-shaped distribution for 95% of the population – from 68 to 132. Measurements rarely appear outside of these ranges. The normal range of muscle strength measurements, shown above, is between 260 and 480, normalized at

370. If these data are normalized to a mean of 100, then the range is from 70 to 130 – similar spread (and standard deviation) to that observed in IQ measurements.

Since there is no quantitative data available on skill variation from the ethnographic or prehistoric record for each individual's unique skill level, I have assigned skill levels for each task randomly in order to reflect this level of individual variability. For each separate task, each individual is randomly assigned a skill level with a normal or Gaussian distribution around a mean of 100 with a standard deviation for each population (the skill spread), as determined from this research. This makes the pattern of skill spreads similar to that observed in IQ, muscular strength, and other typical biological measurements (Lomnicki 1988). This approach simulates the range of inter individual variability within each population.

Since Upper Paleolithic populations are genetically identical to extant humans, I have chosen the standard deviation of 16 to represent the skill spread for early and middle Upper Paleolithic populations. The next sections of this chapter discuss if and why the range of Neanderthal skill spreads may have been narrower than the modern human range of 16.

6.2 Neanderthal Skill Spreads

i. Isolation and Neanderthal Demographics

There is some theoretical support for the idea that Neanderthals were less variable in their range of skills than modern humans. Climatic constraints during the major cold stages after 450 ka resulted in the geographic isolation of the Neanderthals' predecessors, with limited gene flow through the Bosphorus and apparent isolation from Africa (Hublin 1998). Hublin describes an accretion process characterized by

successive occurrences of new features and by an increase in their frequency within the isolated, pre-Neanderthal populations. Directional selection pressures leading to morphological specializations to improve survivorship in periglacial conditions would tend to reduce diversity as it moves the population towards a new adaptive peak (Lahr 1998). In addition, a series of population bottlenecks, caused by these extreme climate fluctuations, and the withdrawal of surviving members of the population to restricted geographic refugia in the south with access to only a limited gene pool, would have raised the level of positive mating and inbreeding. Nevertheless, phenotypic variances among genetically similar individuals would still be observed (Lomnicki 1988).

Isolation is one of the more important factors leading to evolutionary change. Howell (1952) suggests that Neanderthals were restricted to milder climate areas consisting of vertical ecotones with more abundant plants, berries, nuts, small forest animals (with deer and occasional larger herbivorous forms). They were able to survive in these habitats that offered resources and protection against the weather. He then concluded that gene flow was limited within this biotope to the interchange between local interbreeding groups. "Through the even distribution of the genes, all members of the isolate share common genes and gene complexes; there is thus a degree of homogeneity obtained, like that of inbreeding, which would be otherwise impossible if it were widespread transference over large area between migratory groups" (ibid: page 402). Such mating patterns would have increased the amount of homozygosity, indicative of a decrease in variability in the Neanderthal populations, since homozygotes and inbreds usually exhibit lower adaptation to their environment.

The founder effect operates when an exceedingly small group of individuals contributes exclusively to the gene pool of the next generation. The descendants carry only a small portion of the alleles (and of the variation), that were present in the original population. This random drift is likely to be in-adaptive in small populations and increase the likelihood of extinction (Dobzhansky and Pavlovsky 1957). Founding populations may be found when small migrant bands found colonies, as well as when famine ravages a normally larger group.

During OIS 4 Neanderthals suffered the same bottleneck as other primate species, they withdrew to refugia in southwest France, Iberia and the Caucasus and retreated from northern regions. The Neanderthal settlement history analyzed in Chapter 7 shows that in both Western and Eastern Europe the Neanderthals never again achieved the northward geographic expansion that they had previously enjoyed in OIS 5 and earlier. In the warmer OIS 7, early Neanderthals had settled as far north as Pontnewydd in the U.K., and in OIS 5e classic Neanderthals reached Khotylevo in Russia, (both above latitude 53° N), but, in the intervening colder periods, they were restricted to more sheltered areas in central and southern Europe. This distribution suggests that they suffered a series of population crashes culminating in the one during OIS 4 from which they never fully recovered. On the other hand, the archaeological data indicates that modern humans continued to migrate into and expand settlements in the colder northern regions, and did not depart until the height of the pleniglaciation (Gamble 1999; Dolukhanov 2001).

In summary, as a result of their isolation and confinement to small refugia during glacial and stadial episodes, the isolated and inbred Neanderthals likely

expressed a lower range of diversity than that of the immigrating Upper Paleolithic population.

ii. Demographics and DNA Diversity

DNA analysis seems to support the idea that Neanderthals may have been less diverse than the early modern humans. Neanderthals drew from a smaller gene pool than that of modern humans in Sub-Saharan Africa. Neanderthals might not have been able to achieve the rapid expansion achieved by anatomically modern humans during this period and were more likely declining in diversity, while the newly arrived modern humans were expanding and increasing in diversity. At the time of the Upper Paleolithic transition, modern humans were experiencing rapid expansion in numbers and diversity (Relethford 1998a) made possible by some genetic or cultural innovation, perhaps the use of language, the exploitation of novel resources, or more social and supportive behaviors.

Only a limited number of skeletal remains are sufficiently uncontaminated to permit DNA analysis of Neanderthal genetic diversity (Cooper, Poinar et al. 1997). However, mitochondrial DNA (mtDNA) from the type specimen of an early Neanderthal from Feldhofer Cave in Germany and from a late Neanderthal child found at Mezmaiskaya Cave in the northern Caucasus were found to be remarkably similar despite their temporal and geographical distance from one another (Höss 2000; Krings, Capelli et al. 2000; Ovchinnikov, Gotherstrom et al. 2000). Neanderthals seem to be more similar to modern humans than to apes in having a low species-wide, genetic diversity; this may indicate that they too had expanded from a small population through a series of bottlenecks (Krings, Capelli et al. 2000).

A look at mtDNA diversity in living humans provides some insight into the demography of earlier modern human populations and their history of diversity (Relethford 1998a). An examination of the mismatch distribution of pair wise differences in mtDNA sequences of living humans shows a pattern not expected from a stable-sized population (Rogers and Harpending 1992). The authors conclude that the smooth-shaped curve reflects a rapid and extensive expansion in ancient population size. Similar wave-patterns are seen in the mismatch distributions of Eastern chimpanzees, which suggest that the waves of both species reflect some environmental catastrophe rather than the radiation of a genetic mutation (Rogers and Jorde 1995). Some have argued that this catastrophic event was the Mount Toba eruption (Rampino and Self 1992) (Rampino and Ambrose 2000), which also coincided with the start of the glacial OIS 4 (Ambrose 1998b). Such a catastrophe would have most severely affected humans living outside of Africa at that time, notably Neanderthals and maybe some early modern humans that had already dispersed out of Africa. The bottleneck is thought to have occurred after the initial exodus of anatomically modern humans from Africa, perhaps 100,000 years ago – the weak Garden of Eden model (Relethford and Harpending 1994). The subsequent population expansion in Africa and in the dispersed population began about 65,000 years ago and ended about 30,000 years ago, which is at the same time as the appearance of the Upper Paleolithic in Europe (Harpending 1993; Sherry, Rogers et al. 1994). The modern human population size prior to the expansion is estimated at 10,000 individuals with a range from 3,000 to 20,000 individuals, half of them females. The impact was surely as severe for Neanderthals living in more northerly areas.

Craniometrical variation in sub-Saharan Africa suggests that within-group diversity may be primarily a function of population size (Relethford and Harpending 1994), and since between 50-70% of our ancestors lived in sub-Saharan Africa, where population size was larger than any other geographic region, dispersing humans may have inherited their diversity from their African forebears. They might not have lost this within-group diversity, since a daughter population must endure a severe and long-lasting bottleneck in order to reduce the initial level of diversity significantly. Once the population expansion recommences the level of within-group diversity increases (Relethford 1998b). The African population was larger before the expansion and expanded earlier than other populations in other regions. An average of 31% of modern human mtDNA diversity worldwide seems to have accumulated before the expansion but 69% accumulated afterwards, between 65 and 30 ka (Relethford 1998a): a period which spans the time of the first entry of anatomically modern humans into Europe. The magnitude of this population expansion is estimated to have been 100-fold (Rogers and Jorde 1995; Harpending, Batzer et al. 1998). Based on the late timing of population and diversity expansion in modern humans, Relethford concludes that the expansion was driven by culture rather than genetics (Relethford and Harpending 1994).

There is some question as to whether mtDNA is a good measure of diversity. Bazin et al (2006) recently suggested that mtDNA is not a good correlate for population size and diversity since selective recurrent sweeps have reduced mtDNA diversity and homogenized mitochondrial diversity across animal groups, however, Mulligan and associates' analysis of similar data suggests that mtDNA diversity may correlate with

population size in species with smaller populations such as eutherian animals, including humans (Mulligan, Kitchen et al. 2006).

These findings suggest that, while significant increases in DNA diversity to current levels are observed in modern human DNA, DNA diversity in the confined Neanderthal population was static or declining. However, the precise magnitude of any difference in skill spread, if any, cannot be quantified. Maybe, the new pyrosequencing (Green, Krause et al. 2006) or metagenomic (Noonan, Coop et al. 2006) approach being used to decode the Neanderthal genome will provide the tools for extracting DNA from a larger sample of Neanderthal skeletal remains to determine the level of diversity among Neanderthals.

iii. Skeletal Morphology and Diversity

Genetics alone may not totally reflect skill spreads. Post-cranial morphology, in particular, is a function of genetics, ontogenetics, and habitual behaviors. Bones are continuously remodeled by osteoclastic absorption in conjunction with osteoblastic bone formation, and it has been shown that hand dimensions are related to the habitual activities practiced in the course of a man's occupation (Roberts 1995). An examination of limb proportional indices between Neanderthals and early anatomically modern humans shows that, although Neanderthals were generally more robust, the amount of variation in these indices was generally larger in early modern humans (Trinkaus 1983) – Table 6-1.

Table 6-1 Variation in Limb Proportional Measurements and Skill Spread

		Data Source or Data Manipulation		Brachial Index	Crural Index	Humero femoral Index
1.	Neanderthals	(Trinkaus 1983)	Mean	74.8	78.6	72.1
			Std Dev	2.7	1.4	2.2
			N	8	9	7
2.	Early Anatomical Modern Humans	(Trinkaus 1983)	Mean	77.2	86.0	72.3
			Std Dev	3.0	1.8	2.7
			N	17	14	14
3.	Neanderthals	Mean of 100	Std Dev (a)	3.6	1.78	2.2
4.	Early Anatomical Modern Humans	Mean of 100	Std Dev (b)	3.9	2.1	3.7
5.	Neanderthal/EAMH	(a/b)	Ratio	0.92	0.85	0.84
6.		Ratio applied to Std Dev of 16		4.7	13.8	13.4

Rows 3 and 4 show standard deviations normalized to a mean of 100.

Row 5 shows the ratio of Neanderthal standard deviations to EAMH deviations.

Row 6 applied the ratio to the standard deviation used in the model and derived from IQ measurements.

This suggests that, if this variation in limb proportions reflects variations in habitual activities and skill spreads, then Neanderthals had a lower range of habitual skills than anatomically modern humans, maybe ranging from approximately 13.5 to 14.5, as opposed to the 16 observed in modern humans.

Average endocranial capacities are $1,507 \pm 116\text{cc}$ and $1,577 \pm 135\text{cc}$ for European classic Neanderthals and early Upper Paleolithic humans, respectively (Klein 1999). These measurements show that Neanderthals exhibit 89.8% less variability (a lower standard deviation) than early modern humans – equivalent of a spread of 14.4 versus the 16.0 observed in modern humans.

iv. Habitual Manual Dexterity and Diversity

The impact of habitual activity on morphological development may be a meaningful measure of skill levels and skill spreads within groups. The spread of skill applied in any situation may be determined by examining habitual behaviors as interpreted from skeletal morphology and cultural behaviors observed in the

archaeological record. Variations in habitual skills, as seen in the archaeological and anthropological record, are a combination of individually unique, inherited predispositions, modified by habitual patterns of usage.

Middle Paleolithic humans depended for survival on extensively manipulating the world around them, and on the use of planning and foresight. A high degree of manipulative ability is inferable from the stone tools they made, tools that living humans are incapable of reproducing without considerable practice (Chase and Dibble 1987). Variation in manipulative capabilities might provide meaningful information on the differences between Neanderthals and Upper Paleolithic humans. Hand and speech activities are concentrated in the left side of the brain in adjacent areas and many have suggested that the development of fine manipulation capabilities and speech occurred in parallel over time (Donald 1991; Calvin 1998). Hands are depicted in Upper Paleolithic cave art in greater frequencies than any other human form (Leroi-Gourhan and Michelson 1986). The fossil and artifact record may provide more direct evidence of the evolution of manipulative and other early behaviors (Churchill 2001).

Four basic grips are identified for the human hand: the hook, scissor, power, and precision grips (Aiello and Dean 2002). The most basic of these are the power and precision grip. The power grip is one in which objects are actively supported in the palm and gripped by the fingers or fingers and thumb. This hand posture allows for the precision control of objects, with the thumb opposed to the fingers, and, by incorporating the palm in addition, provides support for an extension of the forearm for more forceful actions like hammering. The precision grip is defined as one that holds an object between part or the whole of the flexor aspect of the fingers and the opposing

thumb. The precision grip became the focus in hominid hand evolution and is linked with relative thumb length and the capacity for stone tool making. A refinement of these two basic manipulative capabilities is seen in precision handling and precision rotation (Long, Conrad et al. 1970): these are more active, manipulative processes rather than just a gripping activity.

One line of research considers how living humans use the muscles of the hand in a variety of grips. A second compares Neanderthal and modern human hand morphology to elucidate the implications for Neanderthal abilities from their bone structure and musculature.

In a detailed study of muscle control of the hand in performing a variety of tasks, Long (1970) and his team contrasted free motion, various power grips (squeeze, disc, hook, and spherical), precision rotation, and translation (moving an object toward or away from the palm), and the pinch grip (compression between the thumb and index or thumb and first two fingers). From electromyograms of subjects taken during various grips, Long and colleagues determined the muscle activity associated with each type of grip. Movements produced by the forearm are assisted and made more precise by smaller, intrinsic muscles in the hand (McCracken 1999), see table 6-2. In living humans, the intrinsic muscles provide the additional control required for the more precise grip and handling functions.

Table 6-2 Muscles Recruited in Hand Functions

Hand Function	Muscles Recruited
Free hand	Flexor profundus
Power grip	Extrinsic and thenar Intrinsic: interossei, abductor digiti minimi and fourth lumbricalis.
Precision handling	Rotational force from the interossei The first lumbricalis, first palmar interosseus, first dorsal interosseus, opponens pollicis, abductor pollicis brevis, flexor pollicis brevis, abductor pollicis all participate.
Pinch grip	Most recruited are: the first dorsal interosseus, first lumbricalis, opponens pollicis, flexor pollicis brevis, adductor pollicis, and first palmar interosseus.

Table 6-3 identifies morphological features in the hand associated with tool making (Marzke, Wullstein et al. 1992). Many have concluded that *Homo* achieved a level of manual dexterity and neurological control of the upper limb similar to that of modern humans by the early Late Pleistocene, probably in association with the major increase in encephalization during the Middle Pleistocene (Ruff, Trinkaus et al. 1997).

Table 6-3 The Combination of Expected Features That Appeared with the Advent of Habitual Tool Making

Features	Grip	Purpose
Elongated thumb	Permit pinch grip	For rotation of hammer stones, cores and flakes.
Intrinsic muscle potential	To maintain the pinch grip	Against powerful strong resistance.
Metacarpal joint surfaces	To allow cupping of the fingers	For the cradling of objects
Broad distal phalanges	To balance the load from strong pinch grips	To maintain stability of object held

An analysis of the bones of the Neanderthal hand (Musgrave 1971) focuses primarily on the thumb and index finger to determine the dexterity of Neanderthals. The author notes the radially projecting ridge for the insertion of the opponens pollicis on the thumb together with the marked depression on the opposite side for the origin of the first dorsal interosseus, both used in the power grip. He also notes the shortness and robustness of the thumb proximal phalange heightened by the length of the distal phalange, which he contends supports broad distal tuberosities, useful in a power grip.

He also found that the intrinsic muscles, particularly the first dorsal interosseus, were extremely powerful; these are used to counteract the pressure of the thumb against the index finger in the precision grip. Musgrave suggests that this would be used in grasping large spherical objects, such as hammer stones, and what he classifies as a crude precision grip – the key grip. The metacarpals on the thumb and the fingers have wide heads and narrow mid-shafts increasing the inter-carpal spaces and allowing for larger interosseus, and presumably greater control of precision-grip muscles. Proximal phalanges are relatively short and have thick, wide bases and mid-shafts to accommodate stout tendons for the extrinsic flexor, power-grip muscles. This all provides support for the fact that Neanderthals had a very wide and robust hand. Musgrave does not comment on precision handling or rotation capabilities.

A comparison of the pollical load arm dimensions to power arm dimensions for European and Near Eastern Neanderthals and for European and Amerindian samples for recent humans (Trinkaus and Villemeur 1991) validates Musgrave's findings. Specifically, the Neanderthal hand, when compared to the modern hand, exhibits an enlarged carpal tunnel to support flexor retinaculum, thenar and hypothenar muscles, another power grip advantage (Stoner and Trinkaus 1981). In addition to the features noted above, the contrasts in pollical lengths between proximal and distal phalanges for Neanderthals and modern humans provides significant mechanical advantage to Neanderthals in their pollical flexor muscles for use in power grips at the expense of the precision grip. The wear on the anterior teeth (Aiello and Dean 2002) may be as a result of using them as a vise or third hand for grasping hides and other materials when

scraping, cutting or otherwise preparing for use: this might imply that Neanderthals did not possess the capability for a strong pinch grip.

Two other features of the Neanderthal thumb differ from that of modern humans: the shape of the first metacarpal joint and the relative lengths of the proximal and distal thumb phalanges (Aiello and Key 2002). Palmar carpal tuberosities become smaller, reducing the power of the carpal flexor, thenar (thumb), and hypothenar muscles (pinky). Thumb phalangeal length proportions shift from sub-equal lengths among Neanderthals to the distal phalange being about 2/3 the length of the proximal phalange length in modern humans, indicating a change from greater muscle effectiveness when gripping across the proximal phalanx (as in the power grip) to one emphasizing strength across the distal phalanx (as in the precision grip). From a mechanical point of view, the Neanderthal proportions would decrease the load arm between the inter-phalangeal region and the metacarpophalangeal joint and increase the effectiveness of the thenar eminence muscles (flexor pollicis brevis, abductor pollicis and adductor pollicis), when grasping large objects, and increase the load arm between the inter-phalangeal joint and the fingertip thus decreasing the effectiveness of the flexor pollicis when grasping objects with the fingertips. Since these phalangeal length changes in modern humans took place in concert with the above muscular strength reductions, they merely maintained strength levels at the fingertip at the compounded expense of strength in a power grip (Trinkaus 1983).

Marked reduction in the breadths of distal phalangeal apical tufts, indicating smaller palmar pads among early modern humans, imply a decrease in resistance through friction to shear stress on the terminal fingers, and point to less transversely

oriented impact loading of objects held between the fingertips. The first and fifth metacarpal articulations shift from more condyloid configurations to saddle shaped ones, maybe related to changes in habitual peak stress directions and grip positions rather than mobility. The second metacarpal to capitate facet becomes universally large and obliquely oriented indicating a change to a more oblique (proximo-ulnar) habitual loading of the second digit from a more axial one (Trinkaus 1983).

Many of the above hand studies have involved current humans, but a recent analysis of Skhul/Qafzeh early modern human hand remains suggests that a shift in hand manipulative behaviors did occur with the arrival of modern humans (Niewoehner 2001). The articulations of the capitate and second and third metacarpals (MC) have more sagittally oriented MC2-capitate facets and less projecting MC3 styloid processes (Trinkaus and Villemeur 1991). This suggests that the Neanderthal MC2/3 and capitate structure was not well adapted for oblique force and that Neanderthals did not habitually employ tools requiring oblique power grips and precision handling. This was tested using capitates and metacarpals from European and Near Eastern Neanderthals and samples from an Amerindian population; high-activity, prehistoric, horticulturalists (Niewoehner, Weaver et al. 1997). The univariate and multivariate analysis supported the earlier findings that Neanderthal and recent human capitate-MC2/3 articulations have significant, functionally relevant, morphological contrasts. However, the authors declined to pronounce on any behavioral implications. Niewoehner (2001) determined that the Qafzeh/Skhul hand remains resemble Upper Paleolithic humans, and not Neanderthals, in the functionally significant MC 1 and 3 bases. The findings were that, relative to Neanderthals, both early and late Upper Paleolithic MC3 bases have

increased concavity of the facet for the MC2 base and that these changes are progressive from the early Upper Paleolithic through to recent human samples. These increased Upper Paleolithic concavities permit enhanced pronation of the MC2, which is adapted for the transmission of increased oblique loads as opposed to the axially directed forces for the Neanderthal configuration. There are significant reductions in mechanical advantage on both the radial and ulnar sides of the hand of both Upper Paleolithic humans compared to Neanderthals, and Upper Paleolithic have the broader fingertips observed in the Neanderthal specimens. Niewohner suggests that these MC2/3 changes stabilize the mid-carpalmetacarpal region and are associated with the more widespread use of hafted tools used in the Upper Paleolithic, and that enhanced MC2 pronation, used in the precision grip, are associated with engraving and incising of bone and antler artifacts (Niewoehner 2001). Given the correlations between changes in tool technologies and functional adaptations seen in the hands of Upper Paleolithic humans, it is concluded that the Qafzeh/Skhul hand remains were adapted to Upper Paleolithic-like manipulative repertoires.

These correlations suggest that hand functional anatomy may be used as a primary indicator of frequency shifts in habitual, manipulatory repertoires, because habitual activities affect local rates of bone modeling and remodeling. These results support the inference of significant behavioral differences between Neanderthals, Qafzeh/Skhul humans, and later Upper Paleolithic humans, and indicate that a significant shift in human manipulative behaviors particularly for precision handling of oblique loads was associated with the earliest stages of the emergence of modern humans. Even though many features of the hand such as the broad apical tufts seen as

early as *Australopithecus robustus* developed quite early, the emerging facility for finger-tip precision handling and sensitivity to touch and texture may account for the focus on precision work and the tactile qualities such as luster and polish in Upper Paleolithic artifacts and mobiliary art (White 2003).

Morphology of the hand implies that Neanderthals were capable of the same hand movements as modern humans, but that they habitually exerted a more powerful power grip (Trinkaus 1983), whereas modern humans habitually performed more varied and more precision handling activities (Trinkaus 1989; Niewoehner, Weaver et al. 1997; Churchill 2001; Niewoehner 2001). A shift in the thumb/phalangeal length proportions, from sub-equal among Neanderthals to 2/3 of the proximal phalangeal length among modern humans, the marked reduction in distal apical tufts, and the more to more sagittally oriented MC-2 facets together with less projecting MC3 styloid processes among modern humans suggests an improvement in the range of dexterity with the move from the power grip to better precision handling capabilities in early modern humans (Torrence 1989).

- **Habitual Manual Dexterity Observed in Lithics Analysis**

Lithics analysis provides an indication of the increase in breadth of precision handling behaviors among modern humans. Tools, such as burins and hafted implements used for precision work and common in the Upper Paleolithic, require different manual positions than do the hand-held side-scrapers, notches and denticulates that dominated assemblages of the Middle Paleolithic. Those tools also reduce the need for powerful gripping with the fingertips required by large, hand-held lithic chopping and cutting tools, shifting stress to more oblique trajectories through the carpometacarpal region,

possibly accounting for differences between Neanderthal and early modern human carpal morphologies. Furthermore, effective throwing projectiles, such as could be made with hafted bone and stone points associated with the early Upper Paleolithic, would emphasize a more extended position of the arm than would thrusting spears, wooden or with relatively thick and wide stone points, associated with the Middle Paleolithic (Trinkaus 1989).

The lithic sequence from Tabun has produced evidence of a regular temporal trend for a gradual increase of the relative width/thickness of all complete flakes with a maximum diameter > 2.5 cm. The variance of the mean of this ratio shows a gradual increase through time. The earlier width/thickness ratios for Neanderthal flakes were in the range of 3 to 4, and the later ones ranged from 4 through 6. The early modern human flakes have width/thickness ratios averaging well over 6 (Jelinek 1994). The most recent anatomically modern humans were making finer flakes than their Neanderthal counterparts (Table 6-4).

Table 6-4 Statistics on Width/Thickness of Complete Flakes for Levant Samples

Attribution	Context	Mean
Early Modern Humans	Qafzeh and Skhul	5.97 - 6.74
Neanderthaloids	Tabun Chimney + B and Kebara F	6.04 - 6.20
	Tabun DC, HI-VIII, and II	4.26 - 4.64
	Tabun G, XIV, XIII, XII, XI and X	3.22 - 3.95

(Jelinek 1994)

It is suggested that this correlation is not without significance for the variations in human morphology - the ability to produce more, proportionately thinner flakes may be a reflection of a greater achievement of precision grip or precision handling. Originally, Jelinek used this data to argue for a local development of more gracile hominids from earlier more robust forms (Jelinek 1982). However the recent dating of

the Qafzeh samples at between 120 and 80 ka (Schwarcz, Grün et al. 1988; Grun and Stringer 1991; McDermott, Grun et al. 1993) negates this earlier conclusion, but does not contradict the suggestion that the differences between tools made by Neanderthal and those made by anatomically modern humans might reflect differing manipulative skills.

A similar analysis of more than 100 complete flakes with maximum diameter > 2.4 cm from the sequence from Combe Grenal showed no unidirectional trend through time during the Mousterian period (Jelinek 1994), especially since there is little significant difference in the raw materials employed throughout the sequence, which might have affected the trend. From this evidence, the author concludes that the flakes left at Combe Grenal show some change in flaking techniques that may reflect less use of a precision grip in the later occupations, but the abruptness of the later Upper Paleolithic transition suggests a technologically based rather than a bioevolutionarily based cause (Jelinek 1994).

By examining the reduction sequence of Mousterian scrapers from La Quina and Tabun, Dibble (1987) found that lithic artifacts typically go through several stages of use, wear, and retouch, and that the final form probably reflects the end result of these modifications, with the tool being discarded once the item became too narrow to grasp (Chase and Dibble 1987; Dibble 1987). The end product of various scraper classes has the same average width (Dibble 1989). This might suggest that Neanderthals were limited in their habitual, fine precision handling capabilities. However, recent work at Pech de l'Azé indicates that Neanderthals were making small flakes (some under 3 cm) than had previously been discovered (Dibble and Mcpherron 2006). These flakes were un-

retouched and appear to have been hand-held and not hafted, which suggests that handling such small tools was in the range of Neanderthal capabilities. Nevertheless, this contrasts with the fine precision work of early modern humans who were producing blades of less than 2 cm at Enkapune Ya Muto 40-50,000 years ago (Ambrose 2001), and blades and bladelets at Le Malpas in the later Upper Perigordian with an average width of 20 mm, a length of over 120 mm and a thickness of 6-9 mm (Montet-White 1973).

Unfortunately, it is not possible to look at other than lithic technologies for evidence of manual dexterity in the Middle Paleolithic: the same chipping techniques applied to stone may have been used to perform any bone and antler work. While these resources are amenable to shaping and modification by cutting, chiseling, shaving, grinding, gouging and abrasion, there is virtually no evidence for the use of these methods on these readily available raw materials before the Upper Paleolithic (Jelinek 1977; White 1993b).

The making of spear points from antler was a specialty of the Aurignacians that required fine workmanship. They halved the antler along its length and split off sections to be used for spear points. These were shaped, pointed, and polished. They then made a split in the base end so that it could be wedged into the spear shaft (Knecht 1994). An experimental recreation of a *sagaie à base fondu* and many other artifacts demonstrates the intricacy of the steps involved (<http://www.pole-prehistoire.com/200gestes/>). Later, lozenge-shaped and spindle-shaped points were created for easier replacement and repair. Aurignacian and Gravettian needles were made from split bone that was abraded in a specially shaped whetstone, and finally the eye was gouged or drilled. Small microliths for multiple hafted tools and leaf-points

made by the Gravettians demonstrate that the modern humans were applying their precision handling skills to the creation of stone tools.

Beyond the production of lithics and utilitarian objects, there are other striking examples of precision handling in modern humans. Aurignacian beads found at Vallon de Castel-merle, Saint-Jean-de-Verges, and Brassempouy in France, Geissenklösterle in Southern Germany, and Spy in Belgium demonstrate the fine workmanship required to produce such items (White 1993a). Rods of ivory and steatite were circumscribed and snapped into small segments. They were then shaped into beads of less than six mm in diameter (White 2003), which were subsequently thinned so that they could be pressure-gouged to create a small hole for stringing the beads into necklaces or attaching them to garments. Finally the ivory or steatite beads were polished to a gloss (White 1989a; White 1997). Other fine, polished pendants were made from deer and fox canines or soapstone facsimiles thereof. An Aurignacian ivory mammoth amulet from Vogelherd in Southern Germany, that is only 4.8 cm long, shows equally fine detail carvings of mouth, eyes, and ears. A belemnite fossil pendant from Kostenki and carved incisors and canines from Kostenki, Bacho Kiro, and Mladec in Eastern Europe, demonstrate the fine precision handling skills of Aurignacians across Europe.

The tradition of creating finely detailed, portable art continues into the Gravettian, as evidenced by the ivory head, *la dame à la capuche*, from Brassempouy, the thousands of beads found at Sunghir', and the Gravettian "Venus" figurines that show up from Italy to Russia. Spinning of twine from plant fibers to create weaving warps and wefts of 0.05 mm in diameter (Adovasio, Soffer et al. 1996), and the creation of intricate weaver's and square/granny knots (Soffer 2000), attest to the precision

finger-work of these Upper Paleolithic peoples.

No such precision work appears in the Mousterian record. Mousterians were expert woodworkers and it is unlikely that any finely detailed work would have survived. However, examination of their stone tool kits indicates that the majority of Mousterian scrapers and denticulates were used in adzing, whittling, stripping, or scraping bark (Beyries 1988). They did not create the tools required for intricate graving, such as burins and percoirs.

Both the skeletal and artifactual records suggest that, with the advent of the precision grip, modern humans possessed a wider range of manipulative motions and skills than the Neanderthals, as indicated by the finer precision work observed in tools, artifacts, portable and parietal art. However, once again the measure of this difference in variation is difficult to quantify.

v. Post-cranial Morphology and Implied Habitual Patterns of Locomotion

The morphology of the Neanderthal femoral and tibial shafts, and especially the cross sectional expansion, place them at the limits of, or outside of, the recent human range of variation (Trinkaus 1989). This robusticity is a reflection of both strength and endurance. The shaft hypertrophy of their femora and tibia suggests an adaptation for endurance in prolonged locomotion over irregular terrain and suggests that they spent a significant portion of their waking hours moving continuously and/or vigorously across the landscape, far more than did early modern humans. The wide pedal phalanges of the Neanderthals indicate, along with the cross-sectional shapes of their femoral and tibial shafts that this locomotion included considerable irregular movement, rather than the more straight-line striding usually employed by recent humans. The shaft

configurations, which were characteristic of all archaic members of the genus *Homo*, disappeared with the emergence of modern humans, indicating a shift to predominantly unidirectional striding gaits among early modern humans.

Biological variation and habitual activities are two factors that affect skill spreads. Direct evidence of variation between Neanderthal and modern human skeletal morphology is often hidden within the plasticity of the bone structures by the impact of habitual and repetitive locomotive patterns. The shortness of the distal relative to proximal upper and lower distal limb segments in Neanderthals is attributed to cold adaptation that evolved over many generations of habitation in northern latitudes (Holliday 1997a). This limb pattern is not evident in the recently migrated modern humans until after the glacial maximum. However, the greatest contrasts between the femorae of Neanderthals and modern humans are in the cross-sectional shape of the diaphysis (Ruff, Trinkaus et al. 1993). Pilastering, as evident in early modern human femurs, develops in response to habitual stress and the differences may reflect habitual patterns of movement across the landscape (Rak and Arensburg 1987), striding gait (Ruff 1991), and habitual foraging routines (Tomkins and Trinkaus 1987). However, this may indicate an overall difference between Neanderthals and early modern humans rather than a difference in the breadth of diversity within each population.

A morphological measure of variation of diaphyseal robusticity in lower limbs (femur and tibia) among Neanderthal males was 3.70% and among Gravettian males (LUP) 10.28% (Pearson 2000a; Pearson 2000b). This suggests that modern humans were less robust but more variable in their diaphyseal development, perhaps as a result of greater variation in habitual activities, and that the Gravettian males exhibited almost

three times the variability of Neanderthal males. However, sample sizes are limited to less than three specimens, and not all morphometric measurements confirm this degree of variation.

Neanderthals, though locally mobile, did not range over such wide home ranges and were probably limited to territories of less than 10,000 km² in area (Hoffecker 2002). It is suggested that the narrow, tropical body proportions of the Upper Paleolithic humans may have provided a selective advantage for energetic efficiency in wide ranging foraging activities, so necessary for survival in the open habitats that they occupied in high latitudes (Weaver and Steudel-Numbers 2005). Lithic and exotic networks may provide information on the variations in movement patterns between the Mousterian and Upper Paleolithic periods.

- **Networks and Sourcing of Lithic Materials**

Analysis of lithic sourcing networks in Aquitaine, Moravia and northwestern Europe (Svoboda 1983) (Hahn 1987; Geneste 1988; Rensik, Kolen et al. 1991; Féblot-Augustins 1993; Féblot-Augustins 1997) provides important information on the transport of materials. Late Middle Paleolithic transfers of raw materials were predominantly local (less than 100 km), but six examples over long distance transport (between 100-300 km) have been identified in the later part of the period as opposed to only one example from the earlier Middle Paleolithic (Féblot-Augustins 1993). In the Upper Paleolithic, significantly larger quantities and weight of core and pre-core materials were being transported over larger distances.

In the Aquitaine, during the Mousterian period 88% of the materials came from within 5 km of the site, and these artifacts demonstrated all phases of the *chaîne*

opératoire, indicating that the raw materials were brought to the site and knapped at the site; these artifacts indicate a low utilization rate (Geneste 1985; Geneste 1988). Of the remaining materials, 20% represents materials from 5-20 km away that were brought to the site as partially worked cores; these tools had a slightly higher utilization rate. Less than 2% of the materials came from between 30-80 km away. These were high quality materials, imported to the site in the final stages of preparation, and indicate very high levels of utilization – up to 100%. These preferred, high quality, finished tools were retained and transported and re-used during seasonal rounds, since highly mobile groups are constrained by the fact that they need to transport all their limited possessions as they moved from site to site. On the other hand, the Aurignacians transported a far larger proportion of relatively heavy cores from long distances to be worked on at the site. One or two-dozen river pebbles represent a one-person load (Montet-White 1973), therefore this long-distance transport could have consumed considerable amount of effort. This Upper Paleolithic pattern of long distance sourcing of quality materials to be worked on locally suggests less frequent, residential mobility with dedicated, specialized forays in order to collect large quantities of usable raw materials for working at local, sometimes specialized sites. These materials showed all phases of the *chaîne opératoire*.

The early Upper Paleolithic (Aurignacian) marks the first turning point in procurement and exploitation patterns. Although poor quality local materials are used, higher-grade raw materials are preferred and transported over larger distances as cores or pre-cores. This pattern broadens somewhat across Europe in the middle Upper Paleolithic (Gravettian) with the northwest assemblages containing one fifth of the

artifacts from over 150 km and the central regions about half (Rensik, Kolen et al. 1991). In the Gravettian, there is a more selective attitude towards raw materials, and transport of large quantities of un-worked cores over long distances becomes common. The thin blade technology demanded homogeneous and fine-grained flint that was actively sought. The Gravettians shunned the use inferior quality materials. In the Epi-Gravettian and later Magdalenian more versatile production techniques permitted the use of more local and, if necessary, inferior quality rocks (Féblot-Augustins 1997).

Patterns of transport throughout Europe depend on lithic sources and topography. Therefore, it is more important to examine transport patterns diachronically, region by region, in order to get a picture of how procurement and exchange systems developed. In the Upper Paleolithic in Western Europe, long-distance transfers become more frequent; however, transfers remain circumscribed within the local geographic basins with no contact between each.

The largest transfers are in central and Eastern Europe, where vast areas are totally lacking in sources of siliceous rock (Kozłowski 1991), and where networks extend across geographic boundaries. Distances in the Brno region of Moravia are conditioned by the availability of quality flint from the Moravian Gate, 60-70 km away and radiolarite from 90 km. Mousterian tools in the region are almost exclusively made from local materials and most of the materials from the early Upper Paleolithic layers at Stránská Skála are local materials but leaf points, usually made from Moravian flint, are more widely distributed during the Aurignacian; these leaf points are seen as far away as southern Poland, which may indicate that the annual migration was on a north/south axis through the Moravian Gate (Svoboda 1983; Svoboda 1993), or that they were

exchanged by barter (Oliva 1993). But 6 km to the east at the later, Aurignacian site of Tvarožná 68% of the industry is made from rare but attractive rock from the highlands forming the Moravian-Slovakian border. This location was not occupied, and was not on the north/south seasonal migration route and may have been a specialized, secondary distribution site for this material (Svoboda 1983). In the Aurignacian layers at Bacho Kiro, 53% of the flint was imported from distances over 120 km (Kozłowski 1990). Clearly, the Aurignacians were seeking out the best available materials in the area.

Not all regions show the same pattern, clearly there are significant geographical and temporal constraints on movement of people and resources. The short-stay, Aurignacian sites at Geissenklösterle and Hohlenstein-Stadel/Vogelherd, in Germany have lithic procurement systems that extend less than 10 km with little overlap between the two areas. The only long distance resources are procured along the Danube with jasper being transported from the Swabian Jura (Hahn 1987). At Sprendlingen in the Gravettian, the bulk of the material is local, but with some quartzite and radiolarite coming from about 60 km to the north. Sprendlingen appears to be an extraction site for snails, which may have been distributed north along the Rhine-Rhone valleys, but neither raw materials nor snails indicate the existence of contacts between these two Gravettian areas.

In the Russian Plains, Middle Paleolithic assemblages show the use of local raw materials, regardless of quality, suggesting a localized but highly mobile settlement system (Soffer 1987b). In the early Upper Paleolithic at Kostenki-Borshevo, there appears to be a distinct divide in the sourcing and use of raw materials. The Streletskaya sites use local materials almost exclusively to manufacture a Middle

Paleolithic tool kit, whereas the blade-based industries of Spitsyn culture rely on exotic superior flint, transported for probably 150-300 km; a distance quite consistent within seasonal mobility patterns for the region (Soffer 1991). By the late Upper Paleolithic transport distances for mountain crystal in the Russian Plains range up to 300 km at Mezhirich and Dobranichevka, and high quality Desna flint is found in quantity at Yudinovo, 60 km away (Soffer 1985b).

The transport of large quantities of stone over substantial distances (150-250 km) raises the question as to how the materials were acquired: by exchange, by procurement during the seasonal rounds, or by special purpose forays (Féblot-Augustins 1997). In Western Europe, the transport networks signify changes in the patterns of mobility and suggest a gradual development of the seasonal exploitation of biotopes and resources. In central Europe, transfers of less than 150–250 km can be ascribed to seasonal movement, however there is some evidence of down-the-line transfers over 300 km of finished tools made from distinctive materials such as obsidian or white-spotted flint as indicated by the presence in intermediate site along the route of exchange. Overall the Upper Paleolithic sees an overall shift toward greater distances; lithic transfers exceeding 100 km are more frequent and transfers between 300 and 450 km are recorded (Féblot-Augustins 1997). The Gravettian sites indicate larger procurement networks suggesting higher mobility and/or a more extended exchange pattern. This may indicate an adaptation to worsening climatic conditions or improved alliance networks (Hahn 1987).

- **Networks and Transport of Exotics**

Transport of exotic or non-utilitarian articles is rarely seen in the Middle Paleolithic. Early signs of symbolism appear with the advent of the Late Stone Age in Africa with engraved ochre and bone at Blombos around 70ka (Henshilwood, d'Erricco et al. 2003; Henshilwood and Marean 2003), and ostrich shell beads at Enkapune ya Muto (Ambrose 1998c) at around 40 ka. Extensive networks for the movement of high quality lithics and exotic materials first appear with early modern humans (Kuhn, Stiner et al. 2001; Shea 2003). There is early evidence of long distance (>30 km) transport of exotic marine shells at Skhul/Qafzeh in the Levant (Shea 2003), and indications of local but rare marine shells being used as ornaments in the Levant (Kuhn and Stiner 2001). Perforated shells of Üçağizli Cave and Ksar 'Akil, pierced teeth of Bacho Kiro, and ostrich eggshells from Enkapune ya Muto all embody forms that are repeated later at multiple locations and that persisted for thousands of years, which suggests widely shared symbolism and information networks.

The earliest evidence for long-distance procurement of exotic, raw materials (marine shells) in Europe is linked to body ornament (White 1989a). In the Perigord there is a cluster of fifteen shell-bearing Aurignacian sites (Taborin 1993), ten of which are within 10 km of each other: Vallon de Castel-merle, Isturitz and Totu de Camalhot, and the Midi-Mediterranean and lower Rhone Valley at Abri Rothschild, La Laouza (lower Aurignacian) and La Salpetrière (Final Aurignacian) (Taborin 1985). Vallon de Castel-merle was described as a kind of market due to the remarkable density of marine shells found in three Aurignacian sites there (Blanchard, Castanet, la Souquette). At these sites shells co-exist with other body ornaments, ivory, stone and bone beads, and

with some of the first objects made from animal materials. Aurignacians preferred relatively rare shells; some of the shells at Les Eyzies were collected along the Atlantic littoral (300 km away) as shown by wave marks on the shells, some from Miocene outcrops to the southeast (Languedoc-Rousillon) and some from the Mediterranean. Perigordian shells are predominant in the Western Pyrenees, the Perigord, and are found in the Lot, and Lot-et-Garonne. However, in the dense Aurignacian site cluster in the Charente-Vienne (just to the north and equidistant from the Atlantic) there are virtually no shells and few body ornaments. The Atlantic was the source of most Perigordian shells, with a few Miocene species. Mediterranean shells are rare. The Perigordians did not have the same degree of spatial openness as the Aurignacians and were more west oriented, and there is a strong decrease in the number of shells (Taborin 1993). There is a strong coincidence of these shells with ivory beads and pendants. Ivory for bead manufacture seems to have been imported as cylindrical rods, maybe in exchange for marine shells. No mammoth bones have been recovered from the Vallon de Castelmerle sites in contrast to Aurignacian sites in southern Germany, where the initial stages of tusk working can be reconstructed. The raw materials for steatite beads and pendants come from the Massif Central or the Pyrenees a distance of over 100 km (White 1989a). The idea of shell and other exotic sources reflecting habitual subsistence ranges in southwest France is no longer sufficient to account for the observed pattern. Rather we must imagine the existence of alliance networks.

By the middle Upper Paleolithic there is evidence of much more widespread networks of distribution in the Russian Plains. Amber from the region of Kiev is distributed in the Middle Desna region. Distribution density decreases with distance

from source with the further pieces found over 250 km from the source: a “down-the-line”, non-directional pattern. Fossil marine shells are found at six sites in the same region and are sourced from the Black Sea, up to 650 km to the south (Soffer 1985a). Here, unlike amber, the distribution pattern is not directional; the northern sites contain higher numbers of fossils than southern sites and the shells are more widely distributed among simple and complex sites than in the south. This suggests that distribution was controlled by the complex sites in the north and distributed to simpler sites in the north and complex sites in the south (Soffer 1985b).

These examples of exotic networks for materials used in symbolic ways are a clear departure from the habitual patterns seen in the Middle Paleolithic. However, does this pattern indicate a difference in inter individual variability or does the wider sourcing of utilitarian and exotic goods may tell us more about the extension of social networks and the results of cooperation and exchange? Blades suggests that Aurignacian populations may have acquired most lithic materials by movement directly to sources, an indication of greater variability in distances traveled; a factor in developing specialization and exchange. Yet exotic materials were more likely a part of a social exchange network or the results of specialization and exchange (Blades 1999).

Ethnographic studies indicate that the maintenance of *hxaro*-like social networks demands regular and repeated visits between groups in order to assure continued good relations, and, while it is likely that specialists were involved in travel and procurement activities associated with these networks, it is questionable whether transport distances can be directly converted into skill spreads. However, since skill may be learned as a result of horizontal and vertical cultural transmission (Gamble 1986; Mithen 1996a;

Mithen 1996b; Shennan 2001) these networks might provide greater potential for innovation and improvement in inherited skill proficiencies for the inhabitants of the Upper Paleolithic.

The adoption of these two distinct procurement mechanisms distinguishes the Aurignacian from the earlier Middle Paleolithic populations; the record points to a broader range of movement and locomotive activities in the Upper Paleolithic than in the Mousterian period and hints at a greater diversity in these activities.

6.3 Skill Variation and the Division of Labor by Gender and Age

Previous sections in this chapter addressed variation in skill proficiency between Neanderthals and early modern humans: a key factor in the ICA decision-making algorithm which drives the assignment of tasks or skill-based division of labor.

However, in many societies tasks are assigned based on skill proficiency but within the constraints of traditional gender roles. Division of labor by gender is seen throughout the ethnographic record. Ethnographic studies have highlighted rigid cultural division of tasks within male and female domains. Generally, men hunt and women gather; men make the tools and women prepare the food. However, there are significant changes in these roles where seasonal conditions restrict gathering activities, such as in Arnhem Land in the wet season or in high latitudes in winter when women's gathering foods are not available. Gender priorities change, and over the entire cycle the changing seasonal roles of men and women as prime providers means that interdependence is a prerequisite (Altman 1998).

The Hadza are able to exist singly and maintain a balance diet between carbohydrates and proteins: men provide limited meat within the family group but

sustain few commitments to others (Marlowe 2000; Marlowe 2001). The Mbuti on the other hand, roles are more even handed. They have a relatively rich meat diet (50%), which is hunted by cooperative groups of men and women (Turnbull 1962; Turnbull 1966; Turnbull 1983). There is little qualitative data in the ethnographic record on individual specialization and division of labor except by sex and age, although almost all the groups recognized that some individuals have special skills, as discussed earlier - the Ache (Hill, Kaplan et al. 1987), the Efe (Bailey and Peacock 1989), and the Machiguenga (Johnson 1998; Johnson 2003). However, in high latitude groups there is a very clear distinction in roles. Gathering vegetal foods is not an option during much of the year, the women become totally dependent on the men for food, and the men are totally dependent of the women for the clothing that enables them to bear the frigid conditions experienced when hunting (Dahl 2000). In most current hunter-gatherer groups the sexual division of labor is a key and fundamental component of the family economic unit. Netsilik technology comprises four complexes, three of which are in the male domain: the snow-ice, bone and stone complexes. The skin complex falls in the women's domain (Balikci 1966; Balikci 1984).

Women are more vulnerable to the reproductive penalties of variations in nutritional input, injury and stress, affecting ovulation, pregnancy and lactation. An extremely high protein diet is toxic to pregnant or lactating women (Fagan 2004), safe protein intake is about 20% of total caloric intake (Kelly 1995). After menarche about 22% of female body weight must be fat for the maintenance of normal reproductive function (Frisch 1978). It is in their interest for females to assure a stable level of carbohydrate (from vegetable matter or fat) in their diet. Also, since women have a

greater, and more certain, investment in their children, they should assign greater efforts to childcare; childbirth and nursing are the main constraints on the sexual division of labor (Burton, Brudner et al. 1977). Worldwide the raising of child is the responsibility of women (Brown 1970). Women of childbearing age must be able to multi-task; to be productive their tasks must be compatible with simultaneous childcare and child watching (Panter-Brick 2002). It is argued that these multi-tasked duties should not require rapt attention, are easily interruptible and easily resumed once interrupted; they do not place the child in potential danger; and they do not require the participant to range very far from home. As a result women choose to seek resources that are local, less mobile and pose less danger (Jochim 1988). Almost invariably women gather the less preferred but more reliable and more predictable vegetal and small faunal resources, whereas men hunt for the more dangerous, less predictable, and less productive, but highly preferred fatty meats and honey. In the tropics, more reliable gathered foods provide 75% of the calories but only 10% of the protein. Women are more economically independent than men, they gather locally, their foraging range is typically about half that of the men, and they perform other food processing and manufacturing tasks that do not require long distance movement on a daily basis (Rose 1987). Men roam further a field to search for, pursue, and capture the more dangerous, larger game. Hunting is a mobile activity and requires more extensive travel in pursuit of game. It takes more time and effort and has a lower probability of success. Hunting is a physically more demanding and dangerous activity especially at the point of the kill. But meat is sought; it contains high-quality protein and the nine essential amino acids that the human body cannot synthesize. Meat also provides some essential

minerals such as B12 and some glucose – all in easily digested form. Meat is far less predictable but more preferable even though it costs 2.5 times the effort to acquire (Lee 1998). In the higher latitudes men and women become highly interdependent; the women counting on men for provisioning, since plant foods are scarce, and the men relying on women for clothing and shelter around the hearth.

Children spend their time preparing for adulthood and the responsibilities it brings. They perform more limited gathering tasks and collection of water. Age and acquired wisdom brings deferential prestige and a powerful and respected voice in community affairs, although rarely a strong leadership role. Individuals are respected for their special knowledge of past environmental conditions and the strategies used to buffer against local resource deficiencies.

Each hunter-gatherer group examined appears to have separate lists of male and female duties. Roles are based on physical ability, availability of food resources, risk level of the food acquisition task, and some on taboos. But male and female workloads vary significantly based on ecological conditions (Panter-Brick 2002). Although in most cases the ethnographic data emphasize sexual division of labor, these practices vary by group, ecology and season. Halperin (1980) suggests that, in egalitarian hunter-gatherer groups, sex roles vary on a daily and seasonal basis and do not necessarily follow traditional sex norms.

The extent to which these conventions would have applied to Middle Paleolithic culture is open to question. Behavioral ecology tells us that parenting conflicts govern trade-offs between male mating opportunities and female subsistence activities and provisioning of offspring (Bird 1999). Ruff (Ruff 1987) contends that similar levels of

sexual dimorphism between Neanderthals and early modern humans indicate that division of labor was practiced in the Middle Paleolithic. Neanderthals took care of their sick and elderly, there is no reason why they should not have cooperated in many other economic ventures (Chase and Dibble 1987), and it is possible that the division of labor by gender is evident in later Neanderthals (Binford 1985). However, Kuhn and Stiner (2006) suggest that the Middle Paleolithic archaeology does not support this, indeed, they argue that sexual division of labor evolved earlier in the subtropics / tropics, where biotic diversity is greatest, and was introduced to Europe by the incoming early modern humans. Soffer (1992) argues that the criticality for non-subsistence activities such as manufacture of clothing and construction of shelter and the lack of food gathering opportunities in higher latitudes drives division of labor by gender, and, for this reason, that it is more likely that division of labor by gender and age was practiced by early modern human groups in Europe.

6.4 Summary of Individual Skill Spread

“The behavior of the Upper Paleolithic peoples as revealed by the archaeological record is in no way beyond the limits of behavior that would be expected of any modern human population that found itself in the same environmental and historical circumstances and at a similar level of technological sophistication” (Chase and Dibble 1987: page 264).

From these assessments it seems clear that early modern humans were able to apply a spread of skills equivalent to that manifested by current humans. Locomotion patterns may inform more about local geography and social networking than individual variability, but hand morphology and manual dexterity, particularly the reconstruction of the manufacturing processes associated with bead-making, does provide some credible evidence for such variability among individuals in the Upper Paleolithic.

Overall, the theoretical support for increased diversity in modern humans, coupled with the genetic analysis and examination of morphological, manipulative and locomotive behavioral patterns, strongly suggests that Upper Paleolithic humans had greater skill diversity than the Neanderthals. However, the evidence is not conclusive. Most significantly, this does not imply that Neanderthals were less intelligent than modern human; they just had a different life trajectory, partially driven by the accretion of physical robusticity and the maintenance of traditional foraging patterns that had been successful over thousands of years of occupation of Europe.

For early and middle Upper Paleolithic populations, that are anatomically similar to modern humans, I intend to use the standard deviation of 16 based on a mean of 100 as the basis for skill spreads, as observed in current human measurements described above (such as height, weight, musculature and IQ). The theoretical, archaeological and physical anthropological data for Neanderthals suggests that they exhibited less variation than did modern humans, but the precise measure of the difference is difficult to ascertain. I have summarized the results of my analysis in Table 6-5, summarizing the reasons why the skill spread for Neanderthals might be narrower than that Upper Paleolithic humans.

Table 6-5 Neanderthal Skill Spreads Compared to the Spread of 16 for Current Humans

Section 6.2	Basis	Neanderthal Skill Spread
i. Isolation and Neanderthal Demographics	Founder Effect and Inbreeding	Lower
ii. Demographics and DNA Diversity	Modern population gene pool and expansion	Lower
iii. Skeletal Morphology and Diversity	Post-cranial	13.4-14.7
	Endocranial capacity	14.4
iv. Habitual Manual Dexterity and Diversity	Hand morphology and precision handling	Lower
• Habitual Manual Dexterity Observed in Lithics Analysis	Width/thickness of flakes	Lower
v. Post-cranial Morphology and Implied Habitual Patterns of Locomotion	Diaphyseal robusticity in lower limbs	Lower
vi. Sourcing Networks and Patterns of Movement across the Landscape	Lithic and exotics sourcing networks	Lower

The above data argues for a lower skill spread for Neanderthals than for Upper Paleolithic humans; but the evidence is not definitive and it is difficult to assign a firm quantitative measure to differentiate Mousterian skill spreads from those of the Upper Paleolithic. I therefore use as a baseline the same standard deviation (16) for Neanderthals as that ascribed to modern humans. However, since the analyses above suggest that Neanderthals maintained less diversity than modern humans, I also use 14 as the standard deviation in certain tests for both Neanderthal populations, to assess what might be the impact of lower skill levels on Ricardan benefits for the Neanderthals. In both cases, I presume that mean skill levels at 100 are the same for both Neanderthals and moderns. (These spreads of 14 and 16 are within the equivalent skill spreads used in the prototype).

In order to examine the economic benefits of division of labor by skill alone or by skill within gender I execute the ICA Transition model using both methods; in the one case using the non-gender specific annualized time and task data, and in the other case using the gender specific time and task data. In all cases, I use the activity time and

task repertoire data developed in Chapter 4, and the group size and composition data from Chapter 5.

In Chapter 7, in addition to examining climate and seasonal settlement patterns, I address how seasonal variation might have impacted the time available for accomplishing critical tasks and how that time might have been allocated to male and female tasks in each season.

Chapter Seven

Climate, Settlements, and Extinction

The objective of this chapter is to review the current literature and databases pertaining to the Quaternary paleoclimate, the human settlements, and survival in Europe in the late Pleistocene. I focus on the sequence of climate fluctuations in the late Quaternary in order to compile a picture of the climate existing in northern Europe. During this period there appears to have been a pattern of short-term climate oscillations, with frequencies of between decades and a few thousand years in minor cycles, and tens of thousands of years in major orbital cycles. This is the climate regime within which Neanderthals evolved, radiated throughout northern Europe, were forced to migrate to refugia in the south, and eventually went extinct. And this is the regional climate into which modern humans migrated within the last 50,000 years and survived (Hoffecker 2002; Finlayson 2004).

Scientists have suggested a link between climate oscillations and hominid evolution (Potts 1998a; Calvin 2002a; Calvin 2002b), and the fluctuating climate of the last glacial period may have triggered noteworthy changes in individual cooperative behaviors that secured the survival of modern humans. Low suggest that when variances in climate are small organisms can adapt physically, physiologically, and behaviorally, even if the average conditions are extreme. However, as the amplitude of variances in the physical environment becomes larger and unpredictable, responses are avoidance (Neanderthal moved south), modification (modern humans constructed clothing and shelter), and social cooperation (Low 1990). I argue that another form of response was economic specialization and exchange.

7.1 The Fluctuating Climate of the Late Pleistocene

The general instability of the climate over the last 600,000 years was first identified by analysis of pelagic forams in deep-sea cores from the Atlantic, Caribbean, and Pacific (Emiliani 1955). More recent climate instability is highlighted by analysis of two Greenland ice-cores (Dansgaard, Johnson et al. 1993). A continuous GRIP $\delta^{18}\text{O}$ record from 250,000 years ago to the present was generated and the major glacial interstadials are reconciled with European pollen horizons.

The results indicate large and abrupt climate changes during the later stages of the last glaciation, at least in Greenland. Comparison between GISP2 and GRIP Greenland cores show consistency of results after 87 ka (Grootes, Stuiver et al. 1993). Comparisons with other terrestrial core records show similar oscillations, although sometimes with leads or lags. Further evidence of the abruptness of climate changes is demonstrated by an analysis of electrical conductivity measurements (ECM) from a Greenland ice-core (Taylor, Lamorey et al. 1993). Alkaline dust in ice from cold periods reduces current flows and distinguishes dusty from less dusty periods. The record analyzed was between 10 and 42 ka and permits measurement of timescales from seasons to millennia. The seasonal time resolution shows a system that is frequently changing between glacial and interglacial conditions in periods of a decade or less. Moreover, the transitions are characterized by flickering between preferred states requiring extremely rapid reorganizations in atmospheric circulation. Another analysis of the Greenland ice-core record spanning 90,000 years suggests that larger thermal gradients existed between the Equator and the North Atlantic during the last glaciation (Ditlevsen, Svensmark et al. 1996). This provides evidence that, in addition to

temperature instability, atmospheric circulation was more turbulent during the last glaciation than today. The Greenland record shows that changes were abrupt and widespread. A series of Dansgaard-Oeschger (D/O) events (Dansgaard and al 1984; Dansgaard, Johnson et al. 1993) caused temperatures to cool in a sequence of smaller steps but warm in one large step with as much as an 8° C increase, a doubling of snowfall, large drops in wind-blown detritus, and a 50% increase in methane, indicating large changes in wetland areas (Alley 2000b). High-resolution records of foram assemblages and ice rafted detritus from two North Atlantic deep-sea cores were correlated to the Greenland ice-core record from 65 to 135 ka (McManus, Bond et al. 1994). Analysis of red-green sediment color in the core M23414 in the Rockall Plateau of the North-east Atlantic also indicates that large amplitude millennial scale climate variability occurred, but only if continental ice-mass exceeded a threshold level, equivalent to sea levels at 40% of the lowering during the last glacial maximum (Helmke, Schultz et al. 2002). Changes in the red-green color intensity are probably linked to deposits of ice-rafting materials from different periods and geographic sources. Additional support for the extent and abruptness of climate changes is drawn from data at the end of the Younger Dryas (Broecker 1995; Ralska-Jasiewiczowa, Goslar et al. 2003). Greenland cores show that a series of cold and warm spells each lasting 1,000 years or more, between which temperatures in northern Europe were raised or lowered by 10° C within as little as a decade. Red Sea sediment cores indicate that sea-level changes of 35 m, at rates of up to 2 cm per annum, occurred coincident with changes in climate (Siddall, Rohling et al. 2003).

Reconstructions of Greenland temperatures and humidity cannot accurately reflect the local conditions throughout Europe. However, a limited number of pollen cores in Western Europe do indicate similar oscillations in both temperature and humidity. Analysis of La Grande Pile in the Vosges, France in the earlier Oxygen Isotope Stage (OIS) 5, shows a progression from the warm interglacial of OIS 6 to a very humid but cold period at the end of that stage – a period of major ice-accumulation. This was followed by the colder dryer OIS 5d (Melisey) interstadial, which in turn was followed by the warmer OIS 5c (St-Germain I) at the completion of which the cycle was repeated for OIS 5b (Melisey II) and OIS 5a (St-Germain II), leading to the glacial maximum during OIS 4 (de Beaulieu, Guiot et al. 1991). In the Netherlands, Amersfoort-Brörup and Odderade are correlated with St. Germain 1 and 2, but other correlations are not so straightforward (Zagwijn 1989). In northwestern Germany, Amersfoort-Brörup is recognized as one long interstadial, whereas in the nearby Netherlands Amersfoort and Brörup are recognized as two separate interstadials. Russian chronologies have their own conventions (Markova, Simakova et al. 2002). Thus, dates are not always correlated throughout Europe, maybe because of different dating techniques, but also because topographical features or lags in flora and fauna dispersal produce varying signals.

Pollen cores from Monticchio, Southern Italy have been correlated to D/O events 20, 14, and 12. Based on varve counts, complemented by $^{40}\text{Ar}/^{39}\text{Ar}$ dating of intervening tephra layers, these have been dated to 74.6 - 72.0 ka, 50.0 - 43.6 ka, and 40.0- 37.6 ka, respectively. These episodes appear to start and end abruptly. Monticchio lies in the Mediterranean zone but the climate in the Italian peninsula is still

determined by the surface temperature of the Atlantic and is linked to interstadials in the GRIP ice-core record. When surface waters are cool, precipitation is reduced and grasslands are favored over forest. These cores are floristically rich in tree species, and thus permit detailed analysis of the vegetational climate history and, particularly, the floral progression as different species take hold throughout the course of the interstadial cycle. They show a different profile from La Grande Pile cores from eastern France (de Beaulieu, Guiot et al. 1991) which show low tree diversity during OIS 4-2. At Monticchio, numerous vegetation changes were rapid: the mean interval for absolute changes of > 20% in total pollen from wooded taxa is 142 years, with decreases typically occurring more frequently than increases (Allen, Brandt et al. 1999). This may be explained by the fact that, even if the response of trees to abrupt climate change were immediate, there is an apparent lag in the time it takes time for tree species to mature and disperse seed, and each species has its own niche requirements which will effect the migration and re-growth of that species (Huntley, Alfano et al. 2003). .

Analysis of pollen, forams, dinocyst, coarse lithics, and $\delta^{18}\text{O}$ measurements from a deep sea core from the southwest Iberian coast indicates a high frequency of vegetational change each lasting from 100 to 2,500 years and associated with three phases of Heinrich and D/O cold events (Goñi, Turon et al. 2000). The initial phase reflects a temperate and humid Iberian Peninsula with cold sea temperatures, probably due to the melting of European icebergs, followed by a cold-dry, steppic climate linked to the huge ice discharges from the Laurentide ice sheet, cooling both the sea and the air temperatures.

Vegetation patterns have been inferred for warm and cold D/O events from palynological data from thirty sites throughout Western Europe, but with notable gaps in eastern and southeastern Europe record (Huntley and Allen 2003). Vegetational patterns differ markedly from present-day patterns and do not represent simple north-south shifts of present day vegetation. The vegetation patterns inferred indicate that OIS 3 cold events had temperatures markedly lower than those of the warm events, which themselves were somewhat lower than interglacial conditions. The inferred palaeovegetation also reveals evidence of steep climatic gradients during OIS 3.

The magnitude and periodicity of climate oscillations is a notable characteristic of this period. Extremely warm (OIS 5e) or extremely cold (OIS 4 and 2) periods do not exhibit the same degree of fluctuation as intervening periods. Stochastic resonance was first proposed as an explanation of the 100 ka periodicity of glacial cycles in 1982 by physicists studying turbulence (Parisi and Surlas 1982), and has recently been demonstrated by analyses of Greenland ice cores that identified statistical properties of D/O cycles that are consistent with stochastic resonance (Alley, Anandakrishnan et al. 2001). The simplest stochastically resonant system spends most of its time in one of two stable states: two stable but very different modes of ocean-atmosphere operation (Broecker and Denton 1990; Rahmstorf 2000). Periodic forcing, together with noise (e.g. from ice-melts or El Niño), that separately are too weak to cause frequent mode switches, combine to cause a state-change when the phase of periodic forcing is favorable. By concentrating on D/O oscillation signals in the GRIP and GISP2 cores the authors observed patterns that were fully consistent with stochastic resonance with a periodicity of 1,450-1,500 years. The periodicity indicates some variability of wait

times between warm episodes: longer during OIS 5e and in the Holocene and shorter during the coldest stages of the ice age. From this they postulate a higher noise level at times with more ice. The results suggest that there is a 1,450-1,500-year climate cycle, but that this cycle is too weak to cause North Atlantic mode switches at all times.

Recent reports suggest that El Nino-related fresh water perturbations in the Eastern Pacific may have amplified Heinrich events (Kienast, Kienast et al. 2006). Therefore, both the weak periodicity and other processes need to be present to explain North Atlantic oscillations. It is suggested that self-sustaining oscillations of the large-scale oceanic circulation provide a framework for accommodating D/O oscillations with varying interstadial length, synchronization between D/O stadials and Heinrich events, and rapidly changing boundary conditions as seen in the Younger Dryas (Schultz, Paul et al. 2002). The suggestion is that D/O cycles are not primarily controlled by thermohaline circulation, which generates cycles of 1600-1800 years, nor has any orbital cycle been identified with this periodicity, but stochastic resonance could account for these occurrences (Schultz 2002a; Schultz 2002b). Over the last 23 cycles between 51 ka and 10 ka, this 1,450-1,500-year, as yet unexplained, underlying rhythm appears to have triggered a D/O cycle. The occasional lack of such a trigger explains why some warm interstadials last as long as 3,000 or 4,500 years (Rahmstorf 2001; Rahmstorf 2003a; Rahmstorf 2003b).

Ocean-atmosphere models show that stochastic resonance could be an important mechanism for millennial-scale climate change (Ganopolski and Rahmstorf 2001; Ganopolski and Rahmstorf 2002). The stochastic resonance model simulates a stable, cold, stadial state and a more unstable, warm, interstadial. The ice-core records suggest

that fewer and longer-lasting D/O events occurred in the earlier, warmer part of the glacial (when the warm mode was more stable), and fewer events occurred during the coldest period. In-between, the climate is close to the bifurcation point where stochastic flickering between two modes can easily exist. The model demonstrates that stochastic resonance with plausible noise amplitude and a very weak periodic forcing could have triggered the mid-glacial climate oscillations. In fact, three main circulation modes are identified in the sediment record (Rahmstorf 2001):

- a warm or interglacial one, such as is in operation today, in which deep water forms far to the north in Nordic Seas, resulting in large oceanic heat-transport to high northern latitudes,
- a cold or stadial mode in which deep water forms further south with greatly reduced heat transport to the high latitudes,
- a shut-down mode (Heinrich mode) in which no deep water is formed, the deep water being dominated by Antarctic bottom water.

The warm mode is the short, stable mode that existed during the last interglacial (OIS 5e) and operates today; the cold stadial becomes the stable mode during glacial times, such as OIS 4 and OIS 2. The rapid oscillations that occur when switching between glacial and interglacial conditions are observed during OIS 5a-d and most predominantly during OIS 3, when peak climatic stress conditions occurred (Stringer, Palike et al. 2003).

The ice core data from Greenland (Alley 2000a) and pollen record from cores drilled in the Massif Central (de Beaulieu and Reille 1992; Guiot, Beaulieu et al. 1992) and southern Italy (Narcisi 1996), dating back to 125 ka, provide comparable, detailed

data on climate during this period. Records of beetle assemblages provide additional information on mean summer maximum temperatures and seasonal variation (Coope 2002). The correlation between these results is remarkable (Stringer, Palike et al. 2003; Burroughs 2005). These records show an increasingly variable climate during OIS 3 leading to unrelenting cold with a few short-term, decadal fluctuations during OIS 2. The global average temperature at the height of the ice age was at least 5° C lower than current values, with the largest effects being felt in the mid-to-high latitudes around the North Atlantic region (Burroughs 2005).

The climate record contrasts a warm-event landscape of scattered trees and woodland stands, that would have supported large grazing and browsing herbivores versus the cold-event landscape with a predominance of herbaceous vegetation with steppic taxa leading to reductions in the range and population sizes of the large herbivores, and hence of the associated carnivores and of humans. The record suggests that these fluctuations provided the major challenge to all occupants of northern latitudes, including Neanderthals and modern humans. Since population densities were low (Deevey 1960), and moderns and Neanderthals had little direct contact, at least during the early phases of the modern dispersal into Europe (Bocquet-Appel and Demars 2000), I suggest that climate fluctuation was the driving force in modifying behavior during this period. Migration to the south, technological, and social change are all potential responses to avoid extinction during the most extreme climate swings, and these are seen most clearly in comparisons of Neanderthal and Upper Paleolithic dispersals in the Russian Plains.

7.2 Analysis of Human Settlements on the Russian Plains

The settlement pattern on the Russian Plains provides a meaningful illustration of Neanderthal and Upper Paleolithic responses to the climate of the late Pleistocene. The Russian Plains are relatively isolated from Western Europe. They are circumscribed by the Carpathian Mountains to the west, the Urals to the east, and the Black and Caspian Seas to the south. The open plains reach a maximum height of about 310 meters and are intersected by major rivers with salmon runs: the Don, Volga, Dnieper, Dnestr, and Prut. The relative isolation of this area makes it possible to analyze human migrations within the region and compare how Neanderthals and early modern human inhabitants dealt with the fluctuating climate of the period from 120 to 30 ka. During OIS 5 through OIS 3 in the Russian Plains the early modern humans' response to the deteriorating climate differed significantly from that of the Neanderthals. This leads me to question what social factors that might have lead to these differences.

As in other areas of Europe, the paucity of skeletal remains means that archaeologists rely on analysis of lithic remains to distinguish between Neanderthal and modern human settlements. For the purpose of this analysis I equate Mousterian technologies with Neanderthals.

i. OIS 5e

The generally accepted date for the start of the last interglacial is 128 ka (short chron) as corroborated by dates from the Vostok ice core (Petit 1999), from coral reef platform sequences of Bermuda (Harmon, Mitterer et al. 1983), from ^{230}Th - ^{234}U dating of corals by precise thermal ionization mass spectrometry (TIMS) of corals in Barbados (Bard, Hamelin et al. 1990), and marine speleotherm records from the Bahamas

(Lundberg and Ford 1994) There is general agreement that interglacial 5e lasted until about 115 Ka. During the interglacial the pollen proxy data indicates that temperatures in the mid-latitudes of Europe were warmer than today by about 1- 2° C in winter and 2° C in summer (Guiot, Pons et al. 1989). Sea surface temperatures were from 4-5° C warmer (McManus, Bond et al. 1994). No pollen records are available for this area but high-resolution, multi-proxy lacustrine records from the Ribains Maar in France indicate the last interglacial was a period of climate stability in southwest France, analogous to the Holocene (Rioual, Andrieu-Ponel et al. 2001). The pollen records from France also indicate an abrupt end to the interglacial lasting 900-1,900 years at Ribains and less than 400 years at La Grande Pile. Towards the end of this period, pollen records for 45-50° North indicate a decrease in seasonality accompanied by increased cyclonic activity in winter – typical circumstances for the initiation of subsequent ice growth (Guiot 1990). This continental record contrasts with the Greenland ice core record that indicates that during this warm interlude there were two cold spells that interrupted the three warmer episodes and periods of short-lived (70-750-year) and abrupt (within decades) climate oscillations where temperatures fell by 14° C (Dansgaard, Johnson et al. 1993).

There is no hard evidence of occupation of the Russian Plains before the Riss/Wurm Interglacial (OIS 5) at 115-70 ka (Hoffecker 2002). It is possible that earlier occupations were erased by glacial actions during OIS 6, but the otherwise ubiquitous hand axe is absent from throughout the Ukraine (Klein 1969a). By OIS 5e, Neanderthals had dispersed from Western Europe and migrated into the northern plains, perhaps to avoid the hot humid climate of Western Europe. At this time, sites are not

common in Western and central Europe (Gamble 1999), and their scarcity is thought to indicate unfavorable conditions created by dense forest and marshes (Gamble 1986). In contrast, OIS 5e occupations in Eastern Europe are found in cooler and dryer lowland regions and at higher elevations. During this period, the Neanderthals reached the highest latitude at over 53° N in Khotylevo, Negotino and Chulatuvo III in the Dnepr/Desna region; more southerly sites include those at Shkurlat on the Middle Don, and Sukhaya Mechetka on the Lower Volga (Hoffecker 2002), and Myshtulagty Lagat in the Northern Caucasus (Klein 1973; Hoffecker 1999).

ii. OIS 5d to 5a

At the end of the interglacial (i.e. OIS 5d through 5a), the climate cooled in a series of oscillations of as little as two to six thousand years' duration (Dansgaard, Johnson et al. 1993). Climate reconstructions indicate that during this period, which ranged from 115 ka to 71 ka, winter temperatures reached as low as -10° C (Frenzel, Pecsai et al. 1992). The beginning of OIS 5d saw a decline in air temperature of 9-10° C from the ice cores (Johnson, Clausen et al. 1992) and from pollen data (Guiot, Pons et al. 1989). The build up of ice reflected in the oxygen isotope record amounted to about 50% of that of the last glacial maximum at 20 ka, and was accompanied by a drop in sea level of about 60m. Foram measurements during this change indicate a lag in the drop in sea surface temperatures indicating a continuation of warm water delivery to the North Atlantic that supplied the moisture for the advancing ice sheet (Ruddiman, McIntyre et al. 1980). Deciduous vegetation in Europe gave way to a landscape of tundra and steppe (Tzedakis 1993).

OIS 5c and 5a represent two milder periods with boreal woodlands separated by a cold interval OIS 5b with tundra and steppe vegetation. In France, the St Germain I (OIS 5c) and II (OIS 5a) interstadials have temperatures just 2° C cooler than today but the intervening Melisey stadial (OIS 5b) was 5-7° C cooler than today (Guiot, Pons et al. 1989; Guiot, Beaulieu et al. 1992). More northerly latitudes were 1-2° cooler in both episodes. Ice sheets expanded and contracted correspondingly during these periods. Marine records show evidence of short-lived warming and cooling episodes during OIS 5c-a (Bond, Heinrich et al. 1992; Keigwin, Curry et al. 1994).

As the climate deteriorated, Neanderthals abandoned the northern sites at Korshevo I and II in the Dnepr/Desna Region and began to migrate progressively southward on the Russian Plains (Hoffecker 1999; Dolukhanov 2001; Hoffecker 2002). By the end of the period Mousterian sites are restricted to more sheltered areas on river terraces below 49° N: at Korman' IV, Molodova I and V, Ketrosy, and Ripiceni-Izvor on the Dnestr/Prut river in Romania, at Rozhok I, and Nosovo I on the Sea of Azov, Sukhaya Mechetka on the lower Don, Matzuka Cave and Il'skaya II in the Northern Caucasus, and Prolom, Zaskal'naya, and Chokurcha in the Crimea (Hoffecker 1999).

iii. OIS 4

Temperature dropped about 10° C again at the transition from OIS 5a to OIS 4 – a total of 12°C cooler than today. This was a period of unremitting cold; in July mean temperatures rarely exceeded 10° C (50° F), and mean winter temperatures may have been –25° C (-13° F). This was accompanied by a sharp 5-6° C decline in sea surface temperatures (Bond, Broecker et al. 1993) and a shift to taiga and barren tundra. Heinrich event six marks this transition from the relatively warm northern Atlantic of

the last interglacial to the cold conditions prevailing during the last glacial (Broecker 1994).

Some have linked the massive volcanic eruption of Mount Toba of 74 Ka with the OIS 5a-4 transition (Rampino and Self 1992; Rampino and Self 1993). It is suggested that average global temperatures may have dropped by 3-5° C and summer temperatures by as much as 10°C in northern latitudes. This “volcanic winter” may have triggered or aggravated an already cooling climate by positive feedback (Rampino and Self 1992; Rampino and Self 1993; Rampino and Ambrose 2000) and decimated human populations worldwide (Rampino and Ambrose 2000). In the Eastern Plains, winter temperatures ranged from -30° C on the central Plains to -18° to -20° C in the more sheltered southern regions of the lower Volga and Dnestr/Prut.

With the onset of full glacial conditions during OIS 4, Neanderthals abandoned the central Russian Plains (Gamble 1986; Hoffecker 2002) as well as the sheltered river valleys in the south and southwest, and retreated further south to the Caucasus Mountains, where they were able to exploit the vertical ecotones, moving from the lowlands in winter to the uplands in the spring through fall (Hoffecker and Cleghorn 2000). The only Mousterian settlements during this period are found in the Northern Caucasus – a Mediterranean-like refuge. Archaeologists conclude that, with thousands of years of experience in this type of ecotonally-rich, mountain habitat with high animal biomass, including large herbivores and carnivores, the Neanderthals resorted to the same type of refugia that they had done in Western Europe during glacial maxima: mountainous habitats in Cantabria, SW France, Southern Germany, Czechoslovakia,

Moravia, and the Caucasus (Straus 1990; Mellars 1996; van Andel, Davies et al. 2003; Finlayson 2004).

iv. OIS 3

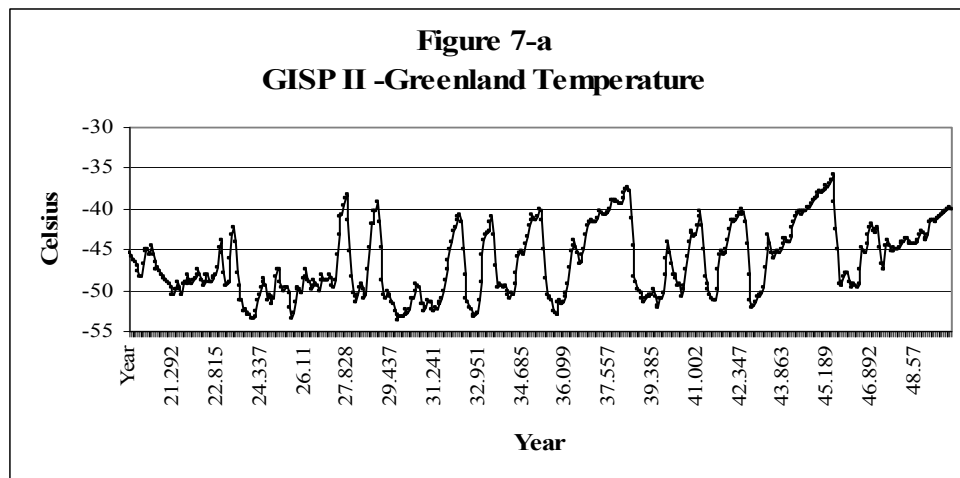
Seven Heinrich events (including the recently discovered Heinrich 5a) occurred between 70 Ka and 14 Ka, these massive, five to ten thousand-year discharges of icebergs from the Laurentide ice-sheet were accompanied by decreases in sea surface temperatures and decreases in salinity (Bond, Heinrich et al. 1992; Bond and Lotti 1995). Shorter D/O cycles with a duration of 500 to 2,000 years occurred throughout this period between the longer-duration Heinrich events (Cortijo, Labeyrie et al. 2000). These caused temperatures to drop to about 4-6° C cooler than present, a change between warm and cold episodes of about 7° C (Johnson, Clausen et al. 1992).

European climate is dominated by the north to south arctic-to-temperate gradient north of the Alps, the west to east maritime-to-continental gradient from the Atlantic to the Russian Plains, and the Mediterranean zone extending from eastern Iberia to Turkey. Throughout OIS 3, warm events lasted a few millennia but cold ones only a few centuries, and the transitions between them sometimes took less than a few decades. Even during glacial maxima, the climate of northern Europe should be distinguished from that of the current Arctic: the summers were long and degree-growing days were more numerous than in the Arctic today (Barron, van Andel et al. 2003).

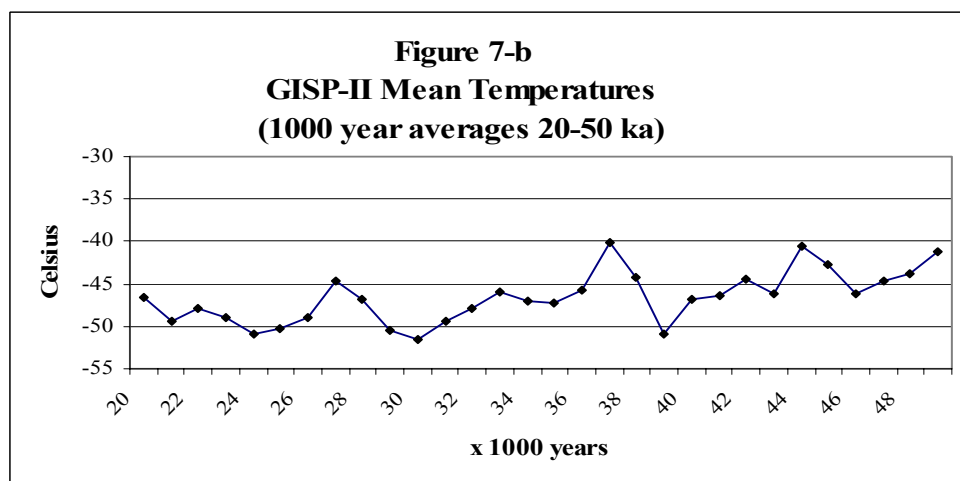
At the onset of OIS 3, a sudden warming initiated a sequence of fairly mild D/O events that were only occasionally interrupted by brief and not yet very cold events (Barron, van Andel et al. 2003). Within these multiple events and cycles, five warm

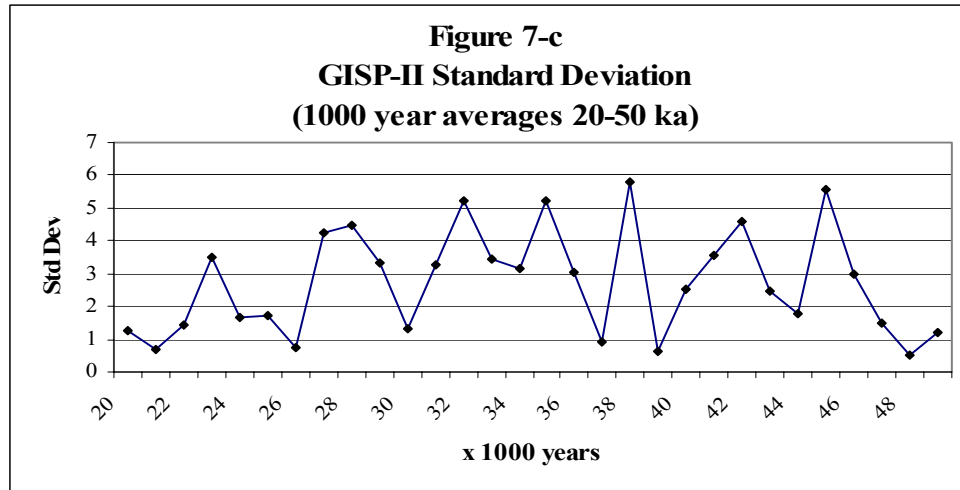
episodes have been identified and attempts have been made to assign dates to these episodes. However, this time period is at or beyond the limits of radiocarbon dating so that, although the stratigraphy is secure, the placement of events in time has been questioned. The five warm episodes for north Western Europe are: Oeeral from 58-54 ka, Glindé from 51-48 ka, Moershoofd from 46-44 ka, Hengelo from 39-36 ka, and Denekamp from 32-28 ka. In the Russian Plains, one long Byransk interstadial is recognized that spans the Hengelo and Denekamp interstadials from 38 ka to 28 ka (Klein 1973). Towards the end of OIS 3, a period of severe cold occurred just after 30 ka as indicated by biological and stratigraphic evidence from La Grande Pile, France (Ponel 1995). Local volcanic eruptions of Phlegrean Fields Caldera, below the Campanian Ignimbrite Formation at 40-37 ka emitted 150 km^3 of magma over the Eastern Mediterranean. This event correlates with the timing of human migrations. The ash layer has been detected in cores from the Gulf of Corinth (Cramp, Vitaliano et al. 1989) and is estimated to have extended over the Balkans, Greece and Turkey (Fedele, Giaccio et al. 2002) and into Russia (Sinitsyn 2001). The signal has been calibrated to the $\delta^{18}\text{O}$ from the GISP2/GRIP cores and Monticchio pollen core (Watts, Allen et al. 2000). It corresponds to the beginning of the 1,500-year cooling event between interstadial 9 and 8 and to the onset of Heinrich event four, and immediately precedes the Hengelo interstadial. This event was coincident with widespread abandonment of southern Italy and possibly regions to the east. It accompanied Late Pleistocene biocultural changes and migrations within the Mediterranean, Balkans and perhaps further East.

The GISP-II ice core record has been calibrated to local pollen core records in Western Europe and offers an indication of the extent of the fluctuations in the climate during OIS 3, even though temperatures were considerably higher in Europe than on the Greenland ice-cap (Alley 2004). The figures below, based on Alley's data, show mean temperatures during two-thousand year intervals from 50 ka to 20 ka as well as deviations from the mean during these intervals. Figure 7a shows estimated actual temperatures at approximately 50-year intervals



Figures 7b and 7c show mean temperatures and deviations within a one-thousand year interval of up to 6°C.





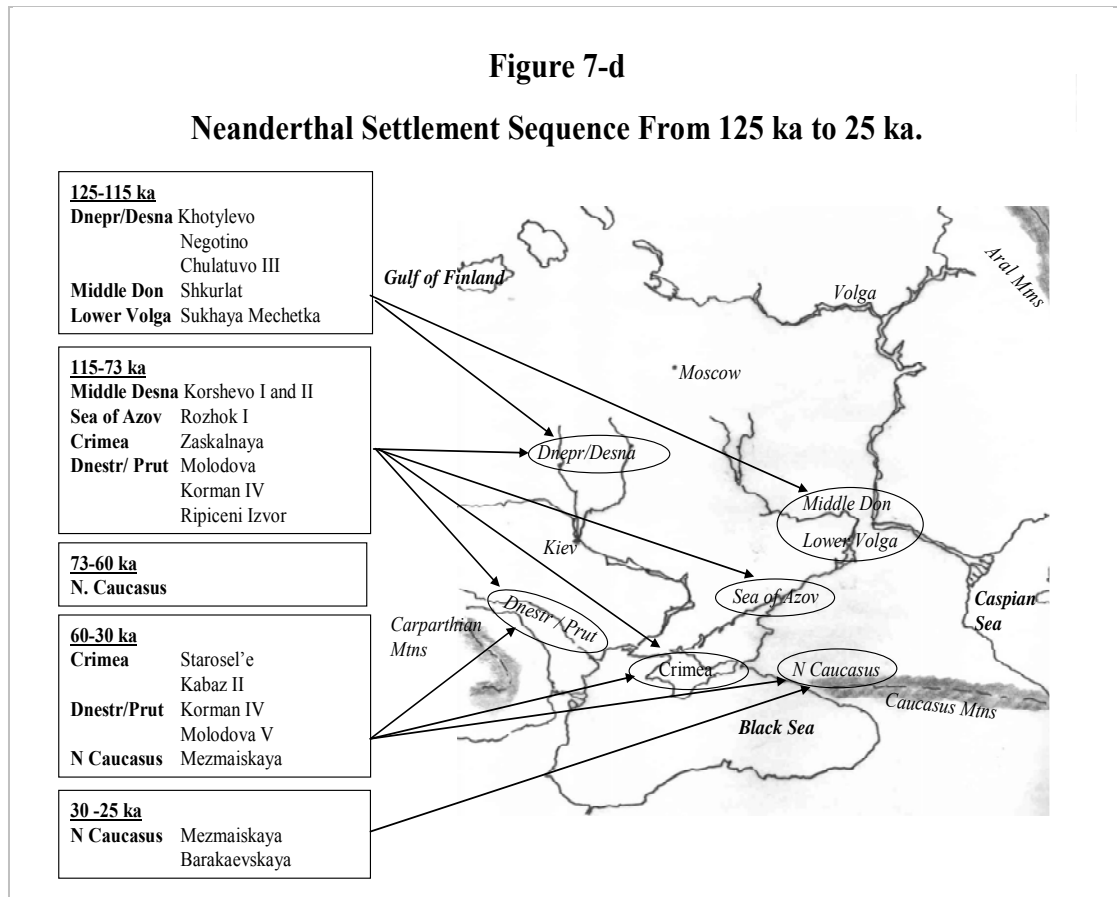
Fluctuations in climate were significant during the period from 48 ka to 27 ka (Figure 7a – 7c), and were unpredictable to the resident populations and must have caused considerable stress.

During the warm early stages of OIS 3, prior to 47 ka, Neanderthals expanded from their refugia in southern Europe and moved slightly northward to re-occupy sites as far north as Molodova V and Korman' IV in the Dnestr-Prut region of Russia and Geissenklösterle in Germany, each at about 48.5° N. This period experienced periods of warming with winter temperatures in the sheltered southern regions rising to above -10° C. However, the central plains continued to experience severe cold temperatures below -10° C (Frenzel, Pecsì et al. 1992), and Mousterian settlements are not found in the higher latitudes that had been occupied during the earlier interglacial (OIS 5e). Between 47 ka and 34 ka, Neanderthals sites are again found in the southerly region, but their settlements were limited to the regions around the Black Sea, (Starosol'e, Kabaz II in the Crimea, and Mezmaiskaya Cave in the Caucasus, as well as Korman' IV and Molodova V in the Dnestr/Prut Region) (Hoffecker 2002). They did not return to the colder central plains. Temperature fluctuations increased in intensity and decreased

in duration during OIS 3 and, in the later part of that stage, temperature changes of up to 8° C occurred between major warm and cold episodes, in some cases in fewer than 20 years (Dansgaard, Johnson et al. 1993; Taylor, Lamorey et al. 1993).

As the climate cooled Neanderthals moved progressively further south so that by 33-30 ka they had retreated to below the 48th parallel. The latter half of OIS 3 experienced a series of rapid climate oscillations where each succeeding peak and trough saw a further decline in temperature and declining humidity. Temperatures declined so that during this period winter temperatures rarely reached above -10° C even in the sheltered southern regions. Conditions deteriorated and peak stress conditions, as measured by both temperature and variation extremes are seen at 30 ka (Stringer, Palike et al. 2003). The Neanderthals retreated further south to their final refugia in this region: the Caucasus Mountains. The latest Neanderthal settlements in the region are found at Mesmaiskaya Cave and Baraevskaya Cave in the Northern Caucasus (Hoffecker 1999), the only refuge to offer moderate conditions (above -10° C). At this time, Mousterian sites are well represented in other refugia in Iberia, southwestern France, as well as the Northern Caucasus (Hoffecker 1999; van Andel 2002).

Although physically cold adapted, the more robust Neanderthals seem to have been unable to survive in winter condition below -10° C with annual rainfall below 500 mm (Smith 2003). The final demise of the Neanderthals began with Heinrich event 4 as recorded in the deep-sea cores (Bond, Broecker et al. 1993), and which probably centers around 33-34 ka (Dansgaard, Johnson et al. 1993). Figure 7d illustrates the gradual migration of Neanderthals southwards as the climate deteriorates.



Early modern humans first entered Europe between 47-43 ka (Hengelo), and between 41-34 ka (Denekamp/Bryansk), during the relatively mild interval of OIS 3, they had settled in areas as far north as Kostenki on the Russian Plains (Dolukhanov 2001), Paviland in the UK, and Trou al'Wesse in Belgium (Aiello and Wheeler 2003), all above the 50th parallel. Early modern human settlements, identified by Upper Paleolithic technologies, first appear in the central regions in the same river terraces abandoned by the Neanderthals some thousand years earlier. Thus, there was a significant temporal gap between the two occupations. Analysis of living sites in the area shows that modern humans settled in areas and climatic conditions that were colder than those occupied by the Neanderthals of the time (Aiello and Wheeler 2003). The

warm-adapted modern humans by-passed the milder areas occupied by the resident Neanderthals and first settled at Kostenki in the colder Middle Don region. The Mousterian Strelets culture is found at Kostenki XII and VI, and Upper Paleolithic Spitsyn culture found at Kostenki XVII and XII, both dated to around 40 ka (Hoffecker 2002). There are no other sites indicative of Neanderthal presence at this latitude at this time and both cultures are commonly attributed to early modern humans.

By 35-30 ka, Northern Europe, north of the Alps, was characterized by a cold and dry climate with continuous steppe tundra vegetation throughout the period and with zones of *Betula* and *Pinus* during periods of ameliorated climate (de Beaulieu and Reille 1992). Modern humans moved into more southerly mid-latitude sites on the Dnestr-Prut Rivers long after the Neanderthals had abandoned these areas, and did not settle into the Northern Caucasus until the height of the pleniglaciation. The average latitude of modern human sites during this period exceeded 47°N as against a mean latitude of below 44°N for the Neanderthals.

Later, at the height of the pleniglaciation, between 33 and 20 ka, the Gravettians showed increased tolerance for climate extremes and expanded into both milder, southern and colder northern, winter isozones and even into effectively empty areas of the Russian Plains (Davies, Valdes et al. 2003). As the climate cooled towards the end of OIS 3, Middle Upper Paleolithic settlements are found even further north at Gagarino, Khotylevo II and Sungir', from 52 to 56° N. Modern human population density increased and the territory expanded to include both the southern sheltered regions, several thousand years after the Neanderthals had abandoned the area, as well as more northern regions at Sungir' and in the Altai Mountains (Dolukhanov,

Shukurov et al. 2002). Not until the peak of the pleniglacial were Upper Paleolithic humans forced to retreat south.

OIS 3 ended at around 25 Ka with the beginning of the pleniglacial period from 25 to 18 Ka. By this time Neanderthals were extinct or at best confined to refugia in the Caucasus and southern Iberia (Bocquet-Appel and Demars 2000; Pettitt and Pike 2001) Only during this late period did modern humans also colonize the Crimea and Caucasus.

I suggest that the first, early modern humans to arrive in Europe did not settle in the preferred southern areas, since Neanderthals already occupied these areas, and the ensconced population of Neanderthals, as top predators familiar with the local fauna, flora, and topography, must have had the advantage over the newly arriving modern humans, who were forced to resort to the colder open plains. A similar pattern of colonization is seen in southwestern Europe. Mapping of Mousterian, Châtelperronian, and Aurignacian sites in southwest France suggests that, during the Cottés/Hengelo interstadial, incoming modern humans initially avoided the Dordogne pocket inhabited by Neanderthals, but, in the subsequent stadial, Aurignacians were to occupy all but a few Châtelperronian sites in the north (Harrold 1989; Gamble 1999), while Neanderthals were restricted to peripheral areas in Cantabria (Mousterian) and pockets in the center and north of France (Châtelperronian).

Clearly, the modern humans had some cultural advantage over the Neanderthals. Based on skeletal anatomy, their advantage was not a physical adaptation to cold. Most anthropologists have focused on cultural behaviors including the improved use of clothing (Aiello and Wheeler 2003; Soffer 2004), fire, shelter, food ,fuel storage facilities (Hoffecker 2002), and social networks (Soffer 1989b; Soffer 1991) that

enabled them to survive the colder climate on the Russian Plains. However, manufacturing clothing, building underground shelters and storage pits, and maintaining wide social networks all require time and effort, and few have examined the economic consequences of this new lifestyle. One cultural behavior that might have enabled early moderns to expend the additional effort to survive under these harsh conditions might have been economic cooperation. I developed this model as a tool to examine the potential benefits of such arrangements in Neanderthal and Upper Paleolithic human groups.

7.3 Human Settlements throughout Europe during OIS 3

Although the settlement history of the Russian Plains provides a long duration record, particularly of Neanderthal movements, in a geographically constrained area, a more fine-grained look at settlements throughout Europe during OIS 3 may provide additional information on human movements and possible local extinctions (van Andel 2003a). This is the period of the early modern humans' entry into Europe and of the demise of the Neanderthals. Using data from the Stage 3 Project databases, I have analyzed human settlements by local climate, latitude, and frequency during specific time intervals during OIS 3.

Stage 3 Project, under the auspices of the Godwin Institute for Quaternary Research at the University of Cambridge, aims to answer the following questions for the middle pleniglacial period from 60 ka – 24 ka (van Andel 2003b):

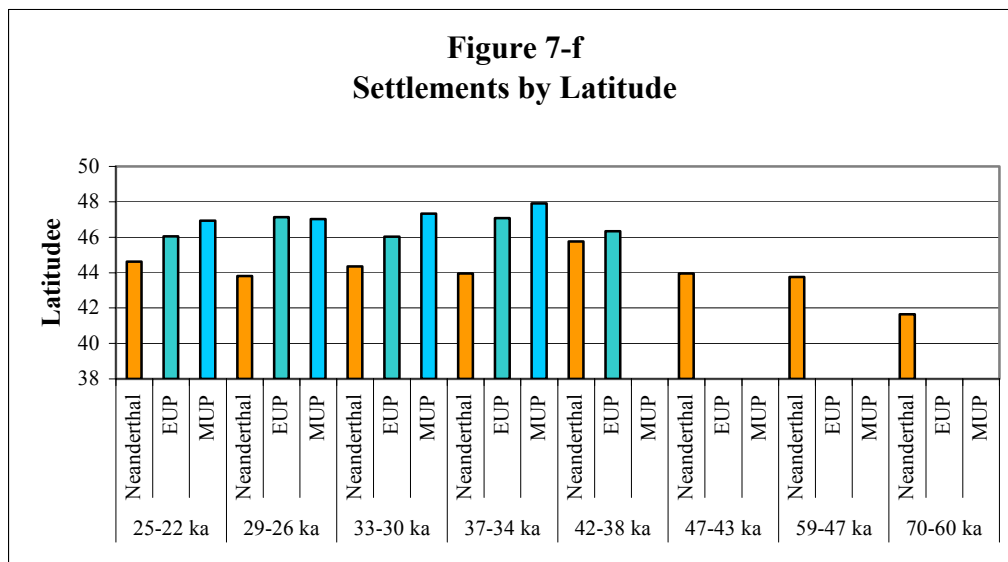
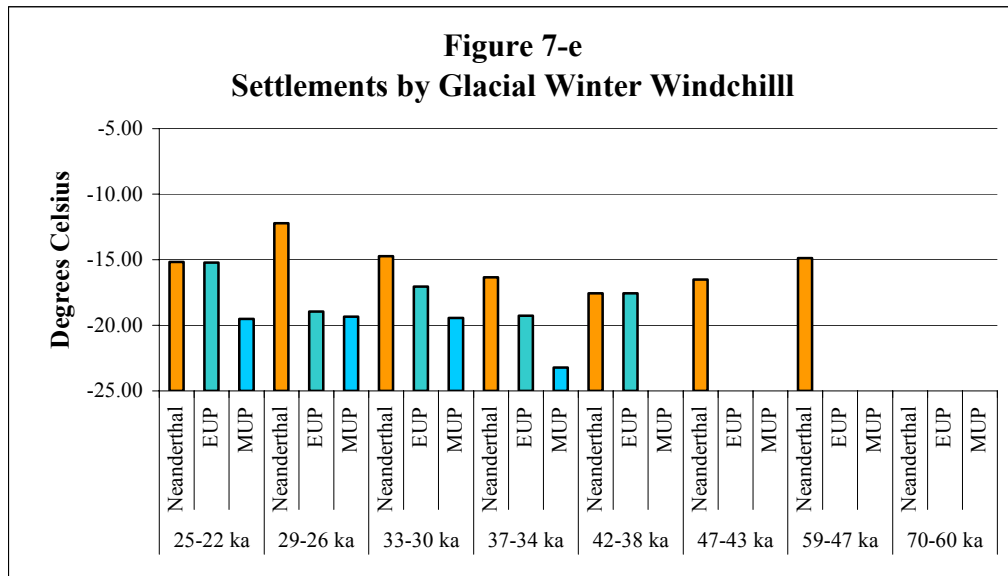
- What was the climate of Europe like during OIS 3 and to what degree did the drastic changes displayed by the Greenland ice-cores influence the European landscape and its flora and fauna?

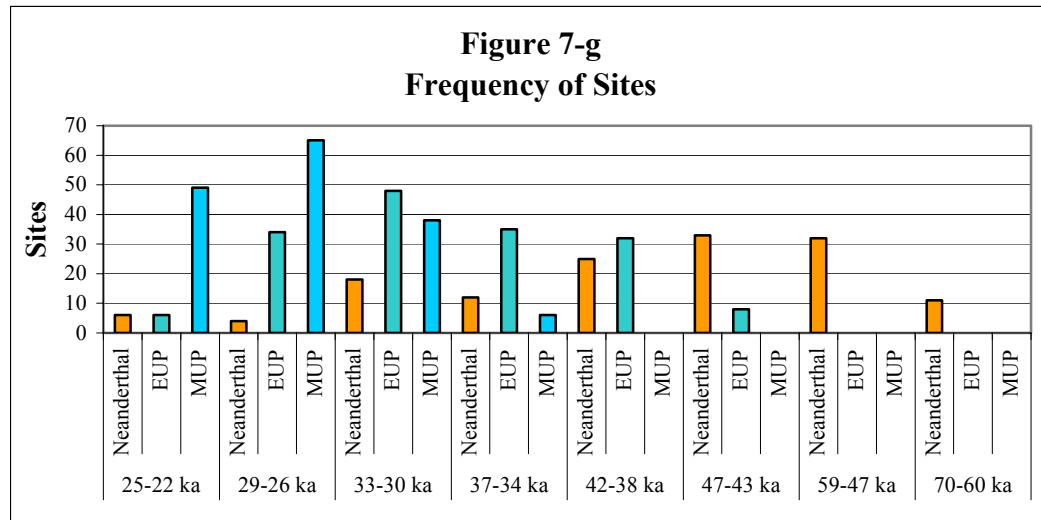
- Do human events of the Middle and early Upper Paleolithic reflect the OIS 3 climatic and environmental history and in what ways and to what degree?

The first phase of the Stage 3 Project is to develop climate and landscape models for OIS 3. Higher resolution models have been achieved using a nested strategy developed by Eric Barron at Pennsylvania State University (Barron and Pollard 2002; Barron, van Andel et al. 2003). The ultimate goal is to analyze the Middle and Upper Paleolithic in the context of the climate model using archaeological site data as proxies for human presence. A chrono-archaeological database has been compiled for the period from 60 to 20 ka. Climate simulations for Europe were developed for specific climate episodes: stable warm (59-45 ka), transitional (44-37 ka), early cold (37-27 ka), and last glacial maximum (27-16 ka) periods (Huntley and Allen 2003).

The data represented below in Figures 7b, 7c, and 7d are compiled from the Stage 3 database. The sites and site location data was retrieved directly from the database (www.csc.cam.ac.uk/oistage3/Details/Homepage.html), the temporal classification of sites and winter wind-chill factors was taken from compilations by Aiello and Wheeler (2003) that also use data from the Stage 3 Database. The Europe-wide analysis mirrors the pattern of movement in the Russian Plains. The windchill data (Figure 7e) illustrates the Neanderthals preference for warmer climates throughout Europe: the latitude data (Figure 7f) shows their preference for more southerly sites. The windchill and location data (Figures 7e and 7f) for early and middle Upper Paleolithic sites suggest an increased tolerance to climate stress and a more diverse set of climate preferences (van Andel and Gollop 2003). The frequency data (Figure 7g)

shows the gradual decline of Neanderthal settlements and increase of early and middle Upper Paleolithic settlements, albeit not necessarily in the same locations.





7.4 Climate Fluctuations and Local Population Extinction

The impact of climate on humans is seen in the archaeological record of the settlements in throughout Europe. Neanderthals migrated to the north and northeast during the last interglacial. They retreated gradually to the south during OIS 5 and abandoned the northern plains during OIS 4. They settled more southerly zones for a short period during the latter part of OIS 3. Modern humans moved into the area, probably in separate waves during the Hengelo and Danekamp (Bryansk) interstadials and were able to survive in more extreme conditions than their Neanderthal counterparts. In the more northerly parts of Europe, modern human settlements reached their peak at 29-36 ka but are absent during the last glacial maximum.

Analysis of climatic conditions at sites associated with Neanderthals indicate that they were unable to survive in arctic conditions, and they preferred to settle in warmer areas with less snow cover than did Aurignacians and Gravettians (Davies and Gollup 2003). With their limited clothing and shelter technology, Neanderthals would not have been able to settle in colder areas without a significantly elevated BMR (Aiello and Wheeler 2003). This suggests that, if the Neanderthals were to survive in arctic

conditions they would have had to support energy expenditures considerably in excess of the 10% included in Sorensen and Leonard's calculated TEE of 4,094 (above). They would need to consume large amounts of animal fat to permit higher rates of non-shivering thermogenesis (Gisolfi and Mora 2000) with a consequent increase in foraging time and activity levels.

Howell (1952) suggests that Neanderthals were restricted to milder climate areas consisting of vertical ecotones with more abundant plants, berries, nuts, small forest animals (with deer and occasional larger herbivorous forms). They were able to survive in these habitats that offered resources and protection against the weather. Finlayson (2004) argues that Neanderthals were adapted to the mid-latitudes and exploited the resources occurring in small areas within the more closed, heterogeneous landscapes of southern Europe. They were able to expand their territory northward as milder conditions permitted the extension of these ecotonal conditions into selected areas of the plains, but retreated to their refugia when conditions became colder and drier. In contrast, despite their gracile, long-limbed morphology, typically suited to warmer climates, modern humans were able to exploit the more wide-ranging homogeneous resources of the colder and drier open plains through the adoption of different social and behavioral lifestyles.

Finlayson and Pacheco (2000; Finlayson 2004) contend that modern humans and Neanderthals were separated by distinct ecological preferences and question the long-held belief that modern humans caused the extinction of Neanderthals. Neanderthals dispersed northwards when conditions were favorable to the creation of their preferred habitat, such as during OIS 5e, and the Neanderthal retreat from, or extinction in, the

northern European plains began before OIS 4, long before modern humans appeared in the area. This retreat continued as climate stress increased in the latter half of OIS 3. Peak stress in climatic conditions occurred around 30 ka (Stringer, Palike et al. 2003) at the time of the Neanderthals' demise. The low-density presence of Neanderthals and Aurignacians in close proximity in southern Iberia for several thousand years between 32 and 28ka, together with the absence of transitional industries, suggests that even here there was limited contact between the two (Finlayson, Pacheco et al. 2006).

The unpredictable, fluctuating climate must have had a significant impact on the Neanderthal and modern human populations and their culture, just as it has in recent times. In historic times, modern human societies have been wiped out by climate extremes much less severe than OIS 4 or 3. As a result of climate downturn (Barlow, Sadler et al. 1998), Norse populations in Greenland dwindled to extinction, doomed by a tradition and lifestyle that could not be maintained during the "Little Ice Age" (McGovern 1990). Despite their close proximity to the Thule, the Norsemen did not adopt the former's fishing and ice-hunting foraging practices (Outram 1999). Major subsistence crises occurred as a results of bad weather and poor harvests in the seventeenth and eighteenth centuries (Burroughs 1997), and the famine of 1697 in Finland is estimated to have killed one third of the population (Burroughs 2005). The Pueblo Indians of the Southwest of North America responded to high frequency changes in climate through cultural buffering mechanism, but were unable to respond to a longer-term, low-frequency climate shift because they had destabilized the local ecosystem through increased sedentism, overpopulation, and deforestation (Jorde 1977). Abrupt climate changes, especially in ecotones, transitional zones between vegetal

communities, where sensitivity to climate is greatest (Peteet 1998), have clear implications for the survival or extinction of local human populations.

This leads to the conclusion that climate, rather than interspecific competition, was a significant factor for the survival of local populations during the transition. If competition with Upper Paleolithic humans were a significant factor then one would expect to see the pattern of extinction of the Neanderthals moving from the south to the north, or the east to the west as modern humans invaded Europe. Instead, the pattern shows final Neanderthal presence in southerly refugia in Iberia, where some of the earliest Aurignacian settlements appear, and in the Balkans and Caucasus, close to potential entry points for moderns into Western Europe (Finlayson 2004). Early modern human remains are rare anywhere in Europe, and recent re-dating to the Holocene of remains from Hahnöfersand, Binshof-Speyer, Paderborn-Sande, and Vogelherd, that were thought to be contemporaneous with Neanderthals, suggests that in west central Europe a long period of coexistence between modern humans and Neanderthals did not occur (Street, Terberger et al. 2006). This argument is supported by evidence that there was a considerable spatial and temporal gap between Neanderthals and early modern humans, as the latter made their advance into Europe (Bocquet-Appel and Demars 2000). During the early stages of OIS 3, settlement patterns appear to have been driven by competitive exclusion. Only in the later stages of OIS 3, when both species retreated to refugia in the south was there any possibility for coexistence and direct contact. Bocquet-Appel and Demars argue that these groups lived in small colonies that were geographically dispersed relative to one another (>500 km). Such small mobile groups residing within areas as large as southwestern France,

Iberia or the Northern Caucasus are unlikely to meet. Analysis of Iberian settlement pattern suggests that desert steppe like barriers separated and protected the Neanderthals in the south from the incoming Aurignacians in the north (d'Errico and Sanchez Goni 2003).

I examine the hypothesis that the major threat to survival of Neanderthals and modern humans during the transition was the struggle of small, isolated groups to avoid extinction brought on by abrupt climate fluctuations rather than inter-specific competition. Further, I contend that the fluctuating climate may have been the driving force in the evolution of more extensive cooperative strategies. If this is the case, then the principal reason that specialization and cooperative behaviors evolved might have been to provide additional time and productive resources to combat the deterioration in conditions in higher latitudes. Neanderthals, with lower levels of cooperation, were forced to migrate south or go extinct during cold phases whereas modern humans were able to develop and execute technologies to mediate the climate because of the additional time made available through cooperation.

7.5 Climate Reconstruction and High and Low Frequency Variation

The climate gradients from north to south and from the Atlantic to the Urals meant that northeastern continental climates suffered more extreme annual swings and even more extreme stadial to interstadial swings than did those of the western Atlantic regions. Southern Mediterranean zones were still driven by North Atlantic fluctuations but were more temperate and represented more of a mosaic controlled by topographical features. Since Europe stands in mid-latitudes, summers, even in the north, remained long and conditions were not as severe and arctic as many have predicted. Table 7-1

shows conservative estimates of temperature and rainfall swings during OIS 3 compared to present day, glacial, and interglacial times.

Table 7-1 Reconstruction of the Climate for Selected Localities

Current-day City and latitude	Temperature (°C) Rainfall (mm)	Paris France 48° N	Bordeaux France 45° N	Moscow Russia 52° N	Krasnodar Caucasus 45° N
Present day	Winter Temperature	2.6	5.6	-10.3	-1.4
	Summer Temperature	18.7	20.4	18.5	23.2
	Annual Rainfall	2,089	851	601	674
Glacial OIS 2 & 4	Winter Temperature	-17.4	-6.4	-34.3	-11.4
	Summer Temperature	8.7	11.4	8.5	16.2
	Annual Rainfall	1589	351	101	423
OIS 3 Interstadial	Winter Temperature	-9.4	-0.4	-20.3	-6.4
	Summer Temperature	13.7	16.4	13.5	19.2
	Annual Rainfall	1789	851	401	674
OIS 3 Stadial	Winter Temperature	-14.4	-5.4	-25.3	-11.4
	Summer Temperature	8.7	11.4	8.5	14.2
	Annual Rainfall	1679	601	251	549
OIS 5e Interglacial	Winter Temperature	3.6	5.6	-3.3	-0.4
	Summer Temperature	20.7	21.4	18.5	23.2
	Annual Rainfall	2389	1151	701	974
<i>Latitude</i>		<i>49° N</i>	<i>45° N</i>	<i>56° N</i>	<i>44° N</i>
<i>Midwinter Daylight</i>		<i>5.6 hr</i>	<i>6.2 hr</i>	<i>4.7 hr</i>	<i>6.3 hr</i>

Data Sources: Present day data (World-climate 2002),
Paleoclimate data for all except OIS 3 stadial (Frenzel, Pecsí et al. 1992),
OIS 3 stadial projected at a conservative 5° below OIS 3 interstadial.
Midwinter daylight hours (Dennell 2003)

i. Seasonal Variations in Daylight Time and Activities

The data developed in climate reconstruction models for the Late Pleistocene represents annual measures for stadial and interstadial episodes. However, reconstructed data offers little insight into seasonal variation. Ethnographic data indicates tasks and gender roles differ considerably from season to season. In higher latitudes, winter is a time of deprivation. Fewer resources are available and fewer available daylight hours means that less time is spent in productive activities and the range of outdoor activities is limited. Indeed, ethnographic studies indicate that in the deepest of winter the Inuit spend their time in festive, social activities with little time devoted to productive

pursuits. Thus an annual record of time allocation to tasks conceals the proportions of work performed in winter versus summer seasons (see Chapter 3: Figures 3a and 3b and Table 3-18).

Although, ethnographic time allocation studies do not distinguish between winter and summer activities, anecdotal data indicates a clear distinction between winter and summer gender roles (Giffen 1930; Mauss 1979). Winter commences in October/November once the harvesting of fruits and nuts are complete and the fall migration of animals to the south is complete. April, the latter part of the winter, is often the time of most deprivation since stored foods may be running out. Spring's vegetal shoots are not yet available and the fauna are lean and the meat may be toxic. Summertime runs from May till the end of the fall migration and is the time of plentiful resources with much work gathering and accumulating stores of food, preparing clothing, and repairing shelter for the winter.

It is reasonable to model these seasonal activities based on the following facts.

- Seasonal differences in daylight hours are quite significant in northern latitudes, as shown in Table 7-5 above. Mid-winter daylight hours are approximately six hours long, and six-monthly variations in available hours range from 75% (winter) to 125% (summer) of an average 12-hour day. Where task priorities and roles change from season to season such variation will tend to amplify the variation between each individual's contributions to the total work effort.
- Time allocation data indicates that productive activities, on an annual basis, usually consume approximately 50% of all activities with leisure and social activities consuming the remaining 50%. Therefore, I project a reduction of 12%

(half the difference in available hours) in time allocated to productive activities in the winter and a corresponding increment of 12% in the summer.

- Wintertime brings limitations on availability of fauna and flora and restrictions on access to outside resources because of the frequency of inclement weather. As a result the range of activities is considerably less than at other times of the year, especially as related to outside activities such as gathering food and fuel. For males food acquisition times are reduced by 12% and for females food acquisition times are reduced to zero and camp maintenance activities are reduced to match a total reduction in time of 12%.

Therefore, I have projected the total winter activity time at 25% less than that in the summer, and have accounted for the decrease by reducing the time devoted to outdoor activities, first food acquisition and second camp maintenance. Summertime activities would show a corresponding increase in those activities so that the annual activity time equates to that recorded in time allocation data. These winter adjustments for late Neanderthals and early Upper Paleolithic humans are shown in Table 7-2 below and in the summary Tables 8-1 to 8-4 at the beginning of the next chapter. The annual activities and units are those determined in Chapter 4, Tables 4-15 and 4-16. Summer adjustments are computed in the model by adjusting summer values proportionately to achieve the total annual output.

Table 7-2 Annual and Seasonal Activities and Units

Activity Name	Annual Activity Tasks	Male Annual units	Female Annual units	Winter Activity Tasks	Male Winter units	Female Winter units
Late Neanderthal						
Food acquisition	5	81	9	3	69	0
Food preparation	3	2	18	3	2	18
Childcare	2	1	20	2	1	20
Tool making	11	10	2	11	10	2
Clothing manufacture	7	0	32	7	0	32
Camp Maintenance	7	6	19	5	6	16
Total (Excluding Leisure)	35	100	100	31	88	88
Early Upper Paleolithic						
Food acquisition	9	61	6	5	49	0
Food preparation	4	2	14	4	2	14
Childcare	2	1	15	2	1	15
Tool making	33	26	5	33	26	5
Clothing manufacture	13	0	46	13	0	46
Camp Maintenance	14	10	14	9	10	8
Total (Excluding Leisure)	75	100	100	66	88	88

ii. **High Frequency Variations in Climate**

Only average temperatures are detectable from climate reconstructions. But groups living in marginal environments do not respond to climate averages, such as temperatures and rainfall (Low 1990). The mean is a poor measure of viability and survival; the extremes encountered by these groups, and the predictability of the occurrence of those means is the critical factor. Regions with the same mean rainfall or temperature may have significantly different characteristic in terms of range of variation, predictability and periodicity. From an examination of cross-cultural behaviors in current hunter-gatherers, Low determined that one of the key responses of groups that move into highly variable and unpredictable climate zones is the development of social cooperation in foraging, food sharing, food storage and trade.

High periodicity year-to-year variations in climate by alter roles and performance. Year-to-year periodic changes in local ecological conditions change the relative importance of specific tasks. An early frost, the failure of the fall migration to follow predicted paths, local flooding, or drought change the relative weightings of specific tasks in the repertoire and the comparative merits of specific individual skills. Humans resort to lower quality foods such as tubers in the event of late frost, or fallback to small prey or fish in the event of a change in the deer migration route. Several such occurrences might occur during an individual's productive lifespan. The top performer in one year may only offer a minor contribution in other years. This short-term variability is likely to make some tasks more difficult and others easier depending on local conditions, and these variations in task priorities are intermittent and stochastic. These behaviors must likewise have been typical of the inhabitants who endured the oscillating and unstable climate of the later Pleistocene.

NOAA records of US temperature and rainfall statistics over the last 112 years (www.ncdc.noaa.gov) shows that annual variation in temperature was 10.3% around an average of 11.6° C, and annual rainfall varied by 16% around an average of 750 mm. In order to simulate this impact on task loads in the ICA model I assign random, periodic variation in task loads within a range of 5% by season and year for each task in the repertoire. Thus, these changes in task loads alter the relative weightings for each task for all individuals to within a conservative 5% of the average, and, since the most time consuming tasks are allocated first, this may affect the allocation of tasks, and consequently the benefits achieved by each individual from year to year. This climate variable is used in the threshold tests of individual variation over twenty periods.

iii. Low Frequency Variations in Climate

Jorde examined high and low frequency variations in climate in the Southwest of North America. From an examination of the annual birth rates as a response of Pueblo Indians to high-frequency variations in rainfall, he observed that cultural mechanisms such as irrigation, food storage and trade were able smooth out the effects of these high-frequency variations. The Pueblo, however, were unable to respond to the unpredicted low-frequency fluctuation and the population crashed (Jorde 1977). He concluded that societies with low technological complexity were able to buffer against high-frequency precipitation but less able to respond to longer-term, unpredicted, low periodicity fluctuations.

During low frequency fluctuations in the late Pleistocene, average annual temperature declines as much as 7-10° C accompanied by increases in aridity in a decade or less would have decimated temperate, interstadial vegetation in less sheltered and northern areas, and subsequent increases in temperature and humidity would have triggered a slow migration of flora and fauna to repopulate previously arid/cold areas. In evaluating vegetational response to abrupt climate change, Peteet (2000) examined dust fluxes, snowfall and methane levels from ice cores and matched these to terrestrial records from more temperate areas. Peteet estimates that the magnitude of these fluctuations may have been as large as 6°C. This figure is significantly less than the absolute variation in temperature developed from climate reconstructions (Table 7-4), but I have chosen to use this more conservative measure of response in the ICA model.

In order to develop an estimate of how a climate swing of 6°C might have affected prehistoric humans I have related it to human body temperature measurements.

In human terms, when compared to regular body temperature of 37°C, such a 6°C swing in annual averages represents a 16% change. If measured against the ambient temperature at which thermoregulatory thermogenesis must be initiated, predicted to be 28.2°C for *Homo sapiens* and 27.3°C for Neanderthals (Aiello and Wheeler 2003), the percentage change is even higher at 21% and 22%, respectively. These climate swings are consistent with evidence for the pollen cores from Monticchio, which show a greater than 20% reduction in pollen from wooden taxa in less than 150 years during rapid cooling episodes (Allen, Brandt et al. 1999). Such short, unpredictable climate oscillations of 16% to 22% would have significant impact on the task loads of humans living during this period. In my model, I use the more conservative 16% to represent the negative climate impact that might be offset by benefits achieved from specialization and cooperation. At the maximum threshold of 16% humans would have to achieve, on average, a 16% improvement in benefits to buffer the negative effects of the climate deterioration. Since averages hide significant year-to-year individual variation, I also test various levels of threshold at which individuals and groups survive or become extinct.

7.5 Climate Data Applied in the Transition Model

I attempt to simulate how the Ricardan benefits might enable groups in the late Pleistocene to respond to high and low frequency deterioration in climate, similar to that experienced in the late Pleistocene. First, in a series of synchronic tests of 1,000 groups living under similar conditions, I test a 16% threshold of low frequency change against the mean Ricardan benefits achieved by all individuals in each group. However, mean benefits hide high and low scores and, therefore, I test individual responses to seasonal

and year-to-year high frequency changes in a series of dynamic, threshold tests over twenty years with two seasons each. Seasonal variations in activity are simulated by adjusting the number of hours available to accomplish the tasks in the inventory and by correspondingly reducing the effort allocated to outdoor activities (Table 7-2). In addition, high frequency, year-to-year variations of 5% are simulated by adjusting the weighting of all tasks in the inventory, on the assumption that seasonal and annual climate variation will rearrange task priorities. I test various thresholds for individual and group survival to determine at what level of Ricardan benefit each group is able to maintain a stable population and at what level the group is extinct. Finally, I look at one focal group in a threshold scenario to examine in detail what might happen to individuals in the group season by season, and how the group might be able to improve its survival prospects by practicing economic specialization and exchange and delayed reciprocity.

Chapter Eight

The ICA Transition Model and Results

The primary objective of this research is to look at the climate challenges faced by late Pleistocene populations and to examine whether cooperation might mediate these. The task, here, is to determine whether the parameter data gleaned from the archaeological and physical anthropological records is sufficiently precise to provide meaningful results from the model. This chapter first summarizes the data on Neanderthal and Upper Paleolithic activities gathered as part of this research. I tabulate the information assembled in the previous chapters and then evaluate the data, its confidence level, and how it might be used in the model to determine the benefits of cooperation through economic specialization and exchange, here called Ricardan benefits.

8.1 The Transition Model and the Data Extracted from the Record

The ICA Transition model has been updated to process the Neanderthal and Upper Paleolithic data gathered through this research. The Transition model is derived from the prototype and modified to include features to handle additional conditions that emerged as a result of this project. I describe how the model has been altered to incorporate the added complexities in tasks, activities, gender roles, and seasonality, as revealed from the record, and I outline the changes to the algorithms used in the Transition Model.

The data extracted from the ethnographic and prehistoric records and to be submitted to the model are compiled from the conclusions reached in Chapters 4, 5, 6, and 7, and are summarized in Tables 8-1 through 8-4 below.

Table 8-1 Early Neanderthal Population Parameters

Local group size	Seasonal group size			Skill spread	Skill mean	
4	12			16 or 14	100	
Tasks and Time Allocation	Annualized			Seasonal		
Activity Name	Tasks in Annual Activity	Men's Annual units	Women's Annual units	Tasks in Winter Activities	Men's Winter units	Women's Winter units
Food acquisition	4	82	9	2	70	0
Food preparation	3	2	18	3	2	18
Childcare	2	1	20	2	1	20
Tool making	9	9	1	9	9	1
Clothing manufacture	7	0	33	7	0	33
Camp maintenance	6	6	19	4	6	16
Total (Excluding Leisure)	31	100	100	27	88	88

Table 8-2 Late Neanderthal Population Parameters

Local group size	Seasonal group size			Skill spread	Skill mean	
4	12			16 or 14	100	
Tasks and Time Allocation	Annualized			Seasonal		
Activity Name	Tasks in Annual Activity	Men's Annual units	Women's Annual units	Tasks in Winter Activities	Men's Winter units	Women's Winter units
Food acquisition	5	81	9	3	69	0
Food preparation	3	2	18	3	2	18
Childcare	2	1	20	2	1	20
Tool making	11	10	2	11	10	2
Clothing manufacture	7	0	32	7	0	32
Camp maintenance	7	6	19	5	6	16
Total (Excluding Leisure)	35	100	100	31	88	88

Table 8-3 Early Upper Paleolithic (EUP) Population Parameters

Local group size	Seasonal group size			Skill spread	Skill mean	
10	30			16	100	
Tasks and Time Allocation		Annualized			Seasonal	
Activity Name	Tasks in Annual Activity	Men's Annual units	Women's Annual units	Tasks in Winter Activities	Men's Winter units	Women's Winter units
Food acquisition	9	61	6	5	49	0
Food preparation	4	2	14	4	2	14
Childcare	2	1	15	2	1	15
Tool making	33	26	5	33	26	5
Clothing manufacture	13	0	46	13	0	46
Camp maintenance	14	10	14	9	10	8
Total (Excluding Leisure)	75	100	100	66	88	88

Table 8-4 Middle Upper Paleolithic (MUP) Population Parameters

Local group size		Seasonal group size		Skill spread		Skill mean
30		90		16		100
Tasks and Time Allocation		Annualized			Seasonal	
Activity Name	Tasks in Annual Activity	Men's Annual units	Women's Annual units	Tasks in Winter Activities	Men's Winter units	Women's Winter units
Food acquisition	11	59	5	7	47	0
Food preparation	4	2	12	4	2	12
Childcare	2	1	13	2	1	13
Tool making	38	28	5	37	28	5
Clothing manufacture	17	0	52	17	0	52
Camp maintenance	15	10	13	10	10	6
Total (Excluding Leisure)	87	100	100	77	88	88

In the above tables, the local group size represents the normal camp size of productive adults that make up the economic engine of the group. Seasonal group size is the size of the aggregated winter group. Skill spread and mean of 16 and 100 are applied in the majority of the tests, although a few tests assess the impact of a lower spread of 14 for Neanderthals. Annualized data represent average activity levels as derived from ethnographic time allocation studies and prehistoric data. Seasonal data show winter tasks; summer tasks comprise what remains to accomplish the annual task load. None of this data reflects any dynamic, seasonal or year-to-year variation in ecological conditions.

8.2 Input Data: Sources, Derivation, Level of Confidence

A model is only as good as the data that is submitted, and one would expect to have different confidence levels for the various data sources. There is much debate as to whether data from current hunter-gatherer groups should be applied to prehistoric human groups, and especially to Neanderthals. For this reason, the data gathered from the prehistoric, archaeological and physical anthropological record of each population

are assigned the highest confidence level for this analysis. The seasonal data obtained from anecdotal data in the ethnographic record, with little support from the prehistoric record, have the lowest confidence level. The data on time allocation and gender roles fall in the middle level of confidence.

It is appropriate now to review the data, and how the model is designed to compensate for the strengths and weaknesses in the data sources. Various versions of operation of the model are used to compare results using selected combinations of the data gathered based on these strengths and weaknesses.

i. Group Size Data

The group size and composition data is for productive adult members. The data are retrieved substantially from the archaeological record, with some validation from ethnography (Chapter 5 and table 5-2). The group sizes reported for early Upper Paleolithic humans corroborate the data observed in ethnographic studies. However, the Neanderthal group size data is solely sourced from evidence in the archaeological record. There appear to be clear distinctions between Neanderthal and Upper Paleolithic group sizes. One would expect the group size data to be compatible and congruent with the task and skill parameter data within each population, and tests are incorporated to check the congruity and optimality of group size data given the corresponding parameter values determined for the task and skill spread parameters.

ii. Skill Spread Data

The data on skill spreads by individual and by tasks are generated using a random, normal distribution algorithm. The dimensions of the distribution are defined by current human measurements of IQ and muscle strength: a mean of 100 and a

standard deviation of 16. Such a distribution should apply to the Upper Paleolithic humans, since physical anthropology indicates that they are identical to current humans. Theoretical analysis and some supporting evidence from the Neanderthal skeletal and behavioral record (See chapter 6) suggest that Neanderthals might have had a narrower distribution of skills, but such a lesser range is not so well supported. Therefore, I execute the model using the same variance of 16 with a mean of 100 for Neanderthals as with Upper Paleolithic humans, but, for certain tests, I use a narrower variance of 14 for Neanderthals, as discussed in Chapter 6, to assess what difference in benefits, if any, the narrower spread might generate.

iii. Task Data

The annualized task data is sourced in several layers. Activities, time allocations, and gender roles are based on the time allocation data collected in the ethnographic record, but the specific number of tasks for each population is based on the archaeological and physical anthropology record. This is all detailed in Chapter 4, and summarized in Tables 4-15 and 4-16. Seasonal activities and roles are derived from annualized data that are modified based on data in ethnographic anecdotal reports: these are from Chapter 7, Table 7-2. Task repertoire data are multidimensional and are, therefore, handled in separate versions based on sourcing and levels of confidence.

Four versions are tested to assess the results based on the source of task data. The first, task-based version uses the raw total number of tasks, as derived solely from the archaeological record. The second, task-and time-based version uses the same list of tasks which are now categorized by activity and time-weighted based on the activity weights determined from time allocation studies in the ethnographic record. The third,

gender-based version uses the gender assignments from gender roles determined in time allocation studies in the ethnographic record. The fourth, subtask version is based on the premise that there might have been more than one subtask associated with each task identified in the research, and that these subtasks were shared in specialization and exchange activities. This version is included to test this premise and to determine whether the added number of subtasks makes any significant difference in the results.

Finally, seasonal data is incorporated into a series of dynamic, threshold tests which extend over several years. These threshold tests examine individual survival prospects in an environment that changes for season to season and year to year.

iv. Climate Data

The climate data extracted in this research provide a reasonable guide as to what might have occurred in the late Pleistocene, but the amplitude and periodicity of such changes cannot be directly associated with any particular time period. The climate deterioration of 16%, at worst, as determined in Chapter 7, is used as a low frequency variation and threshold that humans must offset by Ricardan benefits if these benefits are to be effective in buffering the deteriorating climate of the period. However, this threshold may have been reached only at the peak of climate stress around 30 ka (Stringer, Palike et al. 2003). Earlier periods may have experienced significantly lesser swings. Therefore, I plan to test various thresholds at which a) groups are able to maintain stable populations, and b) at which groups become extinct. In addition to testing low frequency thresholds, the diachronic tests simulate high frequency, year-to-year climate variation based on a year to year variation of 5% as derived from recent climate records. Since the climate in the Holocene is generally more stable than in OIS

3, this 5% is probably less than the variation experienced in the late Pleistocene, and is a conservative estimate. These high frequency variations are reflected in changes in annualized task loads, and, consequently, task priorities, individual roles, and individual performance from season to season.

8.3 Methods of Analysis

Three methods are used to analyze the data and generate results.

i. Mean Ricardan Benefits using Annualized Data

The unmodified, annualized population parameters, derived from Table 8-1 to 8-4, are applied to one thousand groups from each of the four populations to determine the relative rankings in terms of mean Ricardan benefits between populations. Each group represents productive, adult individuals, normally residing in camp. Each individual is randomly assigned a unique skill set of skill proficiencies, task by task. These tests examine how, on average, uniquely skilled individuals in the one thousand groups from each population respond to the same annualized parameter data. The results of these tests are normalized, mean Ricardan benefits. Standard deviations give variation from the mean resulting from these tests. In these tests, all members of the group are counted in the mean, whatever the level of benefits achieved.

ii. Mean Ricardan Benefits using Modified Annualized Data

Modified, annualized data for late Neanderthal and early Upper Paleolithic populations only (Tables 8-2 to 8-3) are used in the Sensitivity tests to determine the relative rankings in terms of mean Ricardan benefits between the two contemporaneous populations. These modifications are designed to test the sensitivity of the results to any error or bias in the data collected. The first sensitivity test is a Monte Carlo simulation

in which parameters are randomly modified by $\pm 25\%$ for each of the one thousand groups. The Monte Carlo analysis tests one thousand permutations of randomized values for group size, task repertoire and skill spreads within a range that brackets the annualized parameter values determined by this research. The Monte Carlo results produce a mean and standard deviation for mean Ricardan benefits.

The second sensitivity test is a Midpoint Sensitivity analysis in which data are deliberately skewed to narrow the wide gap between late Neanderthal and early Upper Paleolithic annualized parameters. I test the sensitivity of each parameter by performing reasonability tests using group size and task parameter input values that are modified to reduce the gap between Neanderthal and early Upper Paleolithic annualized parameters (Tables 8-2 and 8-3). I assess the results generated with a lower skill spread for Neanderthals by testing skill spreads in a range from 14 to 16. The results of these tests are mean Ricardan benefits derived from the processing of the one thousand groups of individuals each with unique skill sets. In both of these sensitivity tests, all members of the group are counted in the mean, whatever the level of benefits achieved.

iii. Individual Ricardan Benefits and Threshold Tests using Seasonal Activity Data

Dynamically modified seasonal data from Tables 8-2 and 8-3 are used in a series of threshold tests. The individual threshold tests for late Neanderthals and early Upper Paleolithic humans are aimed to look beneath the averages to examine how individuals respond in each season, year by year, and in particular to determine if each individual achieves sufficient individual Ricardan benefits to survive certain climate thresholds. Averages hide individual seasonal variations and one bad season might lead to individual extinction. In these tests, forty additional passes are processed for each of the

one thousand groups in each of the two contemporaneous populations. These forty passes represent twenty years, each with a winter and summer season. Seasonal data are input, and task loads are randomly modified by $\pm 5\%$ for each season to simulate changing task loads resulting from high frequency variations in climate and ecological conditions (Chapter 7). Skill sets for each of the one thousand groups are randomly generated at the beginning of the twenty year period and held constant during the forty passes, to simulate the productive lifespan of one group with specific skills. Climate thresholds, representing low frequency climate crashes, may be set at any range and, on completion of a season, each individual's Ricardan benefits are compared to the threshold level set and, if the individual's benefits do not exceed the threshold, the individual is eliminated and not included in the count of survivors. By tallying the total surviving population at the end of each season, it is possible to determine whether the population is stable or in decline and identify equilibrium and extinction climate thresholds for each population.

8.4 The Transition Model

i. The Transition Model Modified for the Data Assembled from the Record

The Transition Model has been modified to incorporate changes to accommodate additional aspects of behavior uncovered in this analysis. For example, the Prototype model does not specifically address relative task weightings and associated division of labor by gender. Most significantly, it does not address the fact that in the highly seasonal higher latitudes, roles change significantly between winters or cold stadials and summers or warmer interstadials. It does not allow for the processing of a sequence of multiple years and seasons, necessary to project individual

survival in a dynamic environment, where task priorities may change from season to season and year to year based on ecological context.

These modifications to the Transition model are described below.

- Task weights within each activity may be assigned, either a) on an equal basis, where tasks are averaged within each activity, for calculating mean Ricardan benefits, or b) on a random basis, where the average weight is modified by $\pm 5\%$ within each activity, for calculating individual Ricardan benefits in threshold tests.
- Modifications allow for the allocation of tasks by gender, based on the proportion of each activity performed by each gender as determined from the ethnographic data.
- Procedures have been added to assess the impact of group aggregations in times of seasonal deprivation and hardship. This type of winter behavior is observed in the ethnographic record for high latitude groups and may be detected in the archaeological record.
- Additional passes have been added to simulate a lifespan sequence of twenty years, with winter and summer seasons. Climate thresholds may be added so that individuals are eliminated from subsequent rounds, if they do not achieve benefits levels necessary to offset the climate threshold selected.

ii. Transition Model Decision-making Engine

The decision-making engine in the Transition model is fundamentally the same as that used in the Prototype as described in Chapter 2, with the exception that annualized and seasonal input parameters are derived from this research. In addition, procedures to generate periodic variation in task loads are added, as detailed in paragraphs c, d, and f below.

- a. Annualized and seasonal input parameters for each population are a) the group sizes for local (dispersed) and seasonal (aggregated) group compositions, b) the number of annual and seasonal activities and tasks in its task repertoire to be achieved, and c) the skill spread. The values used in the Transition model are those values identified as part of this research and shown in Table 8-1 to 8-4.
- b. As in the Prototype model, unique skill proficiencies for each individual within each of the one thousand groups in each population are generated within a Gaussian distribution defined by the population skill spread and mean and these values are retained in the skills matrix: $P_{t,i}$ - tasks by person.
- c. As in the Prototype, task weights (w) are calculated by dividing the activity time by the number of tasks in the activity and are stored in the array: W_t – weights by task. In the mean Ricardan benefit versions, average weightings are applied within the time determined for each activity so that all groups contend with the same standard parameters. In the individual Ricardan benefit versions, the model allows for seasonal variation in activities and tasks, as defined in the basic input tables 8-1 to 8-4. It also calculates variable, periodic task loads, so that groups contend with a different set of parameters in each season. The task

loads are generated randomly, on the assumption that each ecological cycle would present different challenges and consequently affect the amount of time necessary to accomplish each task. A given individual with an assigned skill-proficiency would not necessarily require the same amount of time to accomplish a specific critical task in each period. Periodic task loads are generated and varied by $\pm 5\%$ using the RND pseudo random function. These are stored in the task array: L_t

- d. The task weight (w) and periodic load (l) together with proficiency (p) are used to compute the amount of time that an individual requires to spend to accomplish that specific task in that specific season.

Individual task time: $r_{t,i} = (w_t * l_t * 100) / p_{t,i}$

- e. The following computations are the same as those applied in the Prototype:

- The individual non-cooperative base time: $b_i = \sum r_{t,i}$
- The individual cooperative-exchange time:
- $e_i = \sum r_{t,i}$ if $(b_i - e_i') / r_{t,i} > |b_j - e_j'| / r_{t,j}$ for $j = 1-n, j \neq i$ where e_i' represents the total time already spent in previous recursive rounds.
- The benefits achieved from specialization and exchange: $(b_i - e_i) / e_i$

- f. Finally, additional passes have been added in which skill spreads are held fixed (step b), but tasks loads are randomly changed for each pass (steps c through e).

This simulates each group, with the same skill set, being subjected to twenty years of ecological variation in task loads.

- Extinction occurs if benefits (e_i) do not exceed the climate threshold (c):

Critical survival threshold used in threshold tests: $e_i > c$.

iii. Multiple Executions

Since skill spreads are randomly generated based on the Gaussian algorithm several executions of the model are performed to normalize results and eliminate any bias. One thousand iterations are performed, and, since the activity and task data are based on fixed annualized, or seasonal task time allocations, each pass is the equivalent of one year or season in the life of one thousand unique groups within each population. In order to determine how many passes were necessary to generate normalized results for mean Ricardan benefits, a series of tests of the task-based version were performed: they show that one thousand iterations are quite sufficient to generate stable results. These stable results have mean Ricardan benefits of 9.0% and a standard deviation of 0.0423 for late Neanderthals and a mean of 17.84% with a standard deviation of 0.0187 for early Upper Paleolithic humans.

Therefore, all versions incorporate the results from at least one thousand unique groups. The Midpoint Sensitivity analysis includes those extra passes necessary to process the full range of bracketing values. The threshold versions includes an additional twenty 'years', including winters and summers, forty passes in total.

Table 8-5 summarizes the three methods described earlier and how the data is manipulated in each.

Table 8-5 Methods and Versions of Operation of the Transition Model

	<u>Method 1.</u> Mean Ricardan Benefits using annualized parameters	<u>Method 2.</u> Mean Ricardan Benefits using modified annualized parameters	<u>Method 3.</u> Individual Ricardan Benefits using Seasonal Task Loads
Populations tested	All four populations	Late Neanderthal and early Upper Paleolithic	Late Neanderthal and early Upper Paleolithic
Versions	Tables 8-1 to 8-4 <ul style="list-style-type: none"> • Task-based • Task- & Time-based • Gender based • Subtask Analysis 	Tables 8-2 and 8-3 <ul style="list-style-type: none"> • Monte Carlo Analysis 	Tables 8-2 and 8-3 <ul style="list-style-type: none"> • Midpoint Sensitivity Analysis • Equilibrium & Survival Thresholds • Aggregation Analysis • Focal Analysis
Group Size	Local group size	Local group size randomly varied by $\pm 25\%$	Local group size adjusted to midpoint
Skill Spreads	Neanderthals: 14 and 16 Upper Paleolithic: 16	Both populations 16 $\pm 25\%$	Neanderthals: 14 through 16 Upper Paleolithic: 16
Task Weights	Annualized task and activity data	Annualized task data randomly varied by $\pm 25\%$	Annualized task data randomly varied adjusted to midpoint
Cycles Executed	Tasks are averaged for all tasks in activity 1,000 groups in all four populations	Tasks are averaged for all tasks in activity 1,000 groups in two populations	Tasks are averaged for all tasks in activity 1,000 groups in two populations Plus 40 Neanderthal and 26 Upper Paleolithic additional cycles
			Task loads are seasonally adjusted by $\pm 5\%$ 1,000 groups in two populations Plus forty additional passes, twenty periods of one winter and one summer
Results	Mean Ricardan Benefits	Mean Ricardan Benefits	Mean Ricardan Benefits
			Individual Ricardan benefits

8.5 The Results – Mean Ricardan Benefits using Annualized Data

The Transition Model examines, first, within-group mean Ricardan benefits, and how the various versions of execution for different confidence levels might affect relative results among the four populations.

Four versions are executed using annualized data from Tables 8-1 to 8-4.

2.5.1 Task-based Version

The task-based version considers division of labor by skill proficiency: work is allocated based solely on an individual's proficiency in each of the tasks. This version relies solely on data extracted from the prehistoric record and eliminates any potential bias introduced from the ethnographic record. Since the prehistoric record does not inform on time allocations, all tasks are equally weighted evenly over the entire repertoire in this version. Time allocation and gender data is ignored. End products observed in the archaeological remains are the basis for identifying the tasks, which are grouped into the six major activities (food acquisition, food preparation, childcare, tool making, clothing manufacture, and camp maintenance). This dimension of data provides the basic input for the first, task-based version of the model. The test results are shown in Table 8-6 at the end of this section.

2.5.2 Task-and-Time-based Version

The task-and-time based version also considers division of labor by skill, and work is allocated based solely on an individual's proficiency in each of the tasks. As in the task-based version each activity consists of one or more tasks as identified from the archaeological record. Since the ethnographic time allocation studies record time at the level of activity only and not at the task level, tasks within activities are weighted equally such that the total time for all tasks in an activity equals that specified in the ethnographic record. Thus, if there are five tasks in the food acquisition activity, and the activity is assessed a time allocation of 45 units, then the five tasks are assigned average weights of 9. This limits the amount of time that can be devoted to that activity relative to all other activities and injects an element of opportunity cost into the

equation. The raw count of tasks alone, as used in the task-based version, makes no allowance for the different weightings of each task in terms of difficulty or duration. Logic tells us that the duration and complexity of tasks should have an affect on task priorities and the distribution of workloads in a specialization and exchange situation, and thus influence the benefits of cooperation. This version seems to be the most appropriate if one considers that the division of labor by gender might not apply to one or more of the populations. This composite data provides the input for a second, task- and-time based version of the model. The test results are shown in Table 8-5 at the end of this section.

2.5.3 Gender-based Version

The gender-based version looks at sexual division of labor: work is allocated based on an individual's proficiency in each of the tasks but within gender. The activity time allocations and gender roles, as retrieved from the ethnographic time allocation reports as well as the task list derived from the prehistoric record are used as input. Specific task time allocations are assigned evenly within each activity, as in the task- and time-based version (above), but the total time allocated for all tasks in an activity is limited by the gender distribution derived from the ethnographic record.

Any division of labor or sexual taboo acts as a constraining factor on the unrestricted assignment of work based solely on skill proficiency, and, therefore as a result of this research, I have modified the Transition model to incorporate division of labor and gender roles. Tasks are assigned proportionately along gender lines, as observed from the ethnographic record, and the results compared to non gender-based versions. Although gender roles are not rigid and vary quite considerably between

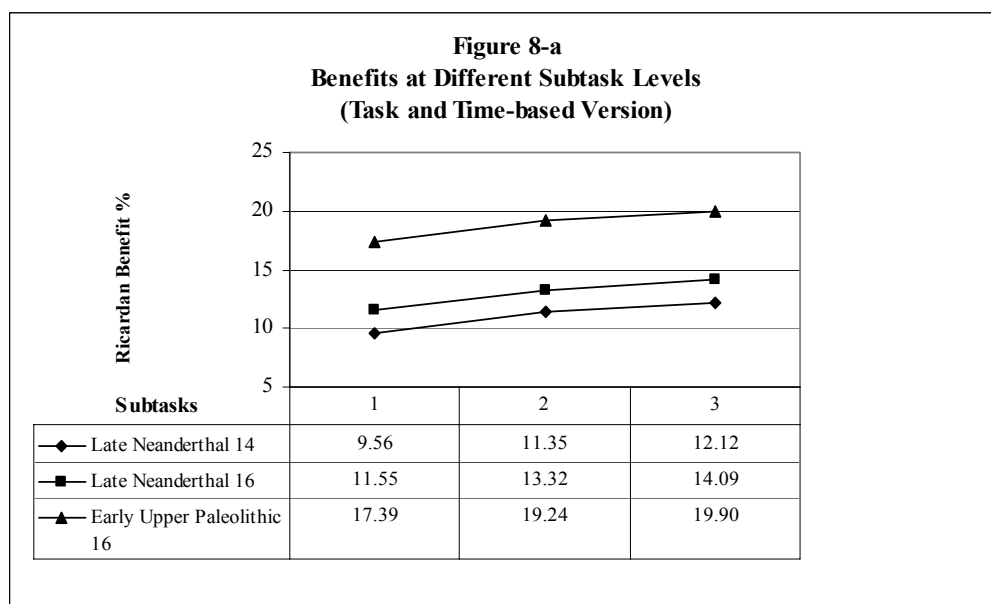
current hunter-gatherer groups, childcare activities seem to be the most significant factor determining the female role. Based on the assertion that the division of labor is determined by the degree to which the task done is compatible with childcare, as suggested by Brown (1970), female roles are arbitrarily assigned to those individuals, who, as a result of the random skill assignments, are most skilled in childcare activities. These data on division of labor by gender are *Homo-sapiens*-centric, and are based on current hunter-gatherer groups living in high latitudes, where, in particular, food gathering and clothing activities are critical swing female roles from season to season.

This data is considered the least worthy of confidence because of its anecdotal source and derivation. The application of sex roles to the model is also questionable since the existence of gender specific behaviors among these late Pleistocene groups are subject to considerable debate (Isaac 1978; Binford 1985; Ruff 1987; Kuhn and Stiner 2006). There is little direct evidence for division of labor by gender in the archaeological record although morphological data, particularly in reference to the upper limbs, and physiological data would indicate that Neanderthals and Upper Paleolithic humans are indistinguishable in terms of division of labor by sex (Ruff 1987). Despite these reservations, I use the gender allocations to provide the input for the third gender-based version of the model that is used for comparison purposes. The test results are shown in Table 8-5 at the end of this section.

2.5.4 Subtask Version

Since it is difficult to determine to what level tasks might have been specialized, I execute version that incorporates subtasks in the suite of activities that are susceptible to division of labor by skill. The tasks identified from the prehistoric record may well have included subtask components that themselves might have been outsourced to the most skilled individual. For example, hunting may involve specialists in tracking, pursuit and kill. Food preparation may differentiate between gross butchery and the fine division of meat, as suggested by the disposal of faunal remains. This subtasks level of specialization is observed in bead making at Castel-merle (White 1989a) and might well have applied to other chores.

I have therefore executed the task-and-time based model assigning one, two, and three subtasks for each task identified in Table 8-2 and 8-3 for late Neanderthals and early Upper Paleolithic humans to determine if the number of total tasks affects the ratio of benefits between the two populations. This is the subtask-based version. The test results are shown in Figure 8-a below.



These results indicate that benefits improve as the number of tasks increases but that the relative difference in benefits between the two populations declines only slightly, if both populations specialize at the same subtasks level. On the other hand, if the early Upper Paleolithic humans took specialization down to a finer subtasks level than Neanderthals the difference would have been magnified. Since the extent of specialization in either population cannot be determined at this time, it is parsimonious to assume that the tasks identified in the analysis are not further divided into subtasks for both populations. For all future tests, I assume that the task repertoire (with no subtasks) is a fair representation of what functions might have been shared.

v. Comparison of Results from Annualized Versions

Results for these four versions are summarized in Table 8-6 below.

Table 8-6 Mean Ricardan Benefits using Annualized Data

	Skill Spread	Task-based Version 1 ^a		Task and Time-based Version 2 ^b		Gender-based Version 3 ^c		Task-based with three Subtasks 4 ^b	
		Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Early Neanderthal	16	12.42	1.86	10.91	0.93	6.72	4.17	-	-
Late Neanderthal	16	12.69	1.81	11.48	0.94	7.29	3.49	14.09	0.69
Early Upper Paleolithic	16	18.35	1.79	17.40	1.29	14.10	2.41	19.90	0.98
Middle Upper Paleolithic	16	21.01	1.943	20.03	1.50	17.11	3.198	-	-
<u>Late Neanderthal</u> EUP		69%		66%		52%		71%	
Late Neanderthal^d	14	10.65	1.54	9.52	0.80	5.75	3.39	12.12	0.56
<u>Late Neanderthal^d</u> EUP		58%		55%		41%		61%	

Notes to Table 8-6

- a. Task data derived from prehistoric record only
- b. Task data from prehistoric record with activity weights derived from ethnographic record
- c. Task data from prehistoric record with activity weights and gender assignments derived from ethnographic record
- d. Test of Late Neanderthals with narrower skill spread of 14.

Since the two intermediate or contemporaneous groups are central to this study, I have focused attention on these two groups. The results indicate that each version

generates slightly different mean Ricardan benefits. For the task-based and task-and-time based versions late Neanderthals benefits achieve between 66-69% of the benefit achieved by early Upper Paleolithic humans when both have similar skill spreads. However, if both populations specialized at the subtask level, Neanderthals would achieve about 70% of the benefits of Upper Paleolithic humans. If the Neanderthals are assumed to have lower skill spreads of 14, they achieve only 55-58% of the benefits of the early Upper Paleolithic humans. The task- and time-based version generates intermediate results and reflects data with a reasonable confidence level. I have based most of the additional tests on this version.

The gender-based version gives a significantly different result. For all populations, the level of benefit is considerably reduced from that of the other versions. Benefits are down to 7.29% for late Neanderthals and 14.10% for early Upper Paleolithic humans, both at skill spread of 16. When compared to the task- and time-based version this indicates a minimal reduction of 36% ($[11.48-7.29] / 11.48$) and 19% ($[17.40-14.10] / 17.40$), respectively. Relative benefits for Neanderthals at a skill spread of 14 show a comparable reduction. This suggests that assigning work based strictly on gender lines instead of based on skill level would be an expensive option, especially for Neanderthals and even early Upper Paleolithic humans in these small groups and under stressful conditions.

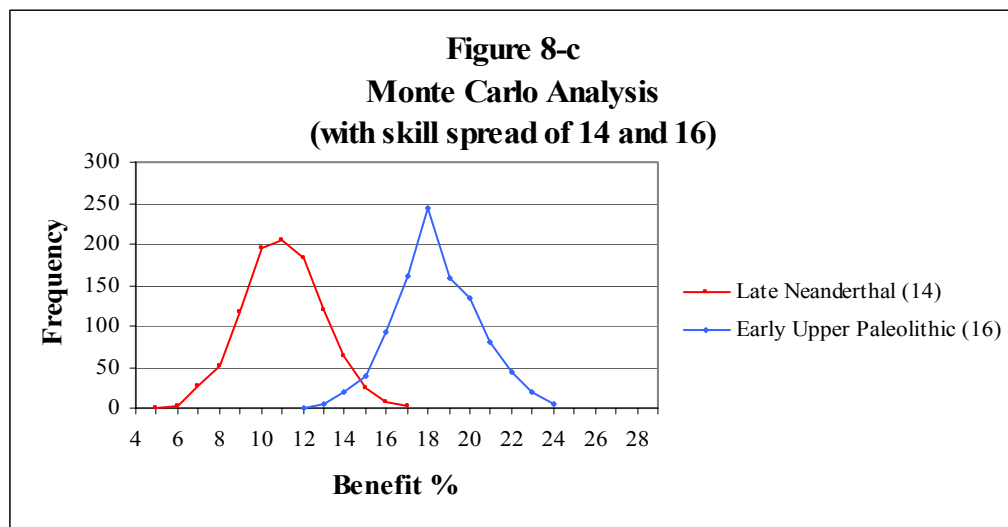
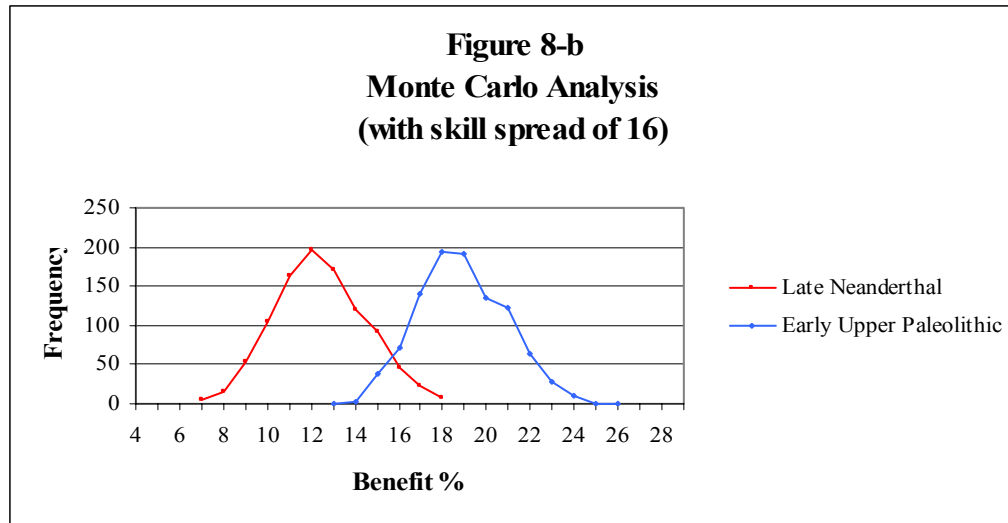
8.6 Mean Ricardan Benefits using Modified Annualized Data

Although the data collected from the record seems to be fairly consistent with other analyses of Neanderthal and early Upper Paleolithic activities, there is clearly some margin of error in my estimates. Both ethnographic and prehistoric data is sparse

and sourced from widely dispersed geographic areas. In order to test variances in parameter values, two further tests are performed: one a random simulation and one an arbitrary skewing of data to test sensitivity to changes in group size, task repertoire and skill spread values.

i. Monte Carlo Simulation

There is inevitably a level of uncertainty in the parameter data assembled from the ethnographic or prehistoric record. The Monte Carlo simulation addresses this issue by repeatedly sampling values on either side of the annualized values from a range of possibilities as defined by a selected distribution curve. This simulation executes the task-based version for late Neanderthals and early Upper Paleolithic humans and uses values, generated by a random, normal distribution of within 25% of the annualized parameter values determined from this analysis (Tables 8-2 and 8-3 above). Group size and task values are limited to integers within the 25% range, but skill spread values are continuous. One thousand passes were executed, each with its own permutation of the three parameter values. This simulation generates probabilistic results which show a wider variance from the mean among the one thousand groups tested Figure 8-b compares the two populations with equal skill spreads of 16. Figure 8-c shows comparisons of populations with differing skill spreads.



Although the mean Ricardan benefits for Neanderthal and early Upper Paleolithic humans remain close to those from the earlier deterministic versions (12.39% and 18.93%, respectively), the distributions indicates a cross-over at about 15-16% at the fringe between the two populations. At this cross-over point, one would expect to find Neanderthals groups that exhibit some of the traits of early modern human behavior, as observed from symbolic artifacts at Châtelperron and more sophisticated domestic arrangements at Abric Romaní. Also, one finds early modern

human groups that appear to retain some of the Neanderthal behaviors, such as in the Streletskaya Culture at Kostenki XII.

ii. Midpoint Sensitivity Analysis

A Midpoint Sensitivity analysis is executed using only task-based data from the two, intermediate groups. This version is intended to examine the differences between the two contemporaneous groups, the late Neanderthals and early Upper Paleolithic humans. These groups are the most germane for this study, and the gap between them, in terms of annualized parameter values is the widest (Tables 8-2 and 8-3). The Monte Carlo version addressed the uncertainty in parameter values by sampling within a normal distribution, equally distributed on either side of the annualized parameter values. However, the degree of uncertainty in parameter values may be skewed in one direction. There is a large gap between late Neanderthal and early Upper Paleolithic values for group size and task parameters; these gaps might be a reflection of species-wide differences or a reflection of the paucity of the prehistoric record. One could reasonably argue that Neanderthal tasks are underestimated since the record is older and less well preserved, or that the early Upper Paleolithic and middle Upper Paleolithic records might have been conflated. This might apply especially to tool making and shelter construction, since the wooden implements and artifacts from Neanderthal woodworkers are rarely preserved in the archaeological record, and there is some debate about the extent of shelter construction in both populations.

I collected data for middle Upper Paleolithic populations as a benchmark to gauge the sequence from late Neanderthal through early Upper Paleolithic behaviors. Although there is a clear discontinuity between Neanderthal and early Upper Paleolithic

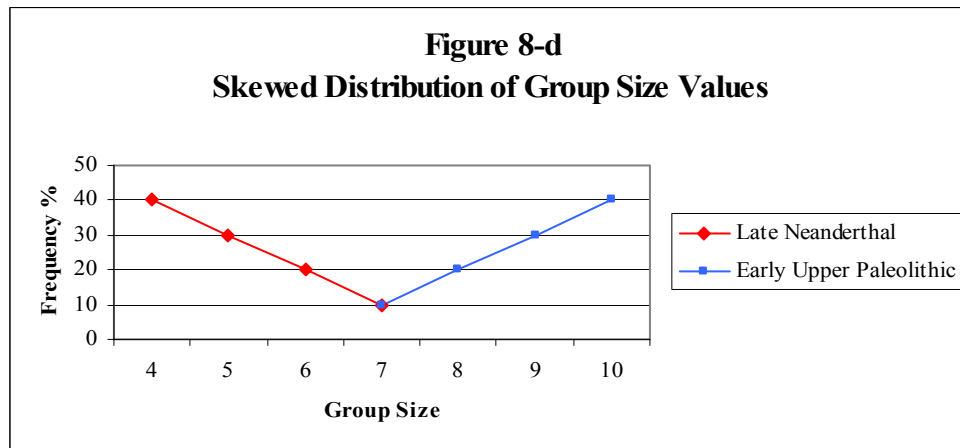
behaviors, as evidenced by symbolic representation, Hoffecker (2005) argues that, as far as technology and economics is concerned, early Upper Paleolithic technologies are primitive when compared to later Upper Paleolithic societies. He posits that the early Upper Paleolithic occupies an intermediate position between the Mousterian and these later societies. If the task repertoire in the annualized data is a reasonable reflection of technology, then the total number of tasks for Neanderthals, early Upper Paleolithic, and middle Upper Paleolithic groups at 35, 75 and 87, respectively, shows a definite skew towards the middle Upper Paleolithic and away from the Neanderthal values. A similar degree of skew might apply to the local group size parameter.

Therefore, for this Midpoint Sensitivity analysis I deliberately skewed the annualized parameter values for group size and tasks towards the midpoint of the values of the two populations in order to reduce the gap between the contemporaneous groups. The midpoint in parameter values between the two contemporaneous groups is used as the upper extreme value for late Neanderthals and as the lower extreme value for early Upper Paleolithic humans. For skill variation, on the other hand, the uncertainty associated with Neanderthal skill variation and diversity might suggest skewing the skill spread parameter downwards. For Neanderthal skill spread I define 14 as the lower and 16 as the upper limit of the range tested.

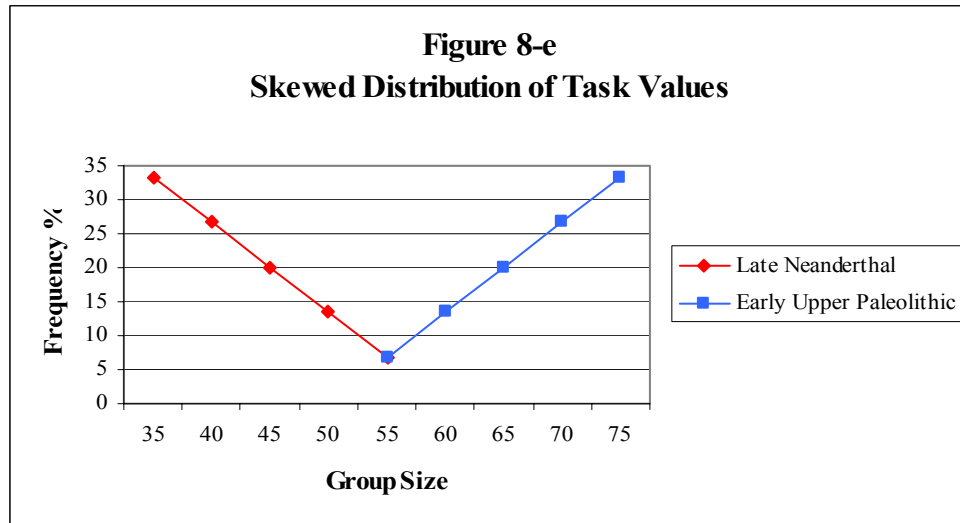
I use the triangle distribution methodology as described by www.decisioneering.com/monte-carlo-simulation.html to define the shape of the distribution curve. The triangle method allows for a frequency distribution of test parameter values around a peak at the annualized or most probable value and a probability distribution skewed in either direction. The slope of the distribution is

defined by the number of intervals selected for sampling. Here, I apply a uni-directional skew (a slope towards the midpoint).

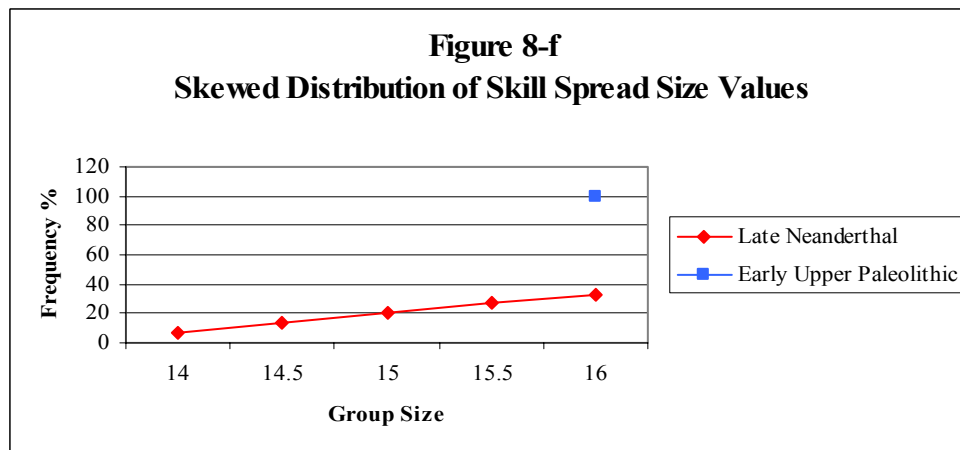
For group size, the midpoint is 7 and the range for Neanderthals is from 4 to 7, and for early Upper Paleolithic humans from 7 to 10. The frequency distribution determined by the triangle method means that there is a 40% chance that the Neanderthal value is 4, a 30% chance that it is 5, a 20% chance that the value is 6, and a 10% chance that the group size is 7. For the early Upper Paleolithic group size, the probabilities range from 10% at 7 to 40% at 10. This is illustrated in Figure 8-d below.



For tasks, the midpoint is 55, with ranges in increments of 5 from 35 to 55 for Neanderthals, and 55 to 35 for early Upper Paleolithic humans. The frequency for Neanderthals decreases from a maximum 33% at 35 down to 6.7% at 55, and for early Upper Paleolithic humans from 33.3% at 75 down to 6.7% at 55 (Figure 8-e). Since the slope of the curve is defined by the number of increments, these frequencies are lower than those for group size because the range of increments is larger.

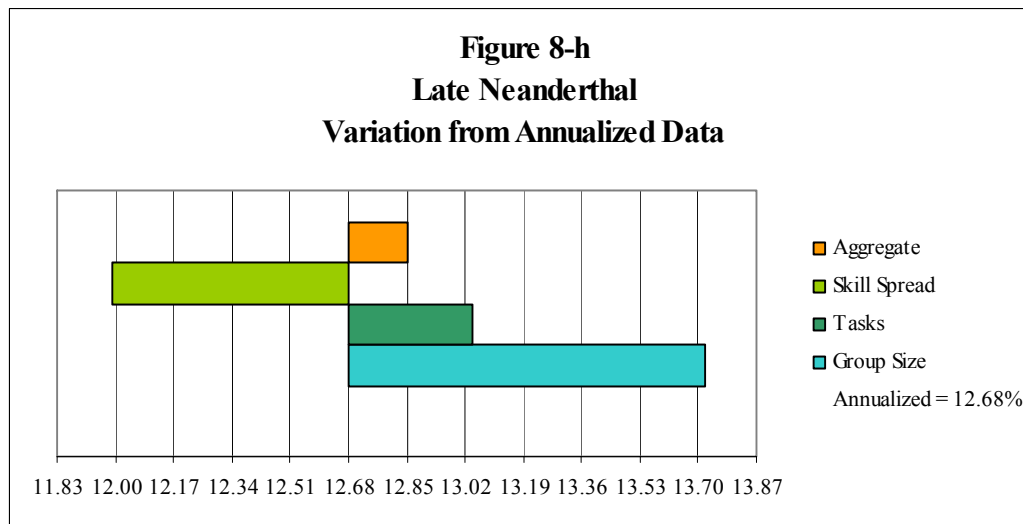
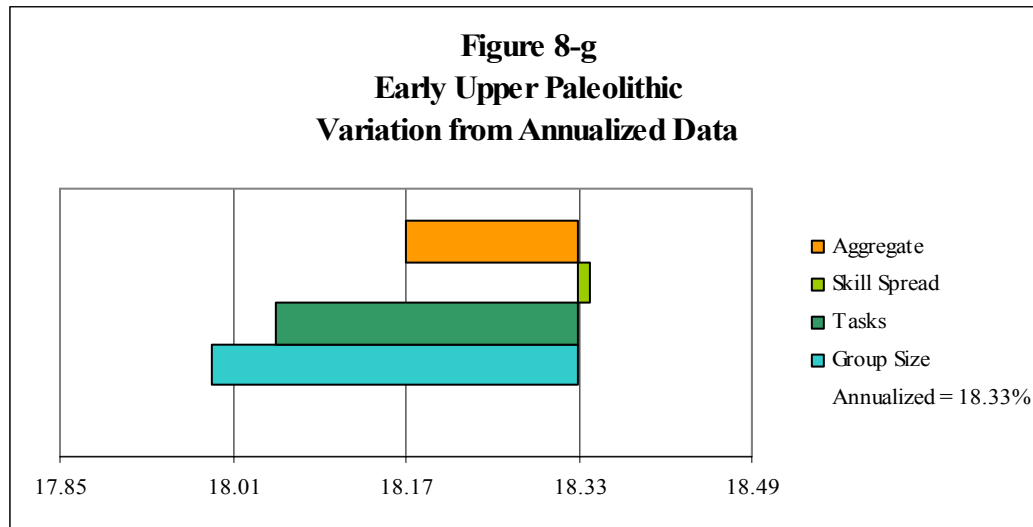


For Neanderthal skill spreads, the modal value is 16 and the distribution ranges down to a value of 14 in increments of 0.5 - a frequency of 33.3% at 16 down to a frequency of 6.7% at 14. Skill spreads for Upper Paleolithic humans are held constant at 16 (Figure 8-f).



By narrowing the differences between group size and task parameters and by testing probability frequencies for lower Neanderthal skill spreads, I test how the differences in mean Ricardo benefit between late Neanderthal and early Upper Paleolithic humans respond to smoothing of the annualized parameter input between the two populations. During this process, each parameter is varied within the ranges

defined above, while the other two parameters remain constant at the annualized value. Thus, results show the range of variation for each parameter independently. Aggregate results show the combined effect. The following figures (8-g and 8-h) indicate the sensitivity of each modified parameter in comparison to the annualized parameters used in all other versions of execution.



As is to be expected from these skewed distributions, the gap between results for late Neanderthal and early Upper Paleolithic humans is reduced. The early Upper Paleolithic data (Figure 8-g) indicates that, in aggregate, the benefits are reduced by

0.16% to 18.17% as a result of group size and task parameter changes. A reduction in the technology component (tasks) alone would lower the Upper Paleolithic benefit by 0.28% to 18.05%. The Neanderthal benefit (Figure 8-h) is increased by 0.17% driven by a group size changes, offset by reductions from skill spread changes. An increase in the technology component (number of tasks) would increase the late Neanderthal mean benefit by 0.36% to 13.04%, or 72% of the Upper Paleolithic task value.

This approach deliberately skews parameter data in the most conservative manner, at least for Neanderthals, but this Midpoint Sensitivity analysis shows that the difference between the early Upper Paleolithic and late Neanderthal results are not significantly altered by applying these skewed, modified parameter. In aggregate, the Neanderthals, with benefits of 12.85%, would achieve 71% of the benefits of Upper Paleolithic humans with benefits of 18.17%.

8.7 Analysis of Mean Ricardan Benefits Results using Annualized and Modified Annualized Data

i. Comparison between Versions

The average rankings from all mean Ricardan benefit versions of the Transition model are consistent with the findings from the Prototype; in all cases larger groups, with more tasks to share, and greater skill diversity, achieve greater benefits from economic specialization and exchange. The results, with the exception of the gender-based version, suggest that, at best, late Neanderthals would have been able to achieve mean Ricardan benefits at the level of 65-71% of those achieved by early Upper Paleolithic humans. With less variation in skill spreads their achievement would be significantly less, as shown at the foot of Table 8-7. These ratios are fairly consistent across all versions of execution, shown in Table 8-7.

Table 8-7 Comparison of Mean Benefits and Variance with Annualized Data and Modified Annualized Data

	Skill Spread	Task-based Version		Task and Time-based Version		Gender-based Version		Monte Carlo Simulation		Sensitivity Analysis
		Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Aggregate
Early Neanderthal	16	12.42	1.86	10.91	0.93	6.72	4.17	-	-	
Late Neanderthal	16	12.69	1.81	11.48	0.94	7.29	3.49	12.39	2.07	12.85
Early Upper Paleolithic	16	18.35	1.79	17.40	1.29	14.10	2.41	18.93	2.01	18.17
Middle Upper Paleolithic	16	21.01	1.943	20.03	1.50	17.11	3.198			
<u>Late Neanderthal EUP</u>		69%		66%		52%		65%		71%
Late Neanderthal	14	10.65	1.54	9.52	0.80	5.75	3.39	11.03	1.87	-
<u>Late Neanderthal EUP</u>		58%		55%		41%		58%		-

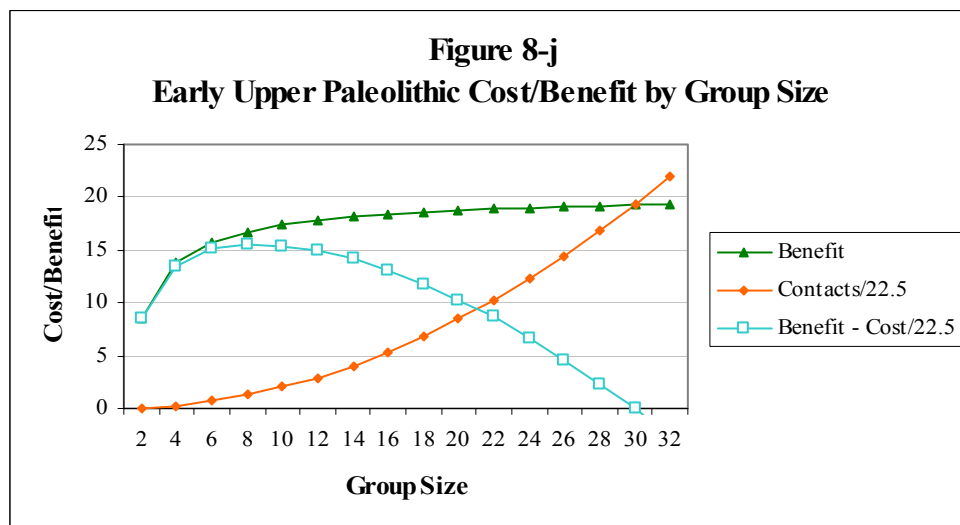
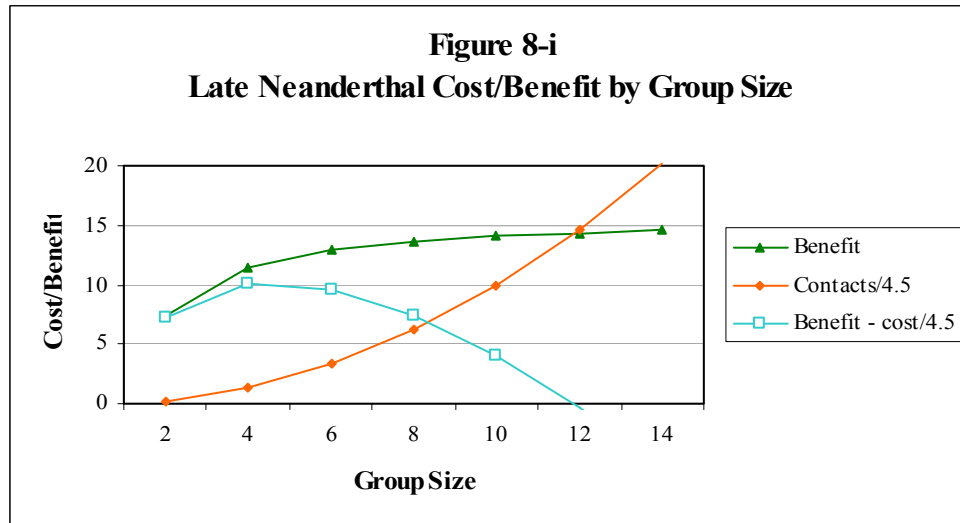
Gender-based results show a significant reduction in the mean Ricardan benefits achieved by both groups. This indicates that there are significant costs associated with sexual division of labor for both groups: a reduction in benefit, below that achieved without sexual division of labor, of about 40% for Neanderthals and close to 20% for early Upper Paleolithic humans. This suggests that, for early Upper Paleolithic humans, sexual division of labor was probably not a habitual behavior, especially in stressful periods, and, for late Neanderthals, the additional costs might inhibit such practices completely. However, if Upper Paleolithic humans did practice division of labor by gender and Neanderthals did not, Neanderthals would have been able to achieve about 80% of the Ricardan benefit of Upper Paleolithic humans: a considerable improvement over the 66-71% achieved without sexual division of labor.

ii. Congruity Test of Mean Benefit Results

At this point it is reasonable to question whether the parameter input to the model is internally compatible and consistent with economic interests of the individuals

in the group. In each population, one would expect group size to be optimized for the range of critical tasks to be accomplished. In order to test this, I executed a series of tests of the time-and-task based version for the late Neanderthal and early Upper Paleolithic populations in which group size was varied while the task repertoire and skill spreads are held constant. The law of diminishing returns predicts that the incremental benefit of adding an individual to the group is relatively high when the group is small but declines as the group increases in size. This effect is shown by the benefit curve for late Neanderthal and early Upper Paleolithic groups in Figures 8-i and 8-j.

The slope of the cost curve is dependent on the type of group being considered: social, foraging, feeding, etc (Wrangham, Gittleman et al. 1993). For social groups it is a function of the number of inter-relationships within the group as defined by: *Contacts* = $(m^2 - m)/2$, where m is the number of group members. This formula defines the basic shape of the cost curve but not its placement. Optimization theory suggests that the maximum group size is limited to the point at which total costs equal total benefits. The group size is at optimum when the cost of adding a new member equals the increase in benefit. Beyond that point there are negative returns from adding each new member to the group (Smith 1985; Cashdan 1992). This analysis indicates that the maximum (or aggregate) group size for late Neanderthals is ten and for early Upper Paleolithic humans is thirty. Thus, the placement of the cost curve is determined by selecting that cost curve that intersects the benefit curve at the maximum group size as shown in Figures 8-i and 8-j.



Significantly, the figures above demonstrate that the social costs for late Neanderthals are number of contacts divided by a factor of 22.5 and for early Upper Paleolithic humans are number of contacts divided by 4.5. Thus it seems that Neanderthal costs are five times that of Upper Paleolithic humans. The higher cost of maintaining stable cooperative, group relationships for Neanderthals raises an interesting question that lies beyond the scope of this dissertation, but suggests future avenues of research in prehistoric economics.

Finally, the benefit-minus-cost curve, shown in the figures, indicates that maximum benefit is achieved at local group size for both populations. This suggests that the task and group size data are compatible and congruent.

If these groups congregate for other than economic reasons then these social costs are incurred whether or not economic cooperation occurs. In this case, the mean Ricardan benefits calculated here represent the incremental gain from cooperation. If, however, these groups assemble solely for economic reasons then the mean Ricardan benefits at local group sizes would be partially offset by the social costs, which reduce the mean benefit by 11.5% in both cases. In this case, the net benefits for both populations would be reduced accordingly: to 10.16% for the Neanderthal and 15.42% for the Upper Paleolithic groups. Neanderthals continue to achieve 2/3 the potential benefits of the Upper Paleolithic counterparts.

8.8 Mean Ricardan Benefits as Mediation for the Challenges Facing Small, Isolated Groups in the Late Pleistocene

Economic cooperative practices involve costs associated with reciprocal altruism and the maintenance of an equitable allotment of labor and distribution of outputs, and such cooperation would not have evolved had it not provided benefits to survival, and ultimately reproductive fitness, in excess of the costs. I have identified two key challenges to survival that small groups in the late Pleistocene faced.

Economic cooperation within groups might have mediated each of these challenges.

Both groups of humans were living in fairly isolated, small groups and were close to the edge of survival during these harsh times. Cooperative benefits would have benefited early humans in two significant ways. First, it might have provided the additional productive time and resources to perform the direct and indirect activities

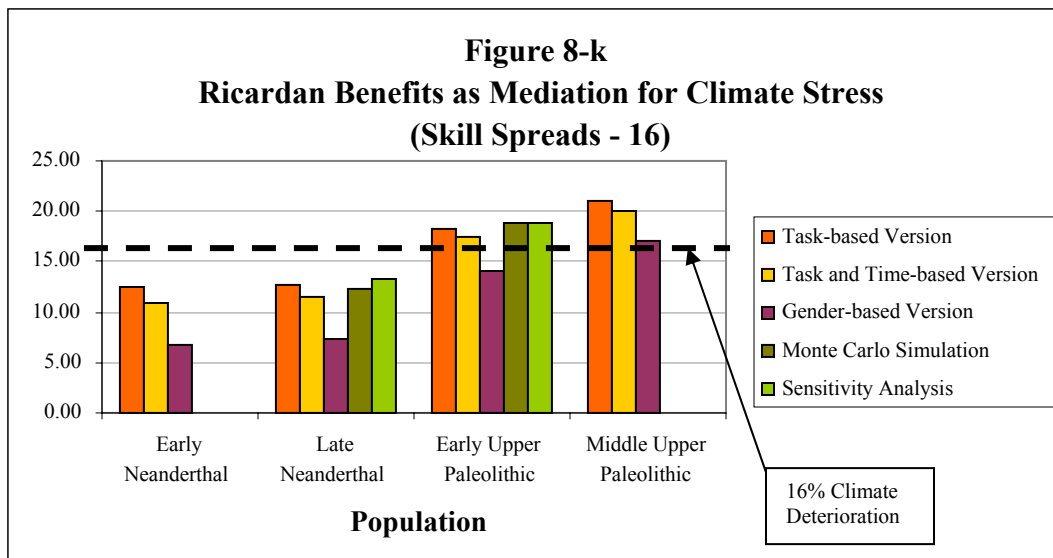
critical to survival during the harshest of times. Second, it might have provided the additional time to support injured and sick members of the group and their dependents and thus maintain the integrity of the small group.

i. Mean Ricardan Benefit as a Mediator for Climate Stress

The first challenge addressed is the response to climate fluctuations. This ecological variable appears to be most significant and unique to this period. Climate data is based on information derived from Greenland ice cores and terrestrial cores from Europe and other high latitude sites (Chapter 7). The data shows general trends, but is not sufficiently fined-grained to be directly associated with specific sites or localities. However, the data show a rapidly deteriorating climate with increasing turbulence and volatility during the period across Europe. It is the low frequency climate oscillations, as seen in OIS 3 in particular, that are used as the measure for climate stress. I argue that this is the driving force for increases in participation in cooperative behavior.

Climate stress escalated during the latter part of OIS 3, peaked at around 30 ka, and climate is estimated to have deteriorated by 6° C during this period, when measured in terms of vegetation response. In human response terms, this represents a decline of 16% to 22% (Chapter 7). Such a deterioration would have severely limited the time available for the performance of critical activities, either because stormy and inclement weather would have limited external activities, or because of the impact of the harsh climate on the availability of vegetal and animal food and fuel resources. The effects on mean Ricardan benefits of a 16% reduction in time available for daily activities are shown by the dotted line on the Figure 8-m. Comparison between the increased time made available through economic cooperation and the reduced time implied by extreme

climate deterioration suggests that mean Ricardan benefits might have been sufficient to permit the early Upper Paleolithic humans barely to survive the most severe deterioration in climate. The Neanderthals would have survived only in a much less severe climate. The figure below, using data from Table 8-7, shows that early Upper Paleolithic humans, without sexual division of labor, would just have been able to survive a deterioration of 16% in environmental conditions. On the other hand, Neanderthals would have succumbed at the 12-13% level even when modern human skill spreads of 16 are applied. This finding is consistent with the migration and settlement patterns as extracted from the Stage 3 database (Chapter 7). Modern humans abandoned sites in northern Europe only at the height of the last glaciaton.



ii. Mean Ricardan Benefit as Mediation for Incapacitation of One Group Member

Another challenge observed in current hunter-gatherer groups is the high rate of mortality, injury or illness within small groups. The most serious challenge is the temporary incapacitation of a productive member of the local group. In this case, the rest of the group may decide to abandon the incapacitated member, resulting in a more

permanent loss. Alternatively, the able members might decide to support that individual and his/her dependents in the anticipation that he/she would soon be able return to productive activities. From the task- and time-based version, Table 8-8 shows that, with the incapacitation of one, productive adult, the costs associated with this support are quite expensive.

Table 8-8 Ricardan Benefits as Mediation for Incapacitation of One Group Member

	Local Group Size (adults/total)	Ricardan benefit with full complement	Predicted additional cost for each active member	Net Cost/benefit after Ricardan cooperation
Late Neanderthal	4/10	11.52	33.33	-26.20
Early Upper Paleolithic	10/25	17.44	11.11	7.24

The Transition model indicates that mean Ricardan benefits in larger local groups would permit the group to better withstand the loss of one individual through incapacitation: economic cooperation permits a larger group to take care of an incapacitated top provider, while still achieving some net Ricardan benefits. That is not the case for smaller local groups where the incapacitation of one member represents a significant reduction in the total productive resources with no reduction in the total needs. As shown above, early Upper Paleolithic humans manage to achieve benefits of 7.24% with the incapacitation of one individual, while still providing support for the incapacitated and dependents. This is despite each active individual having to bear an additional cost of 11%, since the full work load is now divided among nine individuals instead of the full complement of ten group members. However, with Neanderthals the situation is quite different. With a Neanderthal local group size of only four productive adults, each adult normally contributes approximately 25% of the requirements for the entire group of ten. The loss of one productive member means that each member's

contribution is increased by 33% (i.e. from 25% to 33% of the total output required) necessary to achieve the same level of production. This increase is somewhat ameliorated by the mean Ricardan benefits, which reduce the cost to 26.20%, but nevertheless eliminates all benefit. This suggests that early Upper Paleolithic humans would be able to care for the sick under moderate but not the most severe conditions. It is unlikely that ecological conditions would improve by 26% in order to allow for the additional time necessary to provide care to a sick member in the small Neanderthal group. This finding is in conflict with the conclusions about Neanderthal care-giving arising from the analysis of the healed trauma observed in the old man of St Césaire and Shanidar I skeletal remains (Trinkaus 1983), and I explore possible scenarios for this in the last Chapter - Discussion.

The complete loss or death of one member from the local group is only slightly less onerous since it still involves a greater reduction in productive resources (adult labor proportional to the size of the adult group), than needs (required output proportional to the total group size, including infants and juveniles). The loss of a one productive member is slightly less burdensome than caring for an incapacitated individual: the lost member does not need any further support but the dependents do. Nevertheless, such a loss is still more critical to a smaller group than a larger one. In this case, it would be incumbent on the group to replace the lost member as soon as possible in order to reinstate the economic integrity of the group. In either case, the reduction in group size and consequent loss in benefits reduces the buffer against external challenges.

In summary, both groups of humans, in fairly isolated, small, local groups, were living close to the edge of survival during these harsh times. Cooperative benefits would have benefited humans in two significant ways. First, it might have provided additional productive time and resources to perform those direct and indirect activities that were critical to survival in the most stressful periods during both high and low frequency climate fluctuations. Second, in less stressful times, it might have provided a buffer to overcome injury and mortality of a member of the groups and thus maintain the integrity of the group

8.9 Variances from the Mean Ricardan Benefits

There are several ways to examine within-group variances in individual performance. The standard deviations, shown in Table 8-9, represent the mean of the deviations between individuals within each of the one thousand groups in the mean Ricardan benefits tests and thus give an approximation of the average range of variation among individuals in each population. Ninety-five percent of the time individual performance will fall within two standard deviations, in the ranges as shown below.

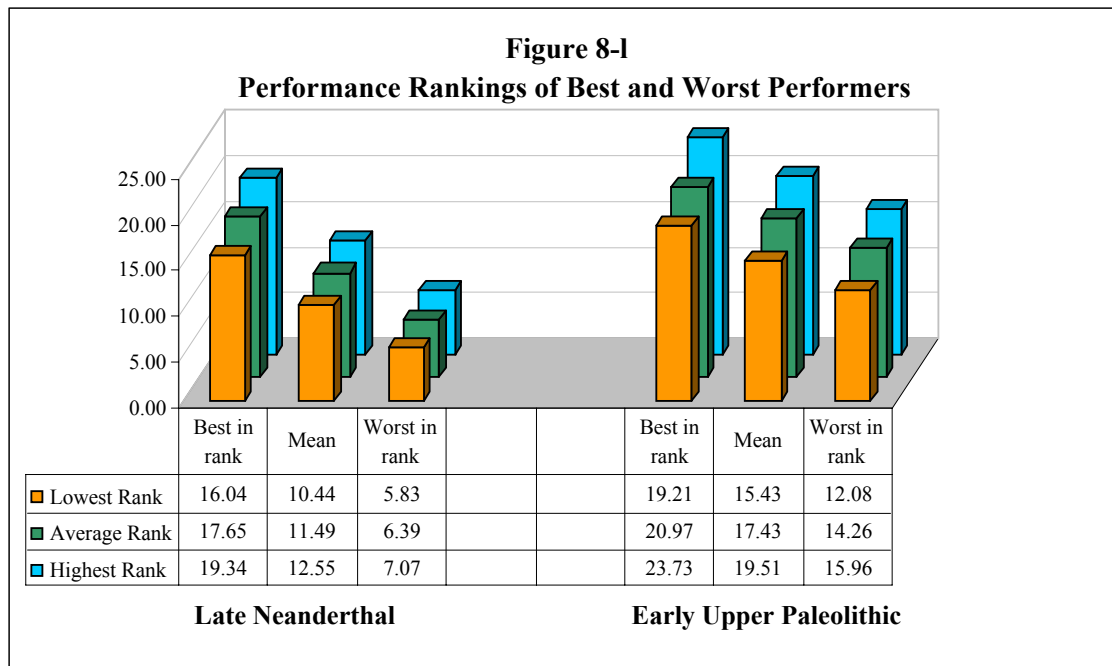
Table 8-9 Range of Within-Group Individual Variation

	Skill Spread	Task-based version	Task and time-based version	Gender-based version	Monte Carlo simulation
Late Neanderthal	16	12.69% ± 3.62	11.48% ± 1.84	7.29% ± 6.98	12.39% ± 4.14
Early Upper Paleolithic	16	18.35% ± 3.58	17.40% ± 2.58	14.10% ± 4.82	18.93% ± 4.02

The standard deviations demonstrate that in the deterministic, task- and task-and time-based versions there is no overlap between Neanderthal and early modern human achievements. In the Monte Carlo simulation, with a spread of parameter values of 25% around the annualized data, there is some overlap, as there is with the gender-

based version. The gender version also indicates the standard deviations show greater variability and that at two standard deviations below the mean, almost all Neanderthal benefits are eliminated: further indication that Neanderthals may not have participated in economic cooperative activities.

An alternate way of viewing individual variation in performance is to rank individuals in each of the one thousand groups based on their performance, and then identify the mean value of all the lowest and all the highest performers as well as the absolute best and worst performance for that group. Figure 8-n shows the results of executing the time-and task-based version for 1,000 groups of late Neanderthals and early Upper Paleolithic humans, both at a skill spread of 16.



A comparison of the absolute worst and absolute best performance for each population gives the outside range of performance results – for Neanderthals this ranges from 5.83% at worst to 19.34% at best and for modern humans from 12.08% to 23.73%. However, these outliers may represent a one-time event, outside of the two standard

deviation range, and a more reasonable comparison is to take the mean within all ranks, which ranges from 6.39% to 17.65% with an average of 11.49% for Neanderthals, and 14.26% to 20.97% with an average of 17.43% for modern humans. For early Upper Paleolithic humans these ranges are narrower than those determined by the standard deviation but for Neanderthals they are somewhat broader.

In either event, both these views suggest that the averages conceal quite a considerable variation between different individuals in different groups, which could seriously affect individual survival and is not taken into account when considering mean Ricardan benefits and average survival rates. The ethnographic data records only average annual time allocations and the prehistoric data can only provide an overall picture of average outputs over time as represented by the artifactual remains and archaeological features. All of the mean Ricardan benefits are derived from the averages of one thousand groups each with unique skill sets, but operating in a static environment based on this limited annualized data. The annualized data makes no allowance for seasonal or periodic changes in task loads and roles that would typically occur over the productive life of an individual. Thus, average rankings and standard deviation variances in such a static environment do not give a clear picture of what is happening to one individual in any one specific season or year.

8.10 Results - Individual Threshold Tests using Seasonal Data

When dealing with the probability of survival or extinction what counts is not mean Ricardan benefits, but whether each individual is able to survive each year by generating individual Ricardan benefits sufficient to offset the worst seasonal conditions when they occur. For survival, it is the extremes that are important. The threshold tests

attempt to simulate variations in ecological conditions that provide insight into how individual Ricardan benefits might affect survival and extinction year-by-year. The threshold versions involve a series of additional tests addressing inter-individual variation over several seasons and time periods, where individual skill assignments are held constant but seasonal task roles and task loads vary for each season.

First, ethnographic records indicate that there are large swings in roles and responsibilities, particularly for females, between gathering activities in warmer climes and clothing manufacture in colder times. Second, not only do roles change but also groups tend to aggregate around scarce or stored supplies in the wintertime. The practice of congregating in larger groups during periods of scarcity or when resources are highly and seasonally clustered might have been an effective way of increasing Ricardan returns. These additional fitness benefits would be especially significant during these most stressful periods, and the ethnographic record indicates that there are significant changes in group size as well as tasks and gender roles from season to season in higher latitudes. Third, annual climate variation is unpredictable and stochastic. Changes in ecological conditions mean that task loads and priorities change. A skill that is valuable in one context may be of little value in another, and thus individual rankings in performance will change from season to season. Periodic, year-to-year changes in task priorities and loads resulting from changes in ecological conditions are simulated by applying variable task loads for each period, based on variance levels recorded from twentieth-century NOAA weather reports (Chapter 7).

These three conditions, seasonal roles, seasonal aggregation, and seasonal climate variation, most critically affect inter-individual variability and efficiency in the

short term and are hidden in the mean Ricardan benefits. In order to assess the results of, and response to, periodic and seasonal climate changes in any one group it is necessary to look at the results one season at a time. Individual and group survival over time is modeled using selected thresholds of climate deterioration.

A series of three tests examine survival and extinction thresholds over a 20 year period. Further tests address the benefits of aggregation and how that might improve survival prospects. And finally, this version zooms in on one focal set of four individuals each from late Neanderthal and early Upper Paleolithic human populations. This view is not representative of the long-term overall impact but does provide insight into what pressures individuals within the population might have experienced from season to season. Significantly, it illustrates how seasonal and period fluctuations probably affected relative individual performances within the group over several years, and how these might have been mediated by cooperation through delayed reciprocity.

i. Equilibrium and Extinction Thresholds in Dynamic Seasonal Settings

A more dynamic environment, incorporating several years and seasons with periodic seasonal variation, is likely to present a more meaningful picture of individual variation in performance from season to season and year to year. In order to exemplify a seasonally, and periodically changing environment, I developed the threshold version that utilizes the seasonal role data and incorporates stochastic variations to simulate changes in task loads over periodic cycles on the basis that humans modify their workloads in response to high frequency climate fluctuations. It is a modification of the time-and-task based version and is here applied to late Neanderthal and early Upper Paleolithic groups only.

Winter and summer seasonal activities are modeled on the ethnographic data from high latitude groups: winter, including spring, reflects the season of scarce resources, and summer, including fall, reflects the period of more widely distributed and abundant resources, as experienced in higher latitudes. Winter seasonal changes in group size, time available, and activities are shown in Tables 8-2 to 8-3. Summer values are computed by subtracting winter data from the annualized data. In the summertime extra time and tasks are included so as to fulfill all annual critical, productive tasks. These seasonal changes are predicated on the fact that less time is available in high-latitude winter, and fewer outdoor activities are pursued because of inclement weather and lack of availability of and accessibility to resources, based on the reasoning outlined in Chapter 7.

High frequency, year-to-year variation in ecological conditions result in changes in the time and effort required to accomplish critical tasks, since tasks change in frequency and duration from period to period, depending on ecological changes in the distribution, accessibility, and availability of resources over the landscape. Stochastic changes in task loads for each season and period are generated to reflect the changing impact of periodic environmental variables on relative task priorities and importance. These changes are randomly generated within a range plus or minus 5% of the values computed in the annual scenarios.

This model is intended to approximate the dynamic environment that an early human might have experienced during his/her productive life. For each of the one thousand groups, twenty additional yearly cycles each with one winter and one summer season, are added to illustrate inter-individual results resulting from the variability

encountered in the very short term and within a typical productive lifespan. Individual skill levels are held constant during these periodic cycles so that is possible to examine how each individual, with the same skill set is able to cope during winter / summer and year-to-year variations in conditions. In order to examine individual survival rates in a deteriorating climate, I tested various climate-thresholds to gauge the impact on individual survival.

Threshold tests examine equilibrium and extinction climate thresholds for late Neanderthals and early Upper Paleolithic groups, the two contemporaneous groups. These tests cover twenty years with two seasons each (forty rounds). Individuals that do not achieve the level of Ricardan benefit necessary to offset climate deterioration at the end of each season perish and are eliminated from subsequent rounds. The level at which all group members survive through forty rounds, as a result of individual Ricardan benefits received, is identified as the Ricardan equilibrium threshold, and the level at which a minimal number survive is identified as the Ricardan extinction threshold.

Table 8-10 shows equilibrium levels for late Neanderthals and early Upper Paleolithic humans. It indicates that over twenty years Neanderthals, with a skill spread of 16, are able to maintain their equilibrium, in terms of maintaining population size, at a climate deterioration of 5% by utilizing the benefits from Ricardan cooperation. Equilibrium for early Upper Paleolithic humans is at the 12% level of climate deterioration. Both tests below assume that groups do not aggregate in wintertime.

Table 8-10 Equilibrium Level of Climate Deterioration

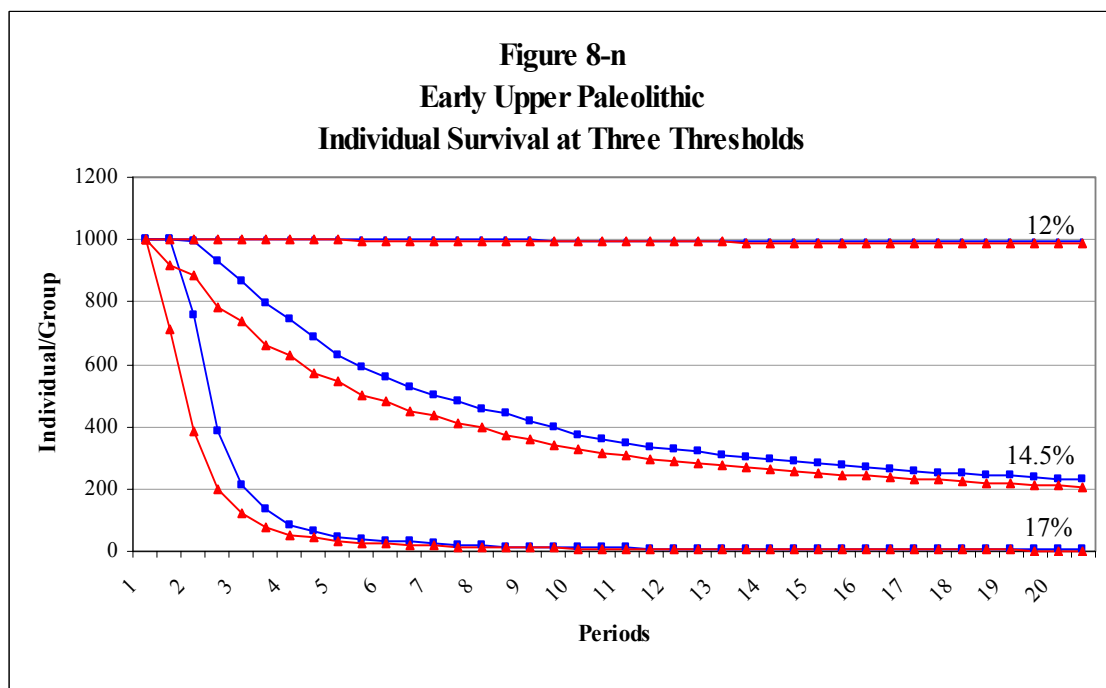
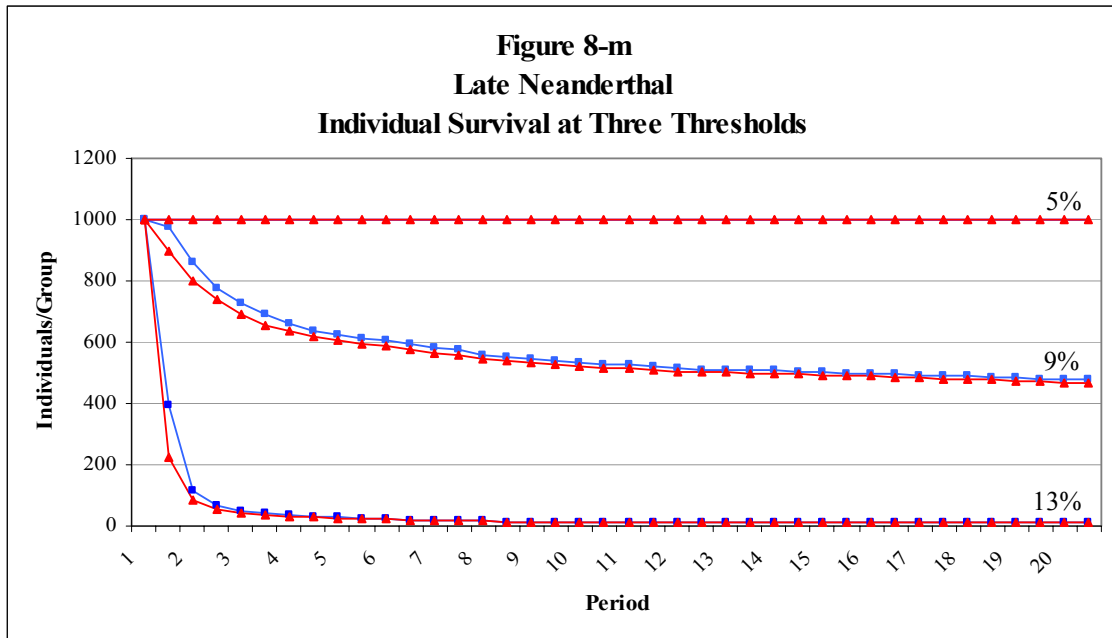
Population	Local group size	Groups at end of 20 periods	Members in all groups at end of 20 periods	Average surviving members in final groups	Mean Ricardan benefit	Ricardan equilibrium threshold
Late Neanderthal	4	993	3968	4.00	11.36	5%
Early Upper Paleolithic	10	991	9833	9.92	17.20%	12%

Table 8-11 shows where populations in both groups are close to extinction at higher levels of climate deterioration: at a threshold of 13% for Neanderthals and at 17% for modern humans.

Table 8-11 Climate Thresholds Causing Near Extinction

Population	Local group size	Groups at end of 20 periods	Individuals at end of 20 periods	Average surviving individuals in final groups	Ricardan extinction threshold
Late Neanderthal	4	13	51	3.9	13%
Early Upper Paleolithic	10	7	54	7.7	17%

The diachronic changes in surviving groups (■) and individuals (▲) are illustrated in Figures 8-m and 8-n below for thresholds at equilibrium (top line), for partial extinction (middle line), and full extinction (bottom line).



In these extinction scenarios, populations decrease through two effects. The first is that the lesser achievers perish when circumstances are unfavorable. The second is that, once a group begins to lose members, the Ricardan benefits for all remaining

members in the smaller group are reduced, and the group goes into decline and rapidly becomes extinct. This is evidenced by the fact that the average group size of those groups surviving throughout the sequence remains high. While the record is not sufficiently fine-grained to determine the precise climate thresholds that late Pleistocene groups experienced, and these stochastic exercises cannot predict the precise level of equilibrium or survival threshold, it is significant that Neanderthals, given their group size, task repertoire and skill spreads, appear to be able to withstand less than 50% of the climate stress of their early Upper Paleolithic human counterparts. In both cases, the equilibrium levels identified above are significantly less than the levels based on mean Ricardan benefits identified earlier in this paper.

ii. The Economic Benefits of Aggregation and Dispersal

Ethnographic evidence indicates that, in some societies, local groups join with other local groups and congregate during seasons of scarce or seasonally clustered resources; a variable pattern also detected in the prehistoric record. The winter season is characterized by fewer activities and one would predict that the benefits of cooperation would therefore decline. However, that decline may be more than offset by an increase in group size, which brings a greater range of skills and talents to address the few critical activities that are undertaken during this period. One should be able to see evidence of Ricardan benefit, if this aggregation of groups contributes some economic benefit beyond purely social and ceremonial purposes. These economic benefits should be realized in terms of an increase in the equilibrium threshold for groups that aggregate. The earlier equilibrium analysis was based on stable local group size throughout the year with no allowance for seasonal aggregations and is shown on

line 1, in Table 8-12. The results of the threshold version with normal, dispersed, local group size during the summer/fall season and an aggregated, seasonal group size in the winter/spring season are shown on line 2, in Table 8-12. Local and aggregate group sizes are 4 and 12 for late Neanderthals, respectively, and 12 and 30, respectively for early Upper Paleolithic humans, as indicated in Tables 8-2 and 8-3 at the beginning of this chapter. The results indicate that, with winter aggregation, Neanderthals are able to raise the threshold from 5% to 6%, together with gains in mean Ricardan benefits, and early Upper Paleolithic humans are able to raise their equilibrium level to from 12% to 13% with comparable gains in mean Ricardan benefits.

Table 8-12 Equilibrium With and Without Seasonal Aggregation

Population	Mean Ricardan Benefit	Groups at End of 20 Periods	Members in all groups at end of 20 periods	Members in local group and seasonal aggregation at beginning	Average surviving members in final local groups	Equilibrium Threshold
Late Neanderthal						
1. No Aggregation	11.36%	993	3968	4 - 12	4.00	5%
2. Winter Aggregation	12.69%	998	3990	4 - 12	4.00	6%
3. Year-round Aggregation	14.15%	994	3963	4 - 12	3.99	8.25%
Early Upper Paleolithic						
1. No Aggregation	17.20%	991	9833	10 - 30	9.92	12%
2. Winter Aggregation	18.11%	998	9940	10 - 30	9.96	13%
3. Year-round Aggregation	18.97%	995	9662	10 - 30	9.71	14%

This begs the question of why groups don't simply aggregate all year round. A simulation of year-round aggregation (line 3, in Table 8-12) generates even better results than winter aggregation alone, and indicates that it might be better to remain all-year round in aggregated and extended groups. The record does not support this, which

suggests that the primary reason for winter aggregation might be economic during harsh times, but lesser economic pressures and costs in summertime may permit dispersal in small groups. Ethnographic reports indicate that social pressures and tensions mount during the season of scarcity and aggregation, and once ecological conditions improve groups are keen to disperse in order to diffuse the tensions, but more importantly to move out to areas with more abundant, high quality, preferred resources (Yellen and Lee 1976). Typically, these resources are more evenly spread across the environment and smaller groups have the advantage of not depleting local resources as rapidly as larger groups would (Cashdan 1992). All of this suggests that the tolerance for the increased costs of maintaining social harmony in aggregated groups is higher during periods of scarcity, but tolerance is reduced during periods of abundance when it is not necessary to incur these costs. This behavior is exemplified in the congruity test results shown earlier.

iii. Focal Analysis of Four Individuals in One Late Neanderthal and One Early Upper Paleolithic Group

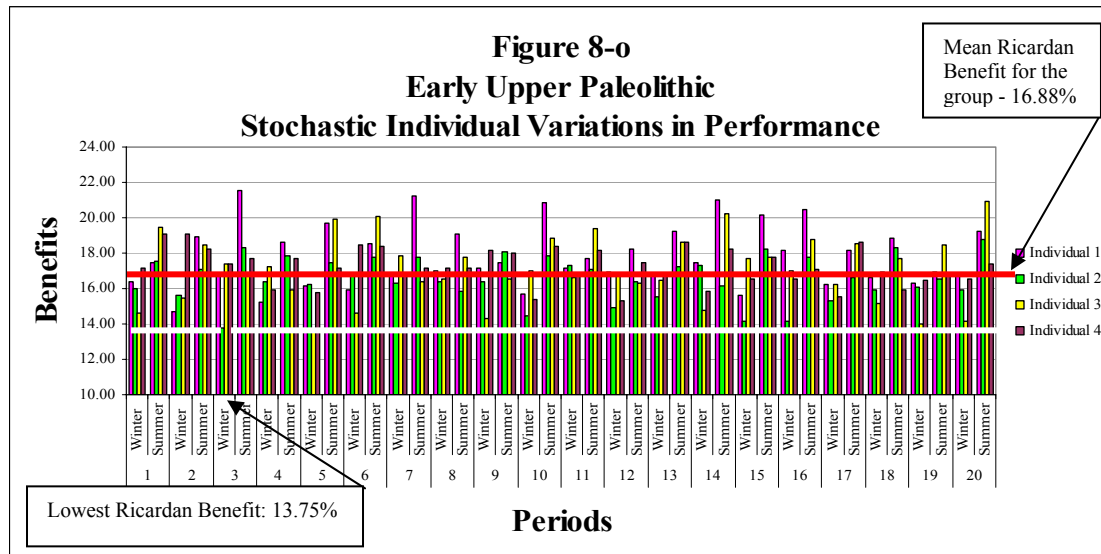
A focal study illustrates how the seasonal roles, high-frequency climate variations, and aggregation might affect a few individuals from each population tested. In order to illustrate individual variance by season and period, I have arbitrarily selected a focal set of four individuals each from one group (out of the one thousand tested) from late Neanderthal and early Upper Paleolithic human populations. I recorded their individual performance over twenty periods, while also recording mean Ricardan benefits for all groups. These figures are illustrative but not statistically normalized through multiple iterations, since this would conceal the stochastic variances shown here. Figures 8-o and 8-p show individual performance variations for the focal set

through twenty years with winter and summer seasons, where groups aggregate during the winter season. The white line shows the lowest level at which individuals in the focal set fail to achieve all their assigned critical tasks and would not be able to survive without additional support from other members of the group. The mean Ricardan benefit shown on the chart by the black line is the mean for all individuals in all one thousand groups computed over all twenty periods.

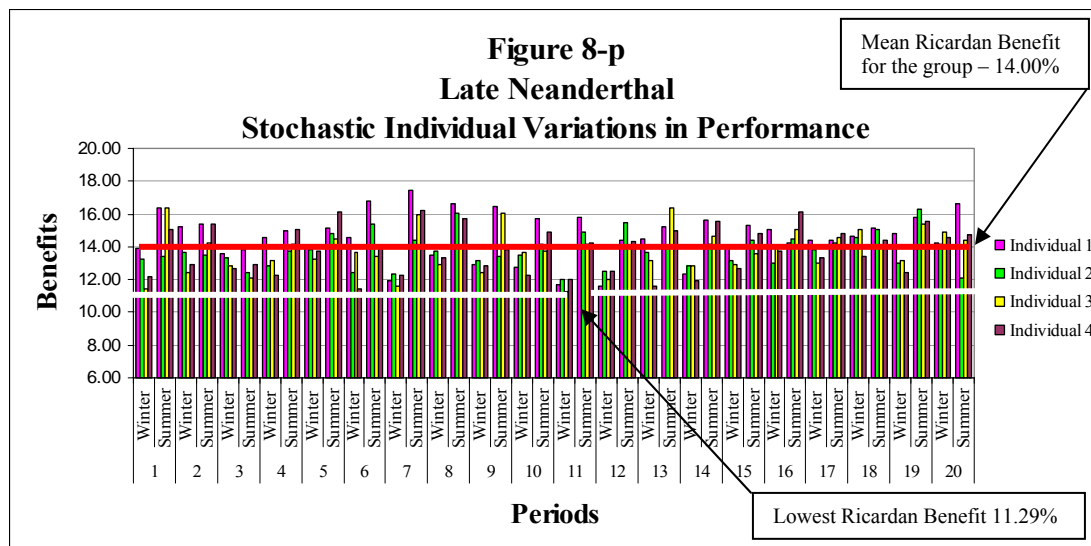
Although these results are not normalized and will contain some bias because of the limited sample size, they do illustrate an important factor, namely that the averages do hide significant inter-individual variation within seasonal and periodic cycles.

- Rarely do individual members of the group achieve the within-group mean Ricardan benefits computed over the long term.
- The best performer in one season is not necessarily the best performer in any other season.

The mean Ricardan benefits for all Neanderthal groups and early Upper Paleolithic groups are 14.00% and 16.88%, respectively and are shown on the charts as a red line. However, the lowest individual Ricardan benefit for one of the four individuals shown is 11.29% for late Neanderthals, and 13.75% for early Upper Paleolithic humans, as highlighted by the white line in Figures 8-o and 8-p below.



In winter of year 3, Upper Paleolithic individual #2 would have been the first to perish if the climate threshold exceeded the benefits of 13.75%.



In the winter of year 11, Neanderthal #3 would have been the first to perish if the climate threshold exceeded the benefits of 11.29%

In both groups, shown above, when conditions are favorable (above the white line) all members of the group benefit and achieve additional time savings. This is a period of abundance. Each member of the group may complete his/her assigned tasks

with the secure belief that the others have sufficient time to complete their respective tasks and make the group whole. Additional time available should accrue fitness benefits for each individual according to their performance, and the group, as a whole, should prosper.

However, in a more extreme seasonal environment, above the white line, more than simple division of labor by skill proficiency is necessary to ensure the survival of the entire group. If seasonal conditions deteriorate, less proficient members are unable to complete their assigned workload within the time available and need some interim support from others to fill their commitments, or they perish. Since all critical tasks have been outsourced among members of the group, all members are interdependent and need to provide mutual support if the full complement of tasks are to be completed. The critical point here is that those who are the most proficient in any one season will need to devote some of their spare time to supporting the laggards, in the anticipation that others will support them as roles are reversed and benefits change. This is a period of mutualism and delayed reciprocity: mutualism in that all work together to fulfill the group's needs, reciprocity in that the laggards in this season may become the best performers and providers in the next.

Thus, survival and diversity within the group and the integrity of the group is supported by two factors. In the above example, for Neanderthals Ricardan benefits provide at least 11.29%, or close to 80% of the mean within-group benefit of 14.00%, the rest must be provided through delayed reciprocity; for early Upper Paleolithic humans 80% is achievable from Ricardan benefit and 20% from delayed reciprocity. These figures are not statistically supported because of the restricted view given by this

focal analysis, but they, together with the performance data showing the gap between best and worst performers (from Figure 8-n), suggest that mean Ricardan benefits are achievable through a combination of a major contribution from Ricardan cooperation together with a supportive role from delayed reciprocity.

Table 8-13 summarizes all results by showing low average and high benefits returns from each, earlier mean Ricardan benefit test. The focal analysis suggests that the lowest benefits computed at two standard deviations below the mean may be achieved solely through Ricardan specialization and exchange but the mean Ricardan benefits that were the focus of the earlier part of this chapter might only have been achieved through delayed reciprocity.

Table 8-13 Comparison of Individual Ricardan Benefit Results

	Skill Spread	Task-based version	Task and time-based version	Gender-based version	Monte Carlo simulation	Best and worst performers	Ricardan equilibrium with aggregation
Late Neanderthal	Low	9.07	9.60	0.31	8.25	6.39	6.00
	Mean	12.69	11.48	7.29	12.39	11.49	12.69
	High	16.31	13.36	14.27	16.53	17.65	n/a
Early Upper Paleolithic	Low	14.77	14.82	9.28	14.91	14.25	13.00
	Mean	18.35	17.40	14.10	18.93	17.43	18.11
	High	21.93	19.98	18.92	22.95	20.97	n/a

In summary, mean Ricardan benefits for late Neanderthals fall in the 11-13% range and for early Upper Paleolithic humans in the 17-19% range. Ricardan equilibrium of 13% for the Upper Paleolithic suggests that Upper Paleolithic humans earned 71% directly through economic cooperation and a further 29% through delayed reciprocity. At equilibrium of 6%, Neanderthals were able to earn only 47% directly. These figures assume that the groups take full advantage of the potential benefits of economic specialization, and that both groups have a similar inclination to do so. If one

group is less inclined to participate in economic specialization or in reciprocal altruism, then their benefits would be considerably lessened.

Thus, on average in clement times, the groups should be able to achieve the higher mean Ricardan benefits, but in inclement times and in the short term these are not achievable without reciprocal altruism. Without the combination of these two behaviors, lesser performing individuals will perish, and the integrity of the group will be negatively impacted, resulting in a smaller group and, consequently, lower mean Ricardan benefits. This means that individuals within the group are interdependent, and there is a significant benefit to each individual in maintaining diversity within the group by supporting lesser performers in any given season as insurance against those times when seemingly inferior performers become superior ones.

These results show that individuals in groups might have participated in cooperative economic and altruistic behaviors in order to mediate the severe high- and low-frequency climate fluctuations experienced in the late Pleistocene. It also demonstrates that comparative advantage behaviors are more effective in larger groups and provide a wider buffer zone for the maintenance of diversity and survival within the group in the face of all the challenges faced in the Late Pleistocene.

8.11 Review and Conclusion

The purpose of this research was first to build an individual-based model that incorporated Ricardo's Law of Comparative Advantage, one that could be applied to small sized, early human societies to determine whether and when economic cooperation might have been a factor in human affairs. In order to do so, it was necessary to identify the Ricardan, economic variables that were applicable to

individuals operating in such societies. Group size is identified as a key variable controlling the pool of labor resources that could be applied to production. Individual variation in skill proficiency is identified as the key parameter governing the variation in the quality of productive resources available. The task repertoire represents the range of activities that may have been shared between individuals in the local group in a specialization and exchange economy. A Prototype model was developed to apply these parameters in the context of Ricardo's Law and to determine potential benefits from economic specialization. The results from the Prototype show that benefits improve as each of the parameter values increases. This raises the question; first, whether such variables are evidenced in the anthropological record, and second, whether the prehistoric data match the Ricardan predictions of the prototype. Data was extracted from the archaeological and physical anthropological record for Neanderthal and early Upper Paleolithic humans, and supported by data from the ethnographic record. The economic outputs are measured based on energetics studies, artifacts, features, and faunal remains that are evident in the archaeological record. These represent the indicators of what tasks and activities occurred. Local group size data was obtained from spatial analyses of archaeological sites, from theoretical predictions, and from current-hunter gatherers. Skill spreads are based on modern human biological characteristics. The Transition model seeks to quantify: a) the level of cooperation to be expected based on the values determined for the three variables, and b) the potential beneficial impact of savings in time and effort derived from Ricardan cooperation in mediating the biggest challenge facing early humans in Europe during the late Pleistocene, namely the deteriorating and fluctuating climate.

Here is a recap of the hypotheses laid out at the beginning of chapter 2, together with the conclusions.

Hypothesis 1: A model can be developed, that uses findings from the archaeological and physical anthropological record, to quantify levels of cooperation and the benefits received there from in late Pleistocene societies.

The prototype model shows that it is meaningful to apply the Law of Comparative Advantage to individuals working in small egalitarian groups, even though the law was originally conceived as a rule for trade between nations. Similar parameters to those originally identified by Ricardo that describe the quantity and quality of productive resources and the resultant output can be identified in the context of individual economic specialization and exchange. For the individual-based model these factors, which drive individual decisions on whether to cooperate or not, are identified as group size, individual skill variation, and the number of tasks necessary to produce the necessary outputs that are critical to survival. To determine whether these factors are discernable and whether they can be quantified from the archaeological and anthropological record of the late Pleistocene with sufficient precision to validate the predictions from the model is the central theme of this research and this data provides the basis for testing hypotheses 2 and 3.

Hypothesis 2: The benefits from Ricardan cooperation may be quantified using data from the prehistoric record of Neanderthals and early Upper Paleolithic humans in Europe. The results should indicate that the potential for fitness benefits to be achieved through economic

specialization is greater the larger the group size, the greater the repertoire of tasks, and the wider the variation of skills. These benefits of specialization accrue individually and offer better survival prospects to each individual as well as the group as a whole.

The model described here does provide quantitative results for the potential for achieving Ricardan benefits, based on the data extracted from the archaeological and physical anthropological record of the late Pleistocene. The results distinguish quite clearly the differences between smaller Neanderthal groups and larger Upper Paleolithic human groups with larger task repertoires, with or without significant differences in skill spread. The increase in benefits is robust, as is shown in various versions.

The model is an individual-based model with no input from group selection. The results are a result of individual decision-making based upon economic self-interest with the critical assumption that work is assigned and outputs are re-distributed equitably. These factors might not apply in larger, hierarchical societies but, from the ethnography, appear to be in force in smaller egalitarian societies where inter-personal pressures and demand sharing enforce a certain level of equity, albeit not the rigid accounting or monetary equity that one expects today.

Hypothesis 3: The benefits of cooperation result in the maintenance of skill diversity within the group, allowing individuals better to adapt to the changing task complexity resulting from unpredictable climate fluctuations, and thus maintain the long-term integrity of the group.

In this context the reliability of the data available from the record is the least well substantiated and any conclusions are merely tentative and based on stochastic data input and seasonal factors that are not so well supported from the prehistoric or ethnographic record. However, the results do indicate that significant variation in individual benefits occurs from season to season and that performance rankings between individuals vary based on ecological and seasonal context.

From the focal analysis, it appears that maintenance of diversity within the group is partially a function of Ricardan cooperation and partially a function of delayed reciprocity. However, the significant impetus for driving the level of benefit is Ricardan cooperation and that impetus is stronger in larger groups with more tasks and wider skill spreads. In the long term, delayed reciprocity might raise the individual Ricardan benefit to the mean Ricardan benefit level of 11-13% and 17-19% for late Neanderthals and early Upper Paleolithic humans, respectively. In the short term and without delayed reciprocity, both groups would resort to the lower equilibrium threshold levels of about 6% for Neanderthals and about 13% for early Upper Paleolithic humans. Even in this case, Ricardan benefits provide a meaningful advantage and in both cases provide a significant, extra advantage for early Upper Paleolithic humans.

Hypothesis 4: Survivorship benefits, accrued from intra-group economic specialization and exchange, provided an advantage to early Upper Paleolithic humans in combating the deteriorating climate in Europe in the late Pleistocene.

For small, isolated groups living in low densities across the landscape of the European Plains, the oscillating climate of the period, with peak stress occurring at around 30 ka, would have proffered the most imminent threat to survival for both populations. In addition, small, isolated groups are especially vulnerable to stochastic variations in ecological conditions. These could wipe out single individuals and lead to significant and irreparable reductions in Ricardan benefits to the entire group, thus lowering the buffer and further raising the risk of individual extinction. Once again the loss of one member is more critical in smaller Neanderthal groups.

The benefits, potentially available though Ricardan cooperation, gave only the Upper Paleolithic humans the advantage of being able to survive at more northerly latitudes and in colder zones than the Neanderthals as reflected in the settlement record. Neanderthals would have been able to survive climate swings of only half to two thirds the amplitude experienced by modern humans.

Mean Ricardan benefits for early Upper Paleolithic humans, whether at Ricardan equilibrium of 13%, or at mean Ricardan benefits of over 17-19%, fall close to the limit of the range of variation in climate during this period and might have provided a significant buffer to mediate stressful climate of the period. The association of these two measures might suggest that a major impetus for the evolution of cooperative behaviors was to counter the deteriorating climate for these new immigrants into Europe. In more clement, interstadial times, such Ricardan benefits may have been dispensed with, or more likely used for the ultimate aim of increasing reproductive fitness and population densities, thus making the populations more robust and able to survive further severe climate episodes.

These findings and conclusions raise additional questions and suggest directions for future research as discussed in the next chapter.

Chapter Nine

Discussion

There are a number of open issues raised during the course of this research. Some involve the basic assumptions made here, and some are related to contradictions with findings from other areas of research. These all open avenues for new research into the economic activities of early man.

9.1 The Potential for Ricardan Benefits

This research shows that it is possible to extract data from the archaeological and physical anthropological record to support an ICA model applicable to small egalitarian societies and based on Ricardo's Law of Comparative Advantage. This ICA model is an individual-based, dynamic decision-making model that uses data from the ethnographic, archaeological, and physical anthropological record to examine individual economic behavior within small groups, each with different individual skill proficiencies, task repertoires and local group composition. It quantifies time savings achieved through specialization and exchange by allocating life-critical tasks to the individual most proficient in performing that task. I show that it is possible to quantify benefits achieved from within-group specialization and exchange activities and that there is the potential for individuals in small egalitarian groups to achieve significant benefit through economic specialization and exchange, and argue that the demands of a harsh and fluctuating climate forced these early humans to cooperate to the fullest extent possible within their local groups.

The results of this analysis show that populations with larger local groups, more extensive task repertoires, and more varied skills might achieve greater economic

benefit in terms of time saved in performance of all of life's critical tasks. By evaluating data from the Neanderthal and early Upper Paleolithic prehistoric record and applying it to the ICA model, I quantify the relative levels of benefits for these two populations. The results support the conclusion that, within certain limits, more is better, and indicate that economic specialization may have played a significant role in these early societies.

The model quantifies the potential benefits of Ricardan cooperation, but I do not argue that all groups fully cooperated economically in all activities at all times. Kuhn (2004) acknowledges the value of intra-group variation in technological strategies, but reasons that economic models may determine only how people might react if they were behaving rationally and within the parameters of the model. The ICA model does not tell us whether early humans did in fact implement rational, economic behaviors in their day-to-day activities, but studies of teams in animal societies indicate that economic cooperation is not the sole prerogative of humans. Vertebrate and invertebrate societies do show evidence of individuals assuming specialized, economic roles within teams, based on the varied skills of those participating in the particular team activity (Anderson and Franks 2001). There is a long history of proto-hominids cooperating in foraging practices and food-sharing at Koobi Fora and Olduvai (Isaac 1978), and more recently of specializing in tool-making activities at Boxgrove (Pope and Roberts 2005). It seems reasonable to assume that by the late Pleistocene humans may have developed more extensive economic cooperative patterns of behavior. Optimality theory suggests that it makes sense to assume that, where there is an opportunity and a need to achieve a meaningful benefit, humans act accordingly (Shennan 2001; Shennan 2002).

9.2 Ricardan Benefits for Climate Mediation

The economic analysis alone cannot assure us that these groups cooperated at all, but the pressures of the climate during this period suggests that they would have good reason to cooperate to their full potential, at least during the periods of greatest stress. An examination of the deteriorating climate conditions experienced by these populations in the late Pleistocene in Europe suggests that the fluctuating climate may have posed the most serious threat to the survival of these populations, and that the benefits of economic specialization may have been useful, if not critical, in mediating this threat. Early modern humans, though not physically adapted to the extreme cold conditions of Europe at the time, settled into more northerly and colder zones than the more robust, and apparently physically cold-adapted, Neanderthals. Upper Paleolithic groups were able to buffer the cold with tailored clothing and well constructed shelter and hearths. These required considerable time and effort that might only have been achieved through cooperative economic activities. Ricardan benefits differ considerably between the populations analyzed. Through economic specialization and exchange, Neanderthals would have achieved a benefit in terms of time saved in critical daily activities of about 12%; at 18% early Upper Paleolithic humans might have achieved about one and a half times the benefit of their Neanderthal contemporaries. For Neanderthals, this is quite a significant improvement, but for Upper Paleolithic humans at least, the benefits might have been sufficient to permit them to create the buffering necessary to mediate against all but the most extreme, climate swings.

9.3 The Level of Task Specialization

This study identified tasks from the archaeological and physical anthropology record. The range of tasks was based on an analysis of archaeological remains guided by the task lists from the Giffen's Inuit studies (1930). However, this listing does not discuss at what level individual specialization occurred. Some tasks may not have been shared at all whereas others may have been broken down to subcomponents that were outsourced for economic production and exchange. Since we cannot determine precisely the level of specialization or even if subcomponent specialization occurred at all, I have assumed that specialization occurred at the component level only and have identified these components in terms of processes attributed to the archaeological record. This is the most cautious approach. However, if specialization had occurred at the subcomponent level in both populations, the ICA model shows that benefits would have been somewhat larger overall, but the relative gap between Neanderthals and Upper Paleolithic humans would have remained essentially the same. If only Upper Paleolithic humans specialized at the subcomponent level, as is suggested in bead manufacture at Castel-merle (White 1989a), then only modern humans would have achieved those additional benefits, and the gap between the two populations would have been wider. In either event, these benefits would have improved the buffer against climate fluctuations.

The task repertoire is a key factor in determining the level of Ricardan benefits. Neanderthals appear to have executed far fewer tasks than early modern humans. Yet, they thrived in northern latitudes for many thousands of years. Their robust morphology may have enabled them to cope with the climate of northern Europe without the

enlarged task repertoire of the Upper Paleolithic (Churchill 1998). However, ethnographic analysis of techno-units used in modern hunter-gatherers shows that the size and scope of the toolkit is a function of latitude and ecology and, therefore, cannot be solely attributed as a species based trait (Oswalt 1973; Oswalt 1976). The size of the Mousterian toolkit is more representative of tropical or subtropical groups and not of current hunter-gatherers living at high latitudes (Oswalt 1973; Hoffecker 2002).

Upper Paleolithic settlements appear at higher latitudes and in colder zones than do Mousterian settlements (Aiello and Wheeler 2003). It appears that the extended task repertoire of Upper Paleolithic humans is associated with their migration into these higher latitudes. Indirect activities such as tool making, clothing manufacture, and camp maintenance substantially expand the Upper Paleolithic task repertoire. Whether early anatomically modern humans were pre-adapted to cope with the severe climate because of their larger group composition, wider skill spreads, and broader task repertoire, or whether these behaviors developed as a result of moving into northern areas at a time of deteriorating climate, is not determined from this analysis. However, as additional early anatomically modern human sites in Africa and other more temperate areas are discovered, it will be possible to compare the behaviors of the predecessors in more temperate areas with those of Upper Paleolithic humans to see if they too behaved more like current, tropical hunter-gatherers, or if they already exhibited the larger groupings and extended task repertoires associated with living in high latitudes. The middle Eastern record seems to indicate that the early modern human behavior was indistinguishable from the Mousterian (Shea 1989; Lieberman and Shea 1994; Kuhn and Stiner 2006). On the other hand, the African record does show signs of “modernity”

(McBrearty and Brooks 2000), but the record is sparse and may indicate an incipient stage towards modern behavior that took off with the migration into northern regions, forced by the necessity of coping with the harsh climate.

9.4 The Degree of Task Specialization

As far as degree of specialization is concerned, this analysis assumes that Neanderthal and Upper Paleolithic humans had the same inherent inclination or propensity to cooperate and that the differences in benefits arose solely as a result of the group size and task repertoires. The ICA model does not measure the propensity to cooperate among different populations, or under different ecological circumstances. Some indicators might suggest that Upper Paleolithic humans specialized and cooperated more actively, or more habitually, than Neanderthals. The rate of technological innovation increased dramatically in the later Upper Paleolithic, and the early Upper Paleolithic seems to have been an intermediate stage between the Mousterian and later Upper Paleolithic as far as technology and economics are concerned (Hoffecker 2005). Specialization and exchange leads to more opportunities to exploit individual skills and thus increases the rate of innovation. If all are a limited to performing the generalized tasks necessary for survival, then there is less opportunity for experimentation and skill improvement. In addition, the more extended lithic and exotic exchange networks in the Upper Paleolithic might have offered more opportunities for the exchange of ideas and transfer of knowledge both within local groups and across wider regions. Thus, it seems likely that economic specialization and exchange in the early Upper Paleolithic was more habitual and might have resulted in the modern humans accruing a larger portion of their potential benefits than

Neanderthals. In this case, the gap between the two populations would increase to the benefit of the inhabitants of Upper Paleolithic societies.

However, despite the relatively large gap in Ricardan benefits between Neanderthals and early Upper Paleolithic humans, there does appear to be an area of overlap, indicating that some Neanderthal groups may have acted more cooperatively, and some Upper Paleolithic groups may have acted more like Neanderthals. These behaviors are observed in the archaeological record at Mousterian sites such as Arcy-sur-Cure (Girard 1976; Farizy 1990) and Abric Romaní (Castro-Curel and Carbonnell 1995; Vaquero, Vallverdu et al. 2001), which show evidence of Upper Paleolithic behaviors, and in the Streletsian Culture (Klein 1973), which has many of the traits of a Mousterian settlement, even though it is usually classified as belonging to the Upper Paleolithic. There are also wide variances in the Upper Paleolithic, particularly with more extensive shelter construction in the east and different regional traditions of symbolic representation all across Europe. These instances suggest that if economic cooperation was a factor, it was not necessarily practiced all the time and in all the places, and that this period saw a mosaic of behaviors in different seasonal and geographical contexts.

9.5 Sexual Division of Labor

The ICA model indicates that division of labor and specialization by skill is significantly more beneficial than division of labor by gender. A skilled, female hunter may well be included in the hunt when physically able, and conversely childcare duties may be performed by any members resident in camp. Although evidence from morphology suggests that both species participated in sexual division of labor (Ruff

1987), the reduced benefits achieved by Neanderthals in the gender-based version suggest that division of labor by gender was not too effective and was probably not characteristic of their behavior. This conclusion is supported by a study of foraging activities in the Mediterranean and near East (Kuhn and Stiner 2006), which concludes that Neanderthals, and even the first early modern humans in the Levant, did not differentiate roles between males and females. Kuhn and Stiner also suggest that division of labor by gender appeared, at least in the Mediterranean areas, with the introduction of the broad spectrum diet associated with Upper Paleolithic humans. This second suggestion is not entirely supported by the ICA model, which is, however, based on data drawn from more northerly sites: Upper Paleolithic humans were able to achieve only moderate but not optimal benefits through the division of labor; in prehistoric, harsher climates (maybe north of the Mediterranean) a division of labor, strictly based on skill levels rather than gender, would be more productive.

Durkheim (1984) in his treatise on division of labor suggests that there are reasons, beyond pure economics, that drive sexual division of labor in modern societies. He argues that division of labor engenders an *organic solidarity* between individuals, where each individual has a sphere of action which is peculiar to him, whereas individual personalities are absorbed into the collective personality through *mechanical solidarity*. Although he concedes that the origins of division of labor lie in an infinitely distant past, Durkheim suggests that sexual division of labor is a special case, and that sexual division of labor developed concomitant with conjugal solidarity in modern societies. I propose that the drive towards sexual division of labor may have more to do with risk management than simple economics. Females in hunter-gatherer societies are

generally either gestating or lactating and therefore are directly responsible for the survival of two individuals, themselves and their offspring. To subject the women to high risk activities such as hunting large game animals would not be a rational strategy. Future modification of the ICA model to incorporate risk factors might support this view.

Data on physical activity levels in current hunter-gatherers suggest that male and female task assignments vary substantially across ecological contexts (Panter-Brick 2002). Halperin (1980) suggests hunter-gatherers exhibit an egalitarian, but flexible and dynamic, division of labor between the sexes with variations in sex roles on a daily and seasonal basis that cross over traditional sex roles. The fine workmanship of many of the Upper Paleolithic tools, art and artifacts suggest that these are quite likely produced by female hands (Soffer 2000). However, if, as Kuhn and Stiner propose, Neanderthals practiced division of labor by skill and Upper Paleolithic humans practiced division of labor by gender, then Upper Paleolithic Ricardan benefits would diminish, Neanderthals would have narrowed the gap in Ricardan benefits, and the early Upper Paleolithic humans would have achieved only one and a quarter times the benefit of their Neanderthal contemporaries.

However, if sexual division of labor was pervasive in both populations, then the results imply that smaller Middle Paleolithic groups would benefit little from practicing sexual division of labor, at least during those times when conditions were the most severe and survival was most challenged. However, the larger Upper Paleolithic groups would still achieve reasonable Ricardan benefits and maintain a significant advantage over their Neanderthal cousins.

9.6 Group Composition and Social Cost

The congruity tests for optimum, local group size for the suite of parameter values used in this analysis suggest that the social costs of living in groups or the costs of sustaining harmony in a larger group might have been considerably less in Upper Paleolithic humans than in Neanderthal societies. These social costs might have increased as a result of participating in economic specialization and exchange. Unfortunately, it is unclear precisely how costly this policing of social and economic behavior was in prehistoric times, and whether these costs offset any potential benefits achieved through cooperation.

- If these prehistoric costs approached 12% of total productive effort for all populations, then there would have been no incentive for Neanderthals to participate in cooperative activities and cooperation would have provided no extra buffer against climate deterioration. Ricardan benefits for early Upper Paleolithic humans would have been cut by two-thirds which would have offered some level of mediation against more moderate climate changes but not the most extreme.
- If these social costs differed between the two species, as suggested at by the group size congruity exercise, then the group with the lower social costs would have retained more of the Ricardan benefit. In the group optimization exercise the benefit curves seem to suggest a lower cost for modern humans than for Neanderthals. In that case, even if costs did not approach 12%, the Neanderthals would have experienced a proportionally greater reduction in their potential benefits than would the early Upper Paleolithic humans.

i. Costs of Egalitarianism

Local group size is a key factor in determining the level of benefits achieved from cooperation: the larger the group size, the greater the opportunity for achieving Ricardan benefits. Optimal group size theory suggests that the upper limit on group size is determined by the cost and benefits of adding an additional member. The social costs of maintaining an equitable and cooperative society include the costs of grooming and maintenance of social relationships, the cost of delivering punishment to those that do not comply to fair sharing norms, and the costs and risks of interdependence (Roberts 2005), when relying on others for the performance of critical tasks. One of the basic assumptions of this analysis is that work assignments and the resulting outputs are distributed equitably within these small groups. There are costs associated with maintaining this degree of equity. Ethnographies inform us that many small hunter-gatherer groups are egalitarian, with no big man or hierarchy. These groups have developed precise rules as to who may share in the bounty of the hunt, the size of the share, and even go so far as to specify which part of the animal goes to which participant. The entire Inuit community often oversees the distribution of the bounty from seal and whale hunting expeditions, and is actively involved with much discussion and negotiation in order to ensure that the allocations are fair (Dahl 2000). Secondary distribution-networks and demand-sharing ensures that all in the community receive some portion of the bounty. In addition, the practice of “insulting the meat” is a method of putting down the successful hunter and limiting his prestige (Lee 2003). Cheaters are discouraged through gossip, humiliation, and sometimes with physical violence or banishment (Howell 2000). Evolutionary psychologists have shown that current

humans are prepared to pay a considerable cost to punish others who do not conform, even to the extent of punishing those who do not participate in the punishment of the cheaters (Boyd and Richardson 1992). In any event, there is a considerable cost to maintaining equity that would be especially critical in an economic, exchange environment where each individual effectively out-sources some of his critical tasks to others and is therefore highly dependent on all other members (Roberts 2005).

ii. Tolerance for Bearing Social Costs May Vary by Ecological Context

Another consideration is that the tolerance for bearing the social costs of cooperation within larger groups may vary depending on ecological conditions. These benefits would have been most valuable in times of stress and may not have been needed, or may not have been cost effective, in less stressful times. Social costs are considerably higher in periods of scarcity during which local groups typically aggregate around scarce, but low-quality, resources. One may be prepared to bear these costs when there are few other options for survival, but not prepared to do so when resources are abundant and self sufficiency within the family unit is easily accomplished, as shown in the social cost analysis. This might explain why groups aggregate in winter and disperse in summertime. Ethnographic anecdotal data indicates that social pressures mount during the seasonal aggregations when groups are closely confined to a restricted area around limited resources, whether naturally located or cached. The data also indicates that small nuclear family groups are glad to disperse once resources become more widely available, and conditions are more favorable for dispersed living. The !Kung eagerly await the arrival of the rains, the time of plenty, when families disperse to the best foraging areas. Individual families can now afford to be the most

selective and concentrate on their favorite, high-quality foods (Yellen and Lee 1976). Humans, like other animals, gather in large groups when food resources are clumped or temporarily abundant, but disperse when food patches are dispersed (Steudel 2000). Patchy resources are rapidly depleted by large feeding groups and repeated movement to a new patch becomes expensive (Chapman and Chapman 2000). Studies of the Amboseli baboons troops show that they reduce group size to lessen competition when food sources are patchy and dispersed (Bronowski and Altmann 1996). Similarly for humans, the competition for limited local resources is reduced and social costs are considerably less when local groups disperse as small multi-family units in the summertime. This reduction in cost could easily offset any small reduction in Ricardan benefits due to the smaller group composition. This suggests that, despite the fact that the ICA model indicates that greater benefits could be derived from living in larger aggregated groups year-round, these benefits may be more than offset by the additional cost and stress of continued, close living arrangements, when conditions are harsh, and when there is little option but to bear these additional costs. Once the ecological conditions improve and local groups become self-sustaining, they no longer need to accept these additional burdens. Smaller, local groups, with lower Ricardan benefits, are able to survive during summertime or during interstadials, when resources are more abundant and more evenly spread across the landscape, than during harsher times.

In the late Pleistocene, a few Neanderthal sites show evidence of aggregation for the slaughter of migrating animals in the fall (Mauran, Champlost), but, overall, Mousterian sites offer little evidence of winter storage facilities or settlements with long-term winter aggregations. Some larger Upper Paleolithic sites contain storage

facilities (Barca II, Kostenki XV). This suggests that local groups congregated seasonally. Shott (2004) describes aggregations as having the following properties: a) size: in terms of numbers of people and numbers of local groups, b) composition: encompassing all members of the group, or merely the working task subgroup, c) duration: from days to months, and d) reason for aggregation: periodic clustering of resources - uneven, time and space distribution seems to favor aggregation. In examining Paleoindian archaeological sites across North America, Shott finds that aggregation patterns vary widely in size, duration, and purpose of aggregation (ibid: page 73), and questions whether there is one single cause or pattern of aggregation. If, as suggested by Hoffeecker (2000; 2002) and Finlayson (2004), Neanderthals habitually settled in vertical ecotones with a rich, resource base, then they might have had less incentive to congregate in multi-family units and, therefore, less need and opportunity to achieve the Ricardan benefits that accrue within larger groups, except during the brief, annual migration of the herds.

iii. Language and Social Costs

Finally, the costs of sustaining a larger local group may have been ameliorated by language. In primate societies, social grooming costs are a significant part of the daily task load. The baboons of Amboseli (Bronowski and Altmann 1996) appear to have an optimum time allocation between foraging (72%), resting (19%) and socializing or grooming (9%), and, when food patches become depleted and foraging time encroaches on resting and grooming time, the groups become restive and ready to move to a new patch. Devoting about 20% of the day to grooming seems to be the absolute upper limit for non-human primates (Dunbar 1993). Grooming time is a function of

group size. As the group gets larger grooming time requirements increase geometrically so that at some point group size is limited by these social costs. Aiello and Dunbar (1993) predict that, based on group size and neo-cortex volume in *Homo habilis* 23% of the time would have been spent in grooming. For archaic *Homo sapiens*, Neanderthals, and modern *Homo sapiens* this time requirement would have risen to about 40%. This level of expenditure would have been too costly. Social grooming time in the larger Upper Paleolithic groups would have been too large to be sustained without the development of language (Dunbar 1993), and Aiello and Dunbar argue that language evolved gradually in response to continuing pressures for more efficient social cohesion resulting in the evolution of modern symbolic language in the Upper Paleolithic. This argument is supported by genetic analysis. A variant of the *FOXP2* gene is implicated in the ability to articulate speech and it is estimated that the fixation of this variant happened within the last 200,000 years, at about the time of the emergence of anatomically modern humans (Enard, Przeworski et al. 2002). Symbolic language capability in early modern humans might account for the lower costs associated with sustaining a large, cooperative group, as indicated by the congruity tests. These lower costs allow larger groups to form in the Upper Paleolithic, and this larger group composition provides one foundation for broader economic specialization and exchange, as is shown in this analysis.

9.7 Care Giving and the Incapacitation of a Member

The ICA Transition model shows that the loss or incapacitation of a member of the group is extremely expensive and might be prohibitively expensive for small Neanderthal groups. This finding contradicts conclusions reached by examination of the injured, but healed skeletal remains of Shanidar I. Shanidar I died at an old age for Neanderthals but was blinded and managed to survive serious injury to the head and right side of the body that had healed with time. A person in that condition was clearly incapacitated yet cared for by others in the group (Trinkaus and Shipman 1992). I can only speculate that one or more of the following conditions applied. First, since Shanidar I was old for a Neanderthal he may have reached non-productive status even before his injuries. In that case, he might not have been a productive adult with 2.5 dependents, as assumed in the model. The model, as time allocation studies do, considers only productive adults, and the efforts of those adults covers the cost of maintaining all other dependents, which would include Shanidar I. The cost to support Shanidar I alone, and without dependents, would have been considerably less (<10%) than that required to support a younger productive adult with several dependents (26-33%). Second, the group may have lived in a more clement climate, such as the lower latitude Zagros Mountains, where there might have been adequate time available to provide the additional support. However, a less than 10% improvement in conditions is reasonable; an amelioration of 23-30% is unlikely. Third, Shanidar I may have been a member of a larger group, or more than one local group may have shared in his and his dependents' support. The Transition Model predicts that an incapacitated, productive member of the group could be supported, at minimal net cost (Ricardan benefits less

cost of care) of less than 1% to the remaining, active members, if group size were doubled to eight adults. This group size falls between the local group size of four and extended seasonal group size of twelve for Neanderthals. If the group size were further increased to the seasonal size of twelve then the group would have been able to support an incapacitated, productive adult member and his dependents and still achieve Ricardan benefits of 5.54%. Perhaps a combination of these situations might account for the support provided Shanidar I.

9.8 Climate Fluctuations and Extinction

Climate fluctuation was an ever-present menace, especially to humans living in high latitudes. The severe climate fluctuation of the middle to late Pleistocene already had a significant impact on an earlier pre-Neanderthal and Neanderthal populations with catastrophic deaths reported at Atapuerca and Krapina, respectively (Bocquet-Appel 1999). During the cold glacial period of OIS 4, Neanderthals abandoned the northern plains. No Mousterian settlements are found there during this period; the only settlements are found on the southern fringes in the Caucasus, southwest France, Iberia and Italy (Chapter 7). In historic times, modern human societies have been wiped out by climate extremes much less severe than OIS 4 or 3. Norse populations in Greenland dwindled to extinction, bound by a lifestyle that could not be maintained during the “Little Ice Age” (McGovern 1990). Despite their close proximity to the Thule, the Norsemen did not adopt their fishing and ice-hunting foraging practices (Outram 1999). Thus, local extinction in high latitudes is not restricted to local Neanderthal populations; pockets of early, modern human populations must have become extinct during sharp downturns in stadial climate conditions. The OIS 3 climate is characterized by a few

long periods of relatively benign conditions interspersed with short intervals of extreme climate fluctuation (van Andel 2003c). It is impossible to determine the precise level of the human response to climate swings during these intervals but the fluctuating climate was clearly a major threat to survival; a threat that might have been partially mediated by Ricardan benefits. I calculate that a 6-8°C deterioration translates into a 16% variation in human response terms. Whatever the level of decline, the higher Ricardan benefits placed early Upper Paleolithic humans in a significantly better position to buffer these climate changes than the Neanderthals. The impact of these climate swings is tested in two ways: first by comparing average group benefits to the 16% threshold, and second by testing various climate thresholds at which populations are able to remain stable or at which populations go extinct.

In this analysis, benefits have been calculated in two different ways: group mean Ricardan benefits of members in one thousand groups over one period, and individual Ricardan benefits over several periods with stochastic variations in ecological conditions. These two methods show very different results. First, the mean results for the group are plotted against a climate deterioration of 16%. This shows that, at this level, Neanderthals would not have achieved sufficient Ricardan benefit to offset such a decline. The settlement record shows that they abandoned the European Plains during these downturns by either migrating to southern refuges or by succumbing to local extinction. The early Upper Paleolithic humans would have been able to overcome most but not the most extreme swings. Here, the Russian record shows that they were able to expand their settlement in the northern plains up to the height of the last glaciation at around 20 ka, when the plains were abandoned.

9.9 Variability in Individual Ricardan Performance and Reciprocal Altruism

Climate thresholds are tested in the focal analyses of inter-individual variation. The analysis illustrates how individual roles and performance are likely to change from season to season and year to year, by focusing on two focal sets of four individuals, each from late Neanderthal and early Upper Paleolithic groups, through a period of twenty years. Rarely would an individual achieve the group average benefits, as computed over many sample groups. The focal analysis, although not a statistically supportable sample, may offer a clearer illustration of what was happening from season to season and year-to-year. On an individual basis, the lowest, seasonal benefits derived solely from Ricardan cooperation, although quite respectable, are considerably less than the group average over time. Since the individual outcome of not achieving the benefit level necessary to survive is extinction, this represents a serious hurdle: one only has to starve or freeze to death once. Threshold analysis examines at what benefit level a population maintains a stable equilibrium and at what level population extinction occurs. Thresholds represent declines in ecological conditions that might offset Ricardan benefits and cause individuals to fail to meet their critical needs and thus expire. The equilibrium threshold achieved from Ricardan benefits alone is considerably less than the mean Ricardan benefits of the groups: poorer performers die and no longer contribute to the group average. The mean Ricardan group benefits, which are up to twice that of the equilibrium threshold, are higher because they do discount for individual deaths, and continue to count their contribution in the average Ricardan benefits for the population. If these lives are saved then the equilibrium threshold level will rise.

One way to bridge this gap, between the benefit levels computed in equilibrium threshold and those computed in the mean Ricardan benefit, is for the individuals in those populations to participate in reciprocal altruism: delayed reciprocity could play a key role in evening out fluctuations in individual performance. By rescuing lesser performers in their time of need, others ensure that the former will continue to survive and contribute when times improve. This will tend to raise the equilibrium and extinction thresholds to the level defined by the mean Ricardan benefits for the group. Although the precise balance between the benefits derived from economic specialization and the additional push provided by delayed reciprocity cannot be precisely determined from the focal analysis, it is obvious that, without delayed reciprocity, those members that are caught in a bad performance season are more likely to perish. Diversity in terms of variations in skill levels and performance of specific tasks in different seasonal settings may be a valuable contribution towards maintaining the integrity of small hunter-gatherer groups. By supplementing the output of poor performers in their worst seasons and anticipating reciprocal assistance in their better seasons (delayed reciprocity), all individuals benefit from the amelioration in survival rates. Winterhalder (1997) suggests reciprocity, even with non-kin related members of the group, is most likely to evolve in small groups where regular role reversals between givers and takers occur as a result of a chance discovery of the best foraging patch. Such seasonal role reversals are observed in current hunter-gatherer groups (Giffen 1930; Mauss 1979; Halperin 1980). In the highly seasonal climate of Europe in the late Pleistocene, such seasonal role reversals across all critical activities would increase the opportunities for economic specialization and exchange and indirect reciprocal

behavior. Whether all populations behaved in a similar, altruistic manner is unknowable. If Neanderthals had been less altruistic than the modern humans, then the gap in Ricardan benefits between the two would increase significantly, to the detriment of the Neanderthals. However, in this regard, I have assumed that Neanderthals and modern humans acted equally altruistically. By improving the survival of individuals within the group and maintaining a diversity of individual skills, each population is better able to survive the exigencies of an unpredictable and fluctuating climate.

9.10 Future Improvements to such Economic Models and Input Data

In terms of future research, the results indicate that one might reasonably be able to assess the relative benefits of cooperation among small groups of the period, solely based on prehistoric data (the task-based version) and without resorting to the, maybe questionable, supporting ethnographic information. As the archaeological record becomes richer, as more sites are uncovered, and as more rigorous excavation techniques are implemented it will be appropriate to reassess the findings for these two populations. New methods of spatial analysis and landscape archaeology may shed more light on settlements, clusters of settlements and local group composition. Micro wear and experimental archaeology may lead to a better understanding of the range of tasks and processes used by prehistoric peoples and provide richer input data for such economic models. New discoveries continue to enrich our view of the life pattern of these early humans, and the discovery of a Mousterian needle or hut-like dwelling would seriously compromise these conclusions about clothing manufacture and camp maintenance. Experimental reconstructions of ancient artifacts may also tell us more precisely what level and degree of specialization occurred in these early societies.

Clearly, the Upper Paleolithic was a time of change and innovation where groups in different locales were experimenting with new technologies. Economic models, such as this, may help throw light on whether this trend was beginning to happen in Africa, the Levant, or even in the late Mousterian.

New findings and advances in genetic analysis may provide more information about issues that are difficult to assess such as gender roles and skill spread variation. One unresolved issue here is skill spread. In this analysis, I have adopted the position that there is no difference in skill levels between the two species, and have based my conclusions on that premise. However, I performed certain tests to determine what might be the results if Neanderthal skill proficiencies were spread more narrowly than modern human proficiencies. In all cases, Neanderthal benefits are reduced and the gap in Ricardan benefits between Neanderthals and modern humans is widened. As discussed earlier, theoretical arguments suggest that Neanderthals may have been less diverse than early modern humans, however there is little direct evidence as yet from the physical anthropological record to support this. Since the skeletal record is particularly sparse, new methods of extracting and analyzing DNA, such as being applied in the Neanderthal Genome Project (Dalton 2006; Green, Krause et al. 2006; Noonan, Coop et al. 2006), may offer new opportunities to cast more light on this issue.

Improved economic models will expand the scope of this economic approach to analyzing cultural behavior, and these conclusions will be tested by new discoveries in archaeology, genetics and physical anthropology. As more data becomes available, it will be possible to apply this methodology to earlier modern human populations before they moved into Europe to determine to what extent they may have been involved in

such economic activities. Meanwhile, these results suggest that individual, skill-based, specialization and exchange activities might have played a significant role in late Pleistocene societies in Europe, but that only Upper Paleolithic societies possessed the suite of characteristics necessary to generate sufficient, economic benefit to enable them to survive the deteriorating climate of late Pleistocene Europe.

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